Consumer is Producer - A Novel Model for Electricity Generation

Alimul Haque Khan
Electrical & Electronic Engineering
Bangladesh University of Engineering & Technology
Dhaka, Bangladesh
Email: alimul_buet@yahoo.com

Hafsa Hakim Pial
Department of Economics
The University of Dhaka
Dhaka, Bangladesh
Email: pial.hakim@gmail.com

Asif Islam & Mohammad Shariful Islam
Information Technology & Electrical Engineering
The University of Queensland
Brisbane, Australia
Email: asif038@gmail.com

Mohammad Saifur Rahman
Electrical & Electronic Engineering
Bangladesh University of Engineering & Technology
Dhaka, Bangladesh
Email: saifur@eee.buet.ac.bd

Abstract— **The aim of this paper is to explore a new model to generate electricity with higher penetration rate of renewable energy. Conventional system to generate electricity is to generate large amount electricity at power station and then deliver to the consumer through long transmission line and distribution system. The losses and costs, incorporated with these processes, are not negligible. Another System is the Solar Home System (SHS) which is being used to replace traditional kerosene based lamp, battery based TV, fan and light bulb from 1998 in Bangladesh. But with the advancement of technology, the demand of the consumer is increasing significantly. To meet this demand it is necessary to expand national grid connection. An alternative way is to produce sufficient power using renewable resources at consuming spots. A novel method to achieve this goal has been discussed in this paper which is supported by the field study of Bangladesh University. Also a comparison has been shown with traditional power system.**

***Index Terms*— distributed energy resources, load management, microgrid, renewable energy penetration**

I. INTRODUCTION

Bangladesh is a small country with large amount of population. The generation of electricity is not enough to serve the population. Presently, 62% of the total population (including renewable energy) has access to electricity and per capita generation is 321 kWh which is very low compared to other developing countries [1]. Along with the centralized generation, till April 2014, about 3 million SHSs have already been installed in the off-grid rural areas of Bangladesh under the program run by IDCOL with co-operation of several. As a result, 13 million beneficiaries are getting solar electricity which is around 9% of the total population of Bangladesh [2]. Most of installed unit of SHS is in a home. Few of them are in educational institute, prayer house and market shop. An SHS is able to provide electricity for few light bulbs, small DC fan and TV, rechargeable torch light, adapter for mobile phone charging is also being used in SHS.

However, demand of the customer is increasing significantly. Many of the customers have intention to use a large TV, fridge, blender, iron, domestic water pump even AC, like a customer having connection of national grid electricity. However, extension of grid is not an easy task. Besides this, most of the power station is based on natural gas which is about 78.12% of total capacity on the FY 2013[1]. On the other hand, gas is in shortage condition and about 900 MW of generation shortfall occurs due to shortage of gas. So it will be very tough to provide more electricity generated from natural gas in future. Government of Bangladesh is trying some alternative to gas such as coal, HSD, Furnace oil based power plant as the fuel diversification program [1]-[3]. Presently, use of gas, HSD, Coal and FO are around 80%, 10%, 5%, 3% of total. On the other hand Bangladesh receives plenty of solar radiation. Wind, mini hydro and micro hydro are also available and there is scope to solve the problem of electricity generation with the combination of several renewable energy resources [4]-[7] with storage and fossil fuels based generation unit.

II. ELECTRICITY GENERATION TOPOLOGY IN BANGLADESH

Bulk of the power in Bangladesh is generated by Bangladesh Power Development Board (BPDB) [8]. There are other independent power sources as well. All the generated power are purchased by BPDB and then transmitted by Power Grid Company Bangladesh (PGCB) to the customer's premises.

Till June, 2013 the total generation capacity of the country is 8537 MW [1]. Though, 3.11% and 11.95% energy is lost due to transmission and distribution respectively. As far as the fuel is concerned, the generation capacity is 5730 MW by Natural Gas, 1876 MW by Furnace Oil, 511 by Diesel, 220 MW b Hydro and 200 MW by Coal. Total net Energy Generation (Excluding REB) in FY 2013 [3] was 16482GWh in which 77.07% is generated from Natural gas (Table I).

TABLE I
GENERATION FROM DIFFERENT FUEL SOURCES ON FY 2013

Fuel Type	GWh	%
Hydro	894	2.45
Natural Gas	28119	77.07
Furnace Oil	5568	15.26
Diesel	745	2.05
Coal	1156	3.17
Total	36482	100

Energy Flow Chart FY 2013 shows that 77.91GWh of energy is produced from 34.79 Million liter of Diesel costing

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30.364 BDT per kWh of energy whereas it is 13.46 BDT for Furnace oil, 3.7 BDT for coal and 0.902 BDT for gas based generation on an average(only for BPDB Generation) [1]. As of June 2013, there is almost 3020 km of 230 kV and 6148 km of 132 kV transmission line available in the country. The number of 230/132 kV substation is 16 and combined capacity of those entire substation is 7525 MVA. Besides, there are 103 substation of 132/33 kV available throughout the country with a capacity of 11792 MVA. The distribution network is the biggest of the lot, with 3728 km, 13128 km and 21839 km of 33 kV, 11 kV and 400 V lines respectively. And of course, there are 158 substations of 33/11 kV for distribution of power around the country [3]. 40.10% of the mentioned generated power is purchased by Rural Electrification Board (REB) and distributed to the pastoral area. BPDB distributes 24.64% of the power among the urban consumers. Dhaka Power Distribution Company (DPDC) and Dhaka Electric Supply Company (DESCO) distribute 18.59% and 10.51% of the power among the consumers in Dhaka metropolitan area. Rest 6.17% of the power is distributed by West Zone Power Distribution Company (WZPDC) in Khulna and Barisal division [1].46.52% of the power is used for resident loads, 10.34% for commercial purposes, 37.42% for industries, 3.17% for agriculture and 2.56% for other purposes [1].

III. FIELD STUDY AND POSSIBILITIES

A field study has been done on several customers of existing SHS including the area of Jessore, Rangpur, Laksmipur, Mymensingh from November 2012 to April 2014. It is found that many of the remote area are yet far from the national grid. In those area most of the inhabitants use kerosene for lighting purpose. Some of them are using diesel or petrol based electric generator in group for a limited period of day due to higher fuel cost. SHS is also being used on this area. SHS system is mainly design for lighting purpose. SHS having comparatively larger size of its panel can provide also energy to TV and small fan. The users of current SHS are interested to use standard TV, fridge, fan, and small water pump. But due to lack of enough power they cannot use these appliances. An alternative way to meet their demand and to achieve same facilities as national grid is to produce enough power everywhere of the consuming spot and connect them locally. This study also shows that a typical house at village area (Nearest Electrified Village) consumes about 50~80 kWh of electric energy per month. The average free space of roof is about 40-50 m^2 and average usable space for solar PV application is about 18-25 m^2 whether the roof is South (or North) faced or East (or West) faced for slopped roof. For a top flatted roof the usable area will be the complete roof area. This area is enough to install solar PV of more than 2-3kW_p [9]-[11]. It will produce more than 200-300 kWh [3] of usable electricity per month which is enough for 3-5 family of a village considering the consumption pattern of a traditional family.

A conventional power system consists of large scale power stations, transmission lines, substations and distribution lines etc., where the generation and consumption of power are not at the same location. By this system, remote areas are normally not connected with the electricity grid thus deprived from development. On the other hand as decentralized generation is known as distributed generation such as 100MW of power may be generated in a power station or it may be done by installing 1000 number of generating unit with 100kW which is situated in different location throughout the gird. It does not need any transmission network rather low voltage distribution network is used for distributed generation. However due some important factors, it is time to think about the higher penetration of renewable energy with decentralize way. These are for traditional power generation system, fuel cost for oil based plant is high sometimes it exceeds 30tk per kWh; reserve of gas is going to be diminish very soon. Besides these most of the generation units emit high amount of CO_2 which increases the green house effect and the global warming, cost and loss associated with evacuation system is not negligible. Moreover, interruption at any node in the grid turns into load shading and hampers a lot of user; customer is completely disconnected from the grid.

If the output of each PV panel is interconnected locally then it will provide enough energy for the entire user of the locality by means of Micro-grid [12]-[14]. A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode [7]. The discretely situated distributed energy resources (DER) are being used as a supplement and an alternative to large conventional central power station worldwide [8]-[10] and the penetration of DER at medium and low voltages is increasing [11]-[13]. The available renewable energy sources in Bangladesh can be used as DER in a microgrid which will reduce the control burden on the grid [13] and may meet a significant proportion of the national demand of electricity with a competitive price compared to the traditional power plants. The penetration of DER based microgrid is increasing in the developing country day by day. Moreover microgrid can be interconnected to any nearer microgrid in case of emergency. Interconnected microgrids have more opportunities to share generated power thus loads and load management and control. With proper technical improvement microgrid is being connected to the national grid without new transmission line [14]-[16].

Considering the points above, a new model for generation and distribution of electricity has been proposed where it is expected that T&D loss and cost will be minimized significantly, emission of CO_2 will be negligible with a new load management technique as well as reliable and quality power within short time.

IV. CONSUMER IS PRODUCER - AN ALTERNATIVE APPROACH

Consumer is Producer (CP) model is a new technique to generate and distribute electricity with higher power quality, stability; reliability and lower T&D loss thus lower cost. It is designed as easier as plug and play equipment and within the shortest time it will be able to provide electricity to a large amount population. Common electricity generation is accomplished by large power station with through T&D. The loss of T&D is enough to reduce the overall efficiency of power system.

The model comprises with Consumer Producer Unit (CPU), micro grid, interconnected micro-grid, and control and management unit.

1. *CPU:* The unit CPU (Fig. 1) consists with source or sources, loads, control and management system in a unit. Each CPU has its unique identification number.

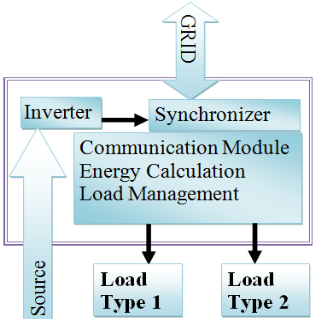

Fig. 1 Block diagram of Consumer Producer Unit (CPU)

2. *Sources:* The sources may be solar PV, biogas based generator, small wind generator, small hydro power generator, Fuel cell, micro-turbine, gas or diesel generator or any storage element such as battery, fly wheel etc.

3. *Inverter:* Whatever the output of the sources is, the output of the inverter will be AC. Inverter output is kept same as the grid.

4. *Synchronizer:* Synchronizer's task is to synchronize the output of the inverter with another CPU or with the grid.

5. *Communication module:* The task of this module is to communicate with a Master controller or central controller about the status of the CPU. It receives command from the central controller and do as the command such as to disconnect any load, disconnect itself or disconnect sources (for example diesel generator was running over the night and at the day time central controller accumulate the data of all of the CPU and decided that, now there is no need to run the diesel generator, then it will send command to the CPU of the diesel generator to stop it.)

6. *Energy meter:* It measures the amount of generated or consumed energy; calculate the bills for peak time, off peak time, demand charges etc. Energy calculation module calculates the energy incoming from grid, outgoing to grid and used amount of energy by the loads.

7. *Loads:* Loads of the consumer is categorized for a better load management such as light load, fan load, fridge, TV, computer and heavy load like AC, pump etc. Synchronizer will synchronize the output of inverter with the microgrid.

8. *Microgrid:* The micro-grid (Fig. 2) is an inter connection of several numbers of CPU.

9. *Interconnected Micro-grid:* Interconnection of several Microgrids with a central controller (Fig. 3).

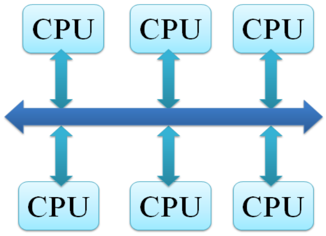

Fig. 2 CPU based Microgrid

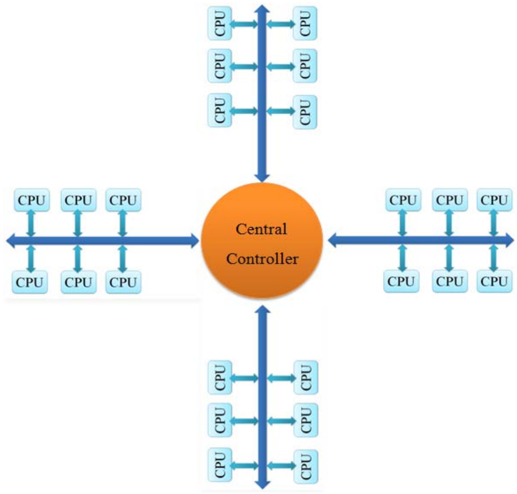

Fig. 3 Interconnection of Microgrid with central controller

10. *Micro-grid Network:* When a large number of interconnected microgrids are combined together it will form a micro-grid network (Fig. 4). The microgrid network may be considered as a unit power source that be connected with nearer T&D lines.

11. *Connection to National Grid*: There is an option to be connected with the nearest national grid (Fig. 5) when available. Through this connection it is possible to transfer power on demand.

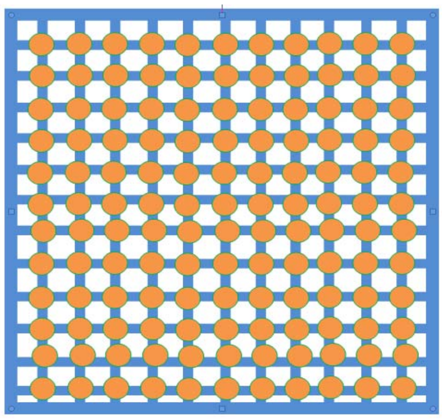

Fig. 4 Microgrid network

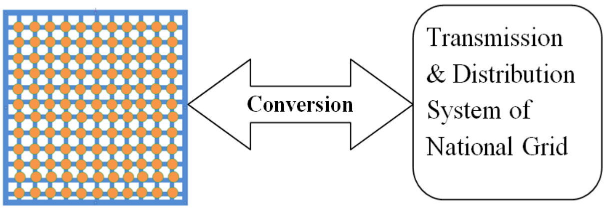

Fig. 5 Microgrid connected to national grid

The Control of voltage, frequency, real and reactive power, droop etc. can be controlled by the central controller of the interconnected microgrid. It will control the frequency, voltage and other parameters for better quality power. Each of the CPU has its own number as like as the central controller. Each Central controller will be connected with some branch of microgrid but it will control only few of the defined branches. As the loads are categorized, the central controller will send command to disconnect some types of load if generation is less than the demand. In this case the traditional procedure is to disconnect the branch completely as a result; a large number of consumers are affected.

V. A COMPARISON WITH 'SOLAR HOME SYSTEM'

The price of an SHS ($100W_p$) is around BDT 35,000 excluding the components not related to generation (such as light bulbs, cable, DC fans etc.) Therefore, the price for $1MW_p$ will be around BDT 350 Million. There is no fuel cost, but the system price of an SHS becomes high mainly because of the larger size of the battery/battery bank, which is used for three days autonomy. However, in the proposed "Consumer is Producer" model, the installation cost for a $1MW_p$ [16] power generation system will be 60 Million BDT for panels and another 30 Million [16] BDT (approximate) for battery, alternative energy resources and controlling equipment.

TABLE II
COMPARISON OF SHS AND "CONSUMER IS PRODUCER" MODEL

Comparison Criteria	SHS	Consumer is Producer
Consumer of the Business model for	The enlisted NGOs	Everyone
Scale of unit	10Wp~150Wp	$1kW_p$~$5kW_p$
Demand meet	Demand is forced to be limited by the size of the SHS	As much as need
Per W_p installation Cost	Higher (400Tk. ~700 Tk.)	Lower (60 Tk. To 90 Tk.)
Contribution to the national grid	Nothing	Has option to be connected with the national grid
Contribution to the national generation	Insignificant	Significant
Penetration of green energy	Lower	Higher

However, unlike the SHS for the alternative energy supply, there would be some extra fuel cost to meet the shortage as well as maintenance cost, whereas a traditional power plant requires a huge amount of fuel cost. In spite of this, if proper policies are undertaken by the government, the proposed "Consumer is Producer" model may have better performance over SHS as this model has some strong arguments over SHS. These are summarised in Table II

VI. PROJECTION ABOUT THE INSTALLED CAPACITY

The SHS program of IDCOL has claimed to be the fastest growing program in the world. This was possible because of the appropriate policy that was undertaken. Thus, the policy taken to enhance any program is very important. Proper policy with subsidy and easy purchase would able to make the CP model achieve higher number of installations like IDCOL or even more. Considering the rate of the installation of IDCOL [16], the possible installation capacity of the proposed "Consumer is Producer" model could be possible to forecast. This is shown in Table III.

TABLE III
POSSIBLE INSTALLATION CAPACITY OF THE PROPOSED "CONSUMER IS PRODUCER" MODEL

Year after starting the program	**Amount of installation at the rate of**		
	150% of IDCOL MW_p	**100% of IDCOL** MW_p	**80% of IDCOL** MW_p
5 Year	303	202	161
10 Year	3765	2510	2008
15 Year	32451	21634	17307
20 Year	327947	218631	174905

It should be noted here that, this analysis has been done considering the number of installation of IDCOL's SHS program, not the installed capacity of the SHS. To find the installation capacity of the proposed model, the number of installation has been multiplied by the unit capacity ($2KW_p$) of each CPU. This is illustrated in Fig. 6.

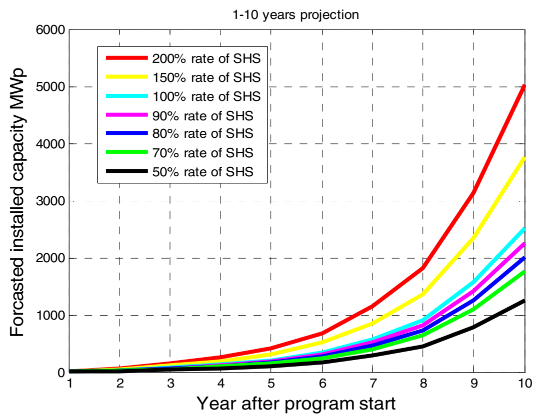

Fig. 6 Forecasted installed capacity of the proposed model based on IDCOL's installation number

VII. Conclusion

The proposed model can be used to be an alternative and supplementary way to the traditional power system. Installation of large power plant based on renewable energy is good but scope is not available everywhere. Moreover, it also needs the evacuation system which already discussed as costly and though loss of this has been minimized. On the other hand the installed figure of SHS is large (about 3 million) but the amount is not enough and also it is not contributing to the national grid. However, SHS is not business model for the customer rather it for the NGOs. So it clear that the number of investors for a smaller system increases exponentially than a larger system. Hence, if the size and the investment are such that both of size of installation and investment is in an optimum level, production of energy will be high. As a result the penetration of Renewable Energy will increase quickly which will be hard by the traditional large system and SHS. By this way it will reduce the green house effect as well as rate of global warming. The day is not so far when people will not count the money rather the government of any country will buy green energy without counting money. Moreover, people will be motivated to produce their capita demand by themselves due to its naming. However, proper policy and steps should be taken to promote this like SHS program by IDCOL. Proper designing and debugging of the hardware system of this model will make this more convenient.

Acknowledgement

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A Review of Current Renewable Energy Activities in Bangladesh

Alimul Haque Khan, Kazi Rehnuma Zafreen & Mir Muntasir Hossain
Electrical & Electronic Engineering
Bangladesh University
Dhaka, Bangladesh
Email: alimul_buet@yahoo.com

Maidul Islam
Electrical & Electronic Engineering
Eastern University
Dhaka, Bangladesh
Email: maidul112@gmail.com

***Abstract*—This paper reviews the prospects of available renewable energy resources along with various private and government future project plans to incorporate renewable energy sources and its potentials in perspective of Bangladesh. In an arising country like Bangladesh demand for energy will be burgeoning. Present day, in Bangladesh dearth of energy is ubiquitous and near about 70% of its population is excluded from access to electricity and bulk of the people are living in rural areas. Among several renewable energy resources, the application of solar Photo Voltaic (PV) is renowned although the largest plant based on renewable energy goes into hydroelectricity. Additionally, wind, biogas, mini hydro and tidal are also well known. A plan has been initiated by the Government of Bangladesh (GOB) to generate 5% of the total energy from renewable energy resources within 2015 and 20% by the year of 2020. Through the approved renewable energy policy, the GOB is devoted to facilitate investment in both public and private sectors in renewable energy projects to substitute contemporaneous non-renewable energy resources and escalate the contributions of renewable energy based electricity generation. With this context, review of recent activities on concurrent renewable energy resources is imperative as well as to explore potentials of the resources. However, not all renewable energy sources are suitable to install indiscriminately in all regions, rather there are certain parameters to choose a source of RER for efficacy. After reading this paper, an investor will get significant information about current scenario and steering for future involvement of renewable energy sources in Bangladesh. Furthermore, this paper will be instrumental to select optimum efficacious renewable energy sources for a particular region.**

Keywords*—*renewable energy, solar PV, biogas, rice husk

I. Introduction

Geographically Bangladesh is situated in the north-eastern part of South Asia between 20.84^0 & 26.838^0 North Latitude and 88.801^0 & 92.841^0 East Longitude. The total population is about 160 million with an average population density near about 1050 per sq. km (among the highest in the world) [1]. 70% of the population live in the rural areas of Bangladesh is seriously deprived of the access to electricity. As because the expansion of grid is inordinately expensive in the rural areas; already initiatives have been taken to popularize the use of renewable energy sources. The prospect, trend, utilization and its technology as well as reviews of the policy, institutions and opportunities based on renewable energy technology towards sustainable development and climate change mitigation has been investigated in paper [3]. A contemporary scenario of the renewable energy associated activities in Bangladesh is presented in this paper [4].

Furthermore comparing with other countries of Asia, energy consumption level is lower in Bangladesh although crisis is intense. Due to perpetual failure of power, development and welfare of the citizens have been inhibited, so the government is compelled to move into contractual agreements at high cost and adopt expedient solutions of purchasing rental power and small IPP on an emergency basis based on diesel or liquid fuel.

In Bangladesh the per capita energy consumption is one of the lowest in the region. On an average in Bangladesh per capita energy consumption is 160 kg oe (Kilogram oil equivalent) compared to 530 kg oe in India, 510 kg oe in Pakistan, 340 kg oe in Nepal and 470 kg oe in Sri Lanka [5]. The average energy consumption in Asia is 640 Kg oe. It has therefore, evinced clearly that per capita average consumption of energy in Bangladesh is lower than any other country of Asia.

Long term strategy has been devised by the government for the melioration of existing debilitated energy situation in order to extenuate the financial problems. The strategy has created equilibrium approach regarding both supply increase and demand management aspects of the energy market. Energy options from the domestic sources need to be complimented with possible options for energy trade. Specifically the strategy would try to determine what can be done by the government about gas and power and to explore for various options to diversify the fuels for power generation.

II. Energy Demand And Generation Capacity Scenario And Future Projects

In Bangladesh, installed generation capability (June 2014) has reached to 10416 MW [2] and the maximum generation is 7500MW where the maximum demand is 8500MW. Nearly 77% of the total generation is obtained from natural gas [2] besides the only renewable part of the generation which comes from hydro and which is around 2.45%. In contrast, around 3 million [6] IDCOLs SHS programme has installed solar home systems. Their goal is to finance 6 million SHSs by the end of year 2016. Moreover, IDCOL financed a 250 kW Biomass based power plant at Kapasia, Gazipur, 100kWp Solar PV and diesel based hybrid power plant in Sandwip, Chittagong and 400-kW rice husk gasification based power generation facility along with a precipitated silica plant at Chilarong, Thakurgaon sadar, Thakurgaon. It has been anticipated that in future the

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biogas technology would be the driving force as because of the ascending poultry industry in Bangladesh.

III. Review Of Various Renewable Energy Activities In Bangladesh

A. Solar PV Application in Bangladesh

The application of solar PV is mainly found in remote areas of Bangladesh. In 2003 IDCOL started the SHS program to ensure access to clean electricity for the energy starved off-grid rural areas of Bangladesh. The program bolsters the Governments vision of ensuring Access to Electricity for All by the year of 2021. Additionally, hybrid microgird (with solar PV), solar PV based irrigation system, grid-tied solar PV systems are also in operation. These are described below.

1) Solar Home System: In Bangladesh, access to energy for services like cooking and lighting in off-grid villages is slender. Most rural households have to rely on kerosene lamps for lighting and traditional stoves for cooking. The Government has initiated various programs and has given enormous efforts to introduce flexibility in rural economy.

Solar power, especially SHS technology, has been welcomed by the rural people as a reasonable way to fulfill the requirement of lighting. In the off-grid rural areas of Bangladesh more than 3 million SHSs have already been installed under the supervision of the program [5]. As a result, 13 million of people are receiving solar electricity that is around 10% of the total population of Bangladesh. IDCOL has a goal to provide financial support to 6 million SHSs by 2017, with an estimated electricity generation capacity of 220 MW.

Currently 47 Partner Organizations (POs) are implementing this program. IDCOL provides refinancing and grant support and at the same time essential technical assistance to the POs. The POs install the SHSs, expand credit to the end users and assistance with after sales services. IDCOL received credit and grant support from the World Bank, JICA and other financial supporting organizations [5].

More than 65,000 SHSs are now being installed every month under the supervision of the program with an average year to year installation growth rate of 58%. The program has superseded 180,000 tons of kerosene which have an estimated value of USD 225 million per year. Furthermore, near about 70,000 people are indirectly or directly engaged with the program. The program has been heralded as one of the biggest and the quickest growing off-grid renewable energy programs in the world [5].

Excessive cost of fuel and regular maintenance forced the telecom operators to cogitate of an alternative energy source by which the remote and off-grid BTSs can be functioned. Many operators have decided to run off-grid BTSs with solar-diesel hybrid power systems for an uninterrupted voice and data services. As the primary power source these systems use solar PV and as backup diesel generator. In the telecom sector so far IDCOL has financed 138 such solar-diesel hybrid power solutions [3].

2) Solar PV based irrigation system: Bangladesh has 14.76 million hectors of total land in which 8.3 million hectors are net cultivable and 7.56 million hectors are irrigable. It is an agro-based country whose irrigation is traditionally dependent on monsoon rain water. Besides this, irrigation pump has been considered as a major invention to ensure food security. According to a recent survey conducted by Bangladesh Agriculture Development Corporation (BADC), there are about 1.42 million diesel based irrigation pumps are operating in the country, consequently requiring about 1 million ton of diesel per year [7].

Solar powered irrigation system is an innovative, economic and environment friendly solution for the agro-based economy of Bangladesh. This particular system fundamentally consists of solar panels and solar power operated pumps. Primarily, diesel operated shallow and low lift pumps, preferably using in triple crops areas, were targeted to be superseded by the solar irrigation pumps. Average capacity of each solar pump will be 8kWp with a head of 12-15 meters. Area coverage will be on an average 13 hector of paddy fields by a single pump. It is estimated that 18,700 diesel-based irrigation pumps will be replaced by solar powered pumps under this program. Total solar power capacity in this case will be 150 MW, which will reduce 95,000 liters of diesel and significant amount of CO_2 emission per day [7]. Till to date, around 46 pumps have been installed [7].

3) Solar PV based microgrid: Many regions in Bangladesh which are deprived of consuming electricity from national grid depend on microgrid to fulfill their electricity demand. Microgrid based on small diesel based generation is being used in Bangladesh. Government has plan to install several microgrid based on solar PV. From this context, initially, 30 remote areas have been identified under this program where grid expansion is not planned for next 15-20 years. Additional new areas will be identified to develop solar mini grid system on the basis of successful implementation. Total solar power capacity in addition from this constituent will be 25 MW. Solar mini grid will ensure quality electricity in remote villages and help the villagers to have an improved income which will in turn mitigate their poverty to some extent [3].

Besides these, BPDB, REB has installed larger size of solar PV systems in various locations of Bangladesh. IDCOL has installed 100-kW solar photovoltaic (PV) based microgrid by PUROBI Green Energy Limited (PGEL) at Sandwip island in Chittagong. To alleviate the problem of low solar radiation a 40-kW diesel generator has been incorporated into the suggested power plant in order to ensure adequate power supply [8].

IDCOL aims to finance 50 solar mini-grid projects by 2017. The World Bank, KfW, JICA, GPOBA, USAID, ADB and DFID are allocating financial support in these projects.

B. Other Renewable Energy Sources

Other than the solar PV, there are some other renewable energy sources available in Bangladesh.

1) Biogas: An agro-based country like Bangladesh has huge potential for utilizing biogas technologies. According to IFRD, Bangladesh has plenty of resources to establish four million biogas power plants. Grameen Shakti has completed installing 13,500 biogas plants. Lately Seed Bangla Foundation has propounded a 25 KW power plant based on biogas in Rajshahi. IDCOL has been implementing domestic biogas programs in Bangladesh since 2006 with support from SNV Netherlands and KfW. IDCOL has financed establishment of over 33,000 biogas plants covering a wide range of regions all over the country with the help of its 24 partner organizations till April 2014. The program saves 80 thousand tons of firewood every year worth $2 million and also reduces the use of 28,000 tons of chemical fertilizer worth $20 million by producing 200,000 tons of organic fertilizer. The program also reduces the use of 1,000 tons of kerosene every year. IDCOL has a plan to install 100,000 biogas plants in Bangladesh by 2018. Some organizations in addition with the partnership with IDCOL have constructed private biogas plants with their own funds. Moreover, since May 2011, IDCOL along with its partner organizations has installed 18,713 biogas plants in different parts of Bangladesh [3]. Besides these, biomass production from rice husk energy (similar process to biogas) is steady over decade and day by day it is showing an increasing trend [10].

2) Hydro energy: The sole hydropower plant in Bangladesh is the Karnafuli Hydro Power station situated at kaptai about 50 km apart from Chittagong. Currently it has the capacity of 230 MW by 5 units. BPDB is appraising the operation and planning to increase its generation up to 330 MW. The Water Development Board (BWDB) and BPDB carried out a joint study on micro-hydro power potential in the country [4]. With a view to install other two hydro power plants at the Sangu and Matamuhuri rivers two sites have been selected. The projects will be named as The Sangu Project and The Matamuhuri Project comprising the generation capability of 140 MW and 75 MW respectively. At Barkal Upazila of Rangamati district, a 50 kW micro-hydro plant was installed in 2005. The ongoing projects are: 50-70 kW Mohamaya Irrigation-cum-Hydro Power Project at Mirersorai, Chittagong. Rehabilation of 50 kW micro-hydro power plant at Barkal Upazila of Rangamati district is underway [9].

3) Wind: The potential of wind energy is limited to offshore islands, coastal areas, rivers sides and other inland open areas with robust wind regime. BPDB installed 4 units of 225 KW which is accumulated to 900 KW capacity grid connected wind plant at Muhuri dam area of Sonagazi in Feni with a hope to generate electricity from wind energy. In 2008, another project of 1000 KW wind-battery hybrid power plant at Kutubdia Island was accomplished, which comprises of 50 wind turbines of 20 kW capacity each.

Refurbishment of the existing Kutubdia 1000 kW wind-battery hybrid power project is in progress. Steps have been taken to install 15 MW wind power plant across the coastal regions of Bangladesh after a year of wind resources assessment in Mognamaghat of Coxsbazar, Muhuri dam area of Feni, Parky beach of Anwara in Chittagong, Kuakata of Patuakhali and Kepupara of Borguna. Wind mapping is going on at Muhuri dam area of Feni and at Mognamaghat of Coxs bazar by Regen Powertech Ltd. of India.

Under the supervision of USAID TA project, installation of wind monitoring stations at Inani beach of Cox'sbazar, Parky Beach of Anwara, Sitakundu of Chittagong and at Chandpur is also underway [4].

4) Ocean wave energy: Ocean wave energy is another special type of renewable energy, which is generated directly from the waves of the oceans and thus helps decrease the harmful emissions of greenhouse gases associated with the generation of power. As Bay of Bengal is situated with Bangladesh so ocean wave energy can be potentially a remarkable source of generating electricity for Bangladesh. Though the main purpose of ocean wave energy is electricity generation, it can also be used for pumping of water and desalination of water as well.

The Oscillating Water Column method is technically feasible and proving very attractive for this purpose. This type of wave energy harnessing device is being commissioned by several countries such as the United Kingdom (500 kW), Norway (100 kW), Ireland (3.5 MW), and India (150 kW). Bangladesh has a good potential for harnessing ocean wave energy from the Bay of Bengal [10].

5) Tidal energy: The energy which is attained from the tides of seas and oceans as a form of hydropower and converted into electrical power is called tidal energy. As tides are more predictable than wind and sunlight, tidal energy can easily be generated from the changing sea levels. The coastal area of Bangladesh has a tidal rise and fall of between 2 to 5 meters. Among these coastal areas, Sandwip has the best prospect (more than 5 meter tidal rise fall) to generate tidal energy [10]. By applying low and medium head tidal movements of height within 2-5 m from coastal tidal resources, Bangladesh can achieve adequate amount of tidal energy. Low head tidal movements are suitable in areas like Satkhira, Barisal, Khulna, Bagerhat and Cox's Bazar regions. In Sandwip, high tidal movements more than 5 meter of tidal wave is utilized to produce tidal energy. Therefore, we can say that Bangladesh is blessed with appropriate tidal height. Availability of such tides can be a great source of electrical energy for Bangladesh.

6) Geothermal energy: Bangladesh shows the prospect to explore the geothermal resources in the northern districts. Countrys first geothermal power plant close to Saland in Thakurgaon district is incipient with a capacity to produce 200 MW of electricity [13]. Dhaka-based private company, namely, Anglo MGH Energy has taken this initiative to enhance the geothermal resource opportunity in this country. They have planned to set up 28 deep tube wells to lift hot steam and the lifted steam will be used to run a turbine and the turbine is connected to the generator to generate electricity. From the above discussion, it is clear that geothermal energy can also be a potential source of harnessing electrical energy in Bangladesh.

IV. Dependent Factor For Choosing A Renewable Energy Resource

There are some factors which should be considered for choosing a renewable energy resource in different region. Among them, geographical location plays a significant role in selecting proper renewable energy resources. Different areas of the Earth receive different amounts of sunlight based on the location, the time of year, and the time of day. A suitable location for installing solar panels has specific characteristics and requirements. Identification of those locations requires that desirable characteristics be defined first. With an ideally suitable site, a solar panel should be placed south faced and a 23.5^0 tilt angle (in average) with the horizontal plane in Bangladesh. The site should be chosen such that it may receive adequate amount of sun light.

The coastal area of Bangladesh is mostly protected by the trees. However, sometimes we may have to cut the trees of the coastal area to ensure exposure of adequate sunlight on the installed panel. As rivers are considered as open space so boats consisting solar panels can receive plenty of solar radiation. However, orientation is important for the installation if that is on a boat or anything movable. It is better to install the panel on any boat or roof-top of an electric car horizontally. In hilly regions, special care should be taken to install interconnection of solar panels/power sources.

Population is another parameter which determines the effectiveness of utilizing a renewable energy resource. In highly dense urban areas where high-rise buildings are common, panel should be chosen for high shadow effect. In these areas interconnected solar system with storage is preferable. High efficiency solar panel with hybrid system is needed where energy demand is high. In low density areas, standalone system is better due to per capita inter-connection cost.

Special care should be taken while installing PV panels at the coastal area for two reasons: firstly to protect them from cyclones and secondly without cutting any trees. Therefore, PV cells should be placed carefully considering all the parameters. Installation of solar PV at the coastal area may hamper the environment because of cutting the overhead trees.

Wind is not always a steady source of energy. Wind speed changes constantly, depending on the time of day, weather, and geographic location. Wind farms can be found near farmland, in narrow mountain passes, and even in the ocean, where there are steadier and stronger winds. Wind turbines are suitable in the coastal areas considering the flow of wind. However, wind farms are not suitable in densely populated areas [11] [12].

Bangladesh is a plain delta having three of the major rivers of the world namely, the Ganges, the Brahmaputra and the Meghna flowing through it. The Jamuna-Padma,-Meghna river system divides it into east and west zones and creates an average water flow of 1.3 trillion m^3 in a year throughout the country. Many other rivers flow throughout the country which are actually the tributaries of these rivers. During monsoon, the flow rates of most of the rivers are high but it reduces substantially during winter. There lies a stricture of hydropower generation in Bangladesh except some southeast part and some specific hilly areas of northeast. However, there are a lot of tributaries, canals, tiny waterfalls which have good potential for setting up hydro power plants. Hydro power plants convert the hydro power of the fluid into mechanical power which is further converted to electrical energy. Many types of hydro power plants can be setup according to the generation capacity.

Bangladesh has a wonderful climate for biogas production. Bangladesh has a lukewarm temperature varying from 6^0C to 40^0C which is quite beneficial for biogas production as the ideal temperature is around 35^0C [13]. An agricultural country like Bangladesh has plenty of biomass. Cow dung, agricultural residue, poultry dropping, water hyacinth, rice husk etc are available in a huge proportion. Therefore, Biogas plants are more effective in densely populated areas.

Small wind turbines can be installed in the coastal area and off-shore islands of the country. Also micro hydro power plants can be installed in the north-eastern hilly regions and in the existing irrigation canal system with sufficient head.

There are scopes of installing integrated small tidal power plants in the coastal areas.It is advantageous to install wind power plants in a less density area or in an open area.

To know the available quantity of rice husk in a cluster, it is important to know the cluster size as well as paddy processing capacity of rice mills in that cluster. Few major clusters, their size and average capacity of the mills of different clusters are tabulated as follows.

TABLE I: TOTAL AMOUNT OF PADDY PROCESSED (MT/YEAR) IN DIFFERENT CLUSTER

Cluster	Annual paddy processed (MT)	Number of rice mills (surveyed)	Average paddy processed (MT)	Total number of rice mills	Total amount of paddy MT/year
Dinajpur	464480	100	4644.8	300	1393440
Naogaon	241062	134	1799.0	775	1394225
Bogra	156611	100	1566.1	110	172271
Nawabganj	91426	16	5714.1	16	91426
Ishwardi	120764	50	2415.3	50	120764

From surveyed data, average paddy processed in metric ton by a mill is found and thus total amount of paddy processed in each cluster is estimated. Quantity of rice husk is assumed as 20% of the amount of paddy and so annual husk production of these clusters would be like this.

Due to use of traditional parboiling system with low efficiency, amount of rice husk consumption during parboiling process shows a great variation. This variation indicates that there is a scope of saving husk if improved and efficient boiler could be used. Maximum mills consume from 100 150 kg of rice husk per ton of paddy parboiling. On average, we assume 125 kg of rice husk is used for per ton of paddy parboiling. Most of the mechanical dryer at rice mills use 80-115 kg husks per ton of paddy drying. On average we can assume 97 kg husk is required for per ton paddy drying. We found that almost all (100%) rice mills in Naogaon and Ishwardi use sun drying. On the other hand 54%, 3% and 99% rice mills use mechanical drying in Dinajpur, Bogra, and Nawabganj respectively. The amount of surplus rice husk after parboiling and drying are shown in the following table.

Finally we can say that power plant location is probably the first consideration that should be made and it should fulfill some requirements. Rice husk availability is the main criteria for these types of power plant. Then size of power plant and process for power generation should be kept in mind.

If the investor plans to invest to produce energy in the area of Dinajpur, Naogaon, Bogra, Nawabganj, Ishwardi, it will be effective and affordable to use rice husk as fuel. Because rice husk grows in abundant in these regions comparing to other districts.

TABLE II: USE OF RICE HUSK FOR PARBOILING AND DRYING

Cluster	Available rice husk (MT/year)	Total number of rice mills	Kg husk/ton paddy for parboiling	Kg husk/ ton paddy for drying	Rice mills use mechanical drying (%)
Dinajpur	278688	300	125	97	54
Naogaon	278845	775	125	97	0
Bogra	34454	110	125	97	3
Nawabganj	18285	16	125	97	99
Ishwardi	24152	50	125	97	0

V. CONCLUSION

For an ascending country like Bangladesh, prudent and judicious use of renewable resources is paramount. Rendering electricity to all the classes of people can ensure a felicitous and more comfortable life. Renewable energy, especially solar PV is getting popular to mitigate energy crisis. Mini Grid along with SHS can be much more efficacious and considered as a better solution to have the power with prime quality, reliability and sustainability.

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CPU Power Consumption Reduction in Android Smartphone

Masuma Akter Rumi,[1] Asaduzzaman,[1] D. M. Hasibul Hasan[2]
Dept. of Computer Science & Engineering
Chittagong University of Engineering & Technology
Chittagong, Bangladesh
masumarumi@yahoo.com, asadcuet@gmail.com, simon_cuet@yahoo.com

***Abstract*— Despite the growing popularity of smartphones, it's extensive power consumption is still now a burning issue. In this regard, we propose and evaluate a system of CPU power consumption reduction which supports Dynamic Voltage and Frequency Scaling (DVFS) and User Driven Frequency Scaling (UDFS) at the same time. At first, a DVFS is used to scale the frequency level continuously based on loads present at that time. Then a UDFS is used to consider user satisfaction. Starting from the highest frequency level, UDFS gradually reduces the frequency level until users feel discomfort. The proposed technique calculates an optimum frequency as the starting frequency and then reduces that frequency until user shows discomfort. When CPU reaches in ideal state, processor frequency goes to the lowest level to save battery life. Our proposed technique is implemented in Samsung Galaxy S2 and it reduces 25% power consumption compared to default DVFS and 3% than existing UDFS technique.**

Keywords—DVFS, UDFS, User satisfaction, Valid working point, Power consumption.

I. Introduction

Power consumption has become a major concern for modern smart handheld devices, on which many applications are run. Specially for handheld smartphones, power consumption has become a critical issue due to it's extensive need of power [1]. In smartphones the principal power consumption occurs in the CPU. CPU power consumption is the process of consuming electrical energy. Generally CPU power consumption is measured by the operating frequency and voltage. It is because power consumption is proportional to the CPU frequency and to the square of the voltage. It is noted that, CPU has some valid working point where frequency and voltage are fixed [19].

To reduce CPU power consumption, the most important concern is user satisfaction [3]. When using a phone, any user wants to operate his/her phone without any difficulty. User satisfaction will be reserved when power consumption is reduced but users can not face the effect of this.

The most common CPU power consumption reduction technique is Dynamic Voltage and Frequency Scaling (DVFS) [1]. In this technique, CPU power consumption can be reduced via the adjustment of operational frequency and voltage of the devices [15]. Here users' satisfaction is ignored and also it is observed that most of the time some extra frequency level is used for each application. Another technique is User Driven Frequency Scaling (UDFS) which considers the users' satisfaction as their major concern [3]. The starting frequency of UDFS is the maximum frequency which may be not necessary all the time.

In this paper, we propose a technique which calculates an optimum frequency lower than the maximum frequency and then continuously reduces the CPU frequency until user feels discomfort. Our proposed technique also considers on stop stage of an android activity. This technique is able to reduce more power consumption than some previous works.

The rest of this paper is organized as follows. Section II briefly describes our contribution to the area of CPU power consumption reduction. Section III gives a brief description of related research. Section IV introduces our proposed power consumption reduction scheme. Section V shows the experimental result of our proposed method and compares the performance of our proposed scheme with well known methods. Finally, section VI concludes this paper.

II. Related Research

In [1], it is stated that the conventional DVFS (Dynamic Voltage and Frequency Scaling) can be enhanced by using dynamic parallelism. They stated that the induced parallelism results in performance gains that allow an application to lower its operational frequency even further and thus save energy consumption. They also included that their solution relies on dynamically reconfigurable isolation cells and an autonomous parallelism, voltage, and frequency selection algorithm. The dynamically reconfigurable isolation cells reduce the area overheads of DVFS circuitry by configuring the existing resources to provide synchronization. Based on DVFS (Dynamic voltage and frequency scaling technique), [2] implies that, due to processes involved in memory accesses, by decreasing the CPU frequency may not always reduce the energy consumption. A critical frequency has been proposed as the CPU frequency, at which energy consumption can be minimized for an application. The relationship between the critical speed and the memory access rate (MAR) is also discussed in [2]. A correlation equation has been constructed to describe the relationship. Furthermore this equation has been used to predict the critical speed. The technique has been implemented in Android operating system. The technique is really an efficient one to reduce energy consumption but it

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faces some difficulties to predict the critical speed. It is noted that, the critical speed is not always the accurate frequency where minimum CPU power consumption is calculated. UDFS (User driven frequency scaling) technique is proposed in [3]. UDFS dynamically adapts CPU frequency to the individual user and workload through a simpler user feedback mechanism. In this mechanism frequency level starts from it's maximum level and the UDFS algorithm reduces the frequency level until no user feedback is taken. As soon as the user shows his discomfort by giving feedback, the algorithm sets the frequency level to the previous level. Each frequency level exits for a specific time interval. This approach dramatically reduces the CPU power consumption and also ensures user's comfort. But the limitation is that, before reaching to the optimum frequency, all the frequency levels is checked for a few moments. So some extra power consumption is faced. Resource-driven DVFS scheme is proposed in [4] which dynamically adjusts the CPU frequency based on the resource access pattern of each mobile application. To predict and adjust the processor speed accurately, a resource monitor and a set of resource state machines are designed to derive the interplay between the CPU utilization and the resource usage of the application. [5] works with two governors such as on demand and conservative governor. Observing the average power of each application, this technique determines that, for the great part of applications the power consumption is not proportionally linear to the frequency. It also said that, on demand and conservative governors performs better energy consumption in different cases. Human and application driven frequency scaling technique also called HAPPE technique is proposed in [6]. The objective of HAPPE is to minimize power consumption without any degradation of user perceived performance. For user interactive systems, the optimal frequency for the current application at the current CPU utilization level is the lowest frequency. To determine the optimal frequency, HAPPE learns user preferences and obtains user feedback by monitoring special keys "performance" and "power", which can be mapped to any two keys or key combinations on a regular keyboard. Users may press the performance key when the performance of the system does not satisfy them. They may press the power key when they are satisfied with performance and want to save power. An approach to scale voltage and detect some new valid working point of voltage and frequency is discussed in [7] and [8]. The paper studies the benefits of dynamic voltage scaling implemented using dynamically reconfigurable DCM blocks. In this technique, a DVS monitor and clock generation module has been developed. In [9], to reduce CPU power consumption both user and processes are considered. They consider user satisfaction and available processes at any particular time. Which voltage is appropriate for which frequency, is discussed in [10]. The governors available in modern android phones are introduced in [11]. In [12], it is showed that within a fixed power budget, some power consumption techniques cause more dissatisfaction than others. In [14] and [17], to reduce CPU power consumption some hardware changes are proposed. They propose some changes in current battery thus power consumption can be reduced.

III. Proposed Method

A. Overview

The proposed method creates an application frequency profile for every interactive application the user executes. As depicted in fig. 3.1, the proposed method consists of six major steps: 1) Preparation phase, 2) OS-CU equation generator, 3) Frequency controller, 4) Power consumption measurement phase. The details of these steps are described in the following sections:

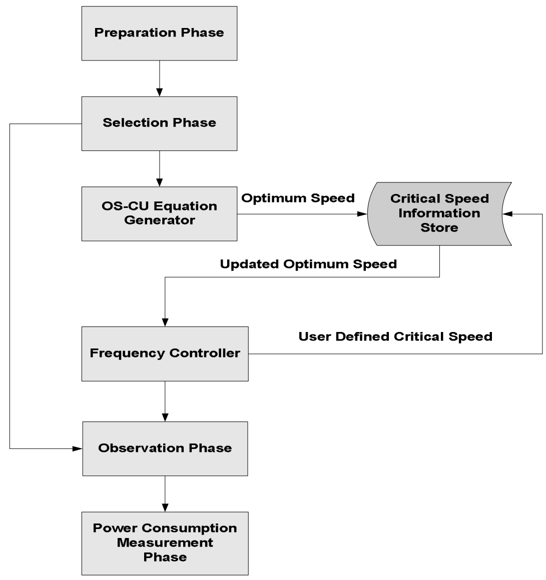

Fig. 1. Overview of our proposed method

B. Preparation Phase

In this phase, an interface is to be established between a laptop and an android smartphone. In our experiment, we used Samsung Galaxy S2 smartphone. The phone has Samsung exynos 4 dual core 1.2 GHz processor. It operates at voltage levels of 0.875 to 1.30 V. The interface is established by using Android Debug Bridge which helps to show the phone's information to the laptop.

C. OS-CU Equation Generator

For highest CPU usage processor operates in highest frequency. Highest frequency always causes highest power consumption. At the beginning of any application the default governor of android phone is "onDemand" [11] which sets the highest frequency. Also in UDFS [3], the initial frequency level is the highest level. So to find an optimum frequency level, OS-CU equation is established. As stated in [2], we know that CPU power consumption is proportional to the product of frequency and square of supply voltage. So by reducing CPU frequency, power consumption can also be reduced. For this, a minimum frequency is calculated where users feel comfort and also performance is not degraded. Here this minimum frequency is called optimum frequency.

To establish the equation, let us consider some variable,

Maximum frequency = f_{max}

CPU usage = CU

Maximum CPU usage = CU_{max}

CPU frequency is proportional to CPU usage.
So when we consider maximum frequency then we have,

$$f_{max} \propto CU_{max} \quad (1)$$

$$f_{max} = k_1 * CU_{max} \quad (2)$$

Again if we consider a particular application and the CPU usage for that application is $= CU_a$

The optimum frequency for that application = f_a

So we have,

$$f_a = k_2 * CU_a \quad (3)$$

Combining (2) and (3) we have,

$$f_a = \frac{k_1}{k_2}\left(\frac{f_{max} * CU_a}{CU_{max}}\right) \quad (4)$$

$$\text{The total frequency} = \sum_{i=1}^{n} f_i \quad (5)$$

If $f_i \le f_a \le f_{i+1}$ then set,

$$f_a = f_i \quad (6)$$

This optimum speed is set to the CPU at the very beginning. This frequency is updated after the user feedback.

D. Frequency Controller

The optimum frequency calculated in (3.8) is used to run the algorithm of frequency controller. The algorithm in form of flowchart is given-

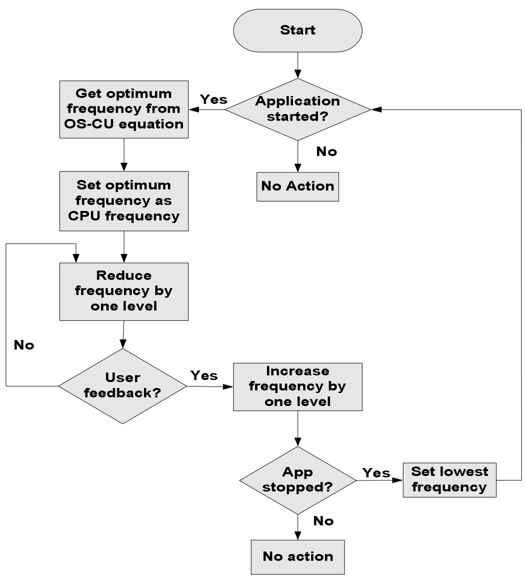

Fig. 2. Flowchart of the algorithm

E. Power Consumption Measurement Phase

This phase of the system measures the power consumption for any application, and also measures how much power consumption is reduced after applying our proposed technique.

Number of frequency levels in the phone = N

The levels are = $f_1, f_2, f_3, \ldots\ldots\ldots\ldots, f_n$

Time interval = t

To set a frequency level in the *i'th* level it takes t time and after m iteration we find the optimum frequency of a particular application.

So, time needed to set optimum frequency = $t * m$

The energy consumption in each level = P_i

The total power consumption to set the optimum frequency

$$P_t = \sum_{i=1}^{m} P_i \quad (7)$$

Let, a particular application is executed q times for a particular time period. Each time P_t amount of power is wasted.

$$\text{So, the total wasted power} = \sum_{i=1}^{q} P_{t_i} \quad (8)$$

F. Conclusion

CPU power consumption is directly proportional to the CPU frequency [2]. In default DVFS, CPU frequency remains maximum most of the time in active state for an application [15]. In existing UDFS [3], frequency is reduced from the highest level. We here calculate an optimum frequency so that, there is no need to go to the highest level at first. So, power consumption is reduced. Our approach also considers idle state to save more power.

IV. EXPERIMENTAL RESULTS

All experiments were done on core-i3, 2.40 GHz with 2 GB RAM and Eclipse IDE environment. To complete testing process six different applications are used. All applications are run in Samsung Galaxy SII.

A. Calculating Optimum Frequency

In our approach, an optimum frequency is calculated from OS-CU equation [6]. Most of the time it is observed that optimum frequency is lower than the maximum frequency. After user feedback, optimum frequency is updated according to user pessimism. To find the optimum frequency, CPU usage is necessary to calculate. We calculate CPU usage by using shell command. CPU usage refers to computer's processor and how much works it's doing. High CPU usage means that, CPU is running at high frequency level. Slow performance and sudden shutdowns are the symptoms of high CPU usage [10].

TABLE I. CPU USAGE, OPTIMUM FREQUENCY AND USER DEFINED FREQUENCY FOR DIFFERENT APPLICATION

Application Name	CPU Usage (%)	Optimum Frequency (MHz) From equation from (3.4.9)	Optimum Frequency after User Feedback (MHz) from TABLE II
SubwaySurf	84	1008	775
TempleRun2	88	1056	925
FM	90	1080	350
FruitNinja	82	984	950
Dictionary	31	372	200
BasketBall	87	1044	1000

Different users may feel discomfort in different level for the same application. So we conducted an experiment for four users and six applications. The optimum frequency according to these four users for six applications are given below-

TABLE II. USERS' DIFFERENT FEEDBACK FOR DIFFERENT APPLICATIONS

Application Name	Optimum Frequency after User Feedback regarding satisfaction (MHz)			
	User 1	*User 2*	*User 3*	*User 4*
SubwaySurf	1000	800	800	500
TempleRun2	1200	1000	500	1000
FM	200	500	200	500
FruitNinja	800	1000	1000	1000
Dictionary	200	200	200	200
BasketBall	1200	1000	800	1000

B. Calculating Reduced Power Consumption Compare to Default DVFS

We conducted an experiment for calculating the power consumption by observing the phone battery information. The time duration of the experiment is three hours in which the phone will be in idle state for 30 minutes and for another 150 minutes the phone will run different application. Each application is run for 25 minutes. The phone battery is observed before starting the application and also terminating it. The difference between these two percentage of the battery is the CPU power consumption for that particular application. The following table calculates the reduced power consumption compare to DVFS (By default).

TABLE III. POWER CONSUMPTION IN DEFAULT DVFS AND OUR APPROACH

Application Name	Execution Time (Minutes)	Default DVFS power consumption (%)	Power Consumption in our approach (%)	Battery save (%)
SubwaySurf	25	14	9	5
TempleRun2	25	17	10	7
FruitNinja	25	16	10	6
FM	25	3	2	1
Dictionary	25	2	1	1
BasketBall	25	13	9	4

In idle state the power save = 1% in 30 minitues.

Total power save = 25% (In three hours).

C. Calculating Reduced Power Consumption Compare to UDFS

We proposed a technique which calculates optimum frequency for any application. But it is observed that, the optimum frequency found from user feedback is lower than calculated optimum frequency. This is because the CPU usage is calculated for starting few seconds but in whole running period, the usage may be changed.

To compare our power consumption reduction technique with UDFS [3], the experimental test is done.

Time interval=30 seconds

Frequency levels are,

f_1=1200 MHz, f_2=1000 MHz, f_3=800 MHz,

f_4=500 MHz, f_5=200 MHz

From the experiment it is seen that, in 30 minutes or 1800 seconds the difference of energy consumption between f_i and f_{i+1} is 1%.

So, if the optimum frequency is 1000 MHz, then our system save the amount of power consumption = (30*1)/1800 = 0.016%

Similarly if,

f_a=800 MHz, The energy save = (2*60)/1800= 0.06%

If f_a = 500 MHz, The energy save = (3*90)/1800=0.15%

If f_a = 200 MHz, The energy save = (4*120)/1800=0.26%

The number of execution and execution of any application is fully dependent on user. For experimental result, we conduct a test with six different application.

The total running time = 180 minutes.

The idle time = 30 minutes

Following table contains the result of the experiment.

TABLE IV. REDUECED ENERGY CONSUMPTION FOR DIFFERENT APPLICATION

Application Name	No of execution	Optimum Frequency (MHz)	Reduced Energy Consumption (%)
SubwaySurf	5	800	.08
TempleRun2	5	1000	.3
FruitNinja	5	500	.3
FM	5	500	.75
Dictionary	5	200	1.3
BasketBall	5	800	.08

In active state the total reduced power consumption = 2.81% The phone is in idle state for 30 minutes

In lowest frequency. 1% energy consumption is saved here.

So the total energy save = 3.81% $\simeq$ 3% compare to UDFS.

D. Comparative Analysis on Idle State

In ideal state, an user may satisfied in a very low frequency [18]. In default DVFS, frequency never goes to the lowest level. In UDFS when feedback is given, that frequency is set for the rest of the time. But in our approach if phone goes to idle state the frequency becomes low. Hence a very little amount of power consumption is reduced here. Though the amount is little but this may have a great impact on the total scenario of CPU power consumption reduction.

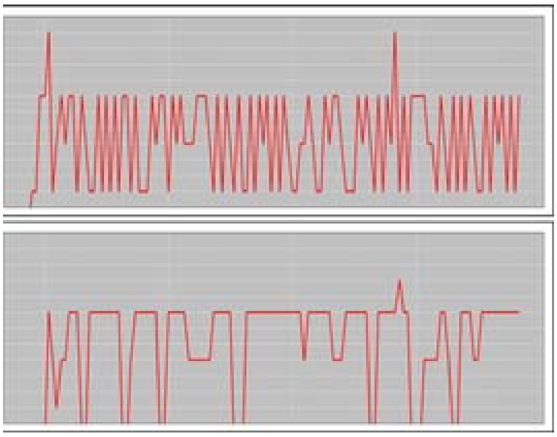

Fig. 3. Friquency graph in idle state in default DVFS

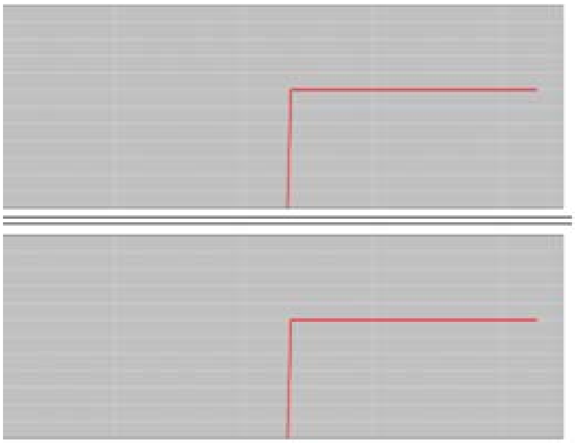

Fig. 4. Frequency graph in idle state in UDFS [3]

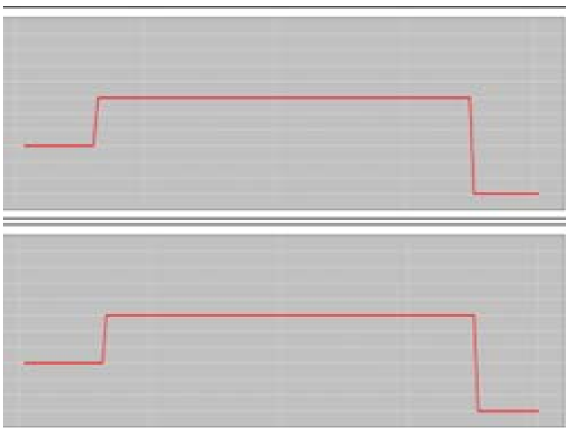

Fig. 5. Frequency graph in idle state (our approach)

E. Comparative Analysis on Active State

We compare the result of active state as most of the power is consumed when any application is in running state in the phone.

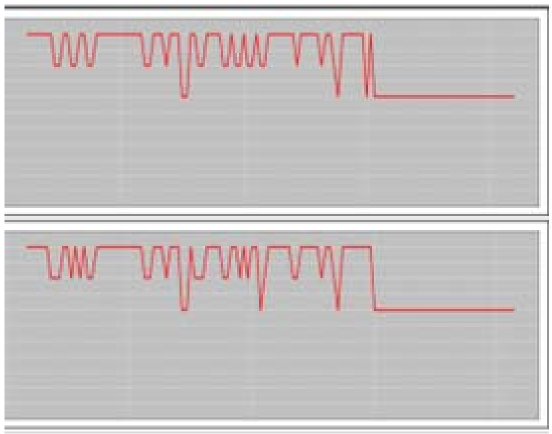

Fig. 6. Frequency graph in active state in default DVFS

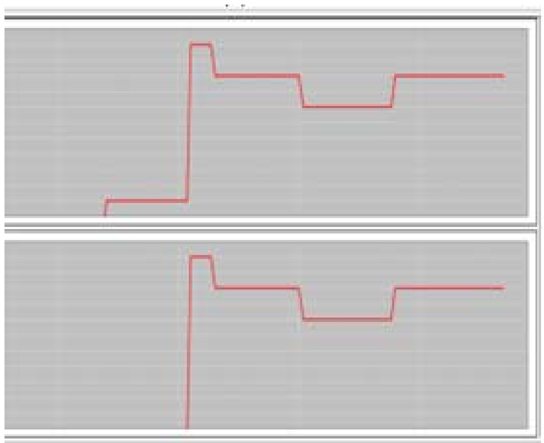

Fig. 7. Friquency graph in active state in UDFS [3]

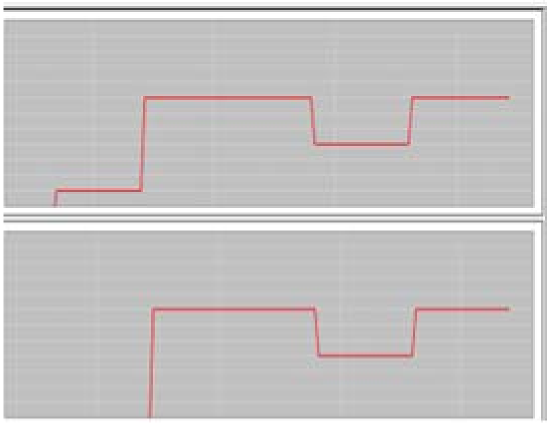

Fig. 8. Frequency graph in active state (our approach)

V. CONCLUSION

Our system presents a framework for CPU power consumption reduction in android smart phone. We proposed a technique, which calculates the optimum frequency for any application. But it is observed that, the optimum frequency found from user feedback is lower than the calculated optimum frequency. This is because we can calculate the CPU usage for starting few seconds. But in running whole period, the usage may be changed. That's why user defined frequency is lower than the optimum frequency.

Experimental results indicate that our approach provides better results than well-known methods. This is because it works on different states of running application for choosing optimum frequency. In addition, it is robust against various types of applications. Moreover, the proposed method not only saves battery life but also assure user satisfaction shown in TABLE II. These results demonstrate that our method can be a suitable candidate for reducing CPU power consumption in android smart phone.

Our approach works on running state and idle state of an android application. This can be enhanced to work on pause state and stop state [11].

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Optimization of Distributed Energy Resources to Balance Power Supply and Demand in a Smart Grid

S.M. Al-imran[1], M.A.R. Fuad[2], T. Ahmed[3], M.R. Ali[4], M.N.I. Maruf[5]
Dept. of EEE, Faculty of Engineering
American International University-Bangladesh (AIUB),
Dhaka, Bangladesh
[1]shad.aiub@gmail.com , [2]fuad.aiub@gmail.com , [3]toyon.007@gmail.com , [4]mdrashedali10@gmail.com , [5]mnimaruf@aiub.edu

***Abstract*— Energy crisis is one of the major problems for the economic growth and development of Bangladesh. The gap between power supply and demand is increasing day after day. Moreover, most of the power plants are based on fossil fuel and have the risk of being phased out in future. This paper aims to solve these problems by balancing the power supply and demand in a smart environment, focusing mainly on distributed energy resources (DER). The main DER components of the system are power plants based on renewable energy sources (RES). Since RES are intermittent, back up from fossil fuel based plants are also integrated in the final model to increase the system reliability. During off-peak hours residual energy from RES will be stored in the proposed storage arrangement. The proactive consumers (prosumer) in the demand side will have the scope to sell this stored energy to the national grid during peak hours in a proposed smart bilateral network. Finally, grid monitoring and metering interface with an advanced control mechanism has been developed, which is expected to increase the flexibility of the prosumer to handle their energy usage and costs.**

Keywords—solar; wind; biomass; smart-grid; smart-meter

I. Introduction

Energy crisis in today's world is increasing day by day because of scarcity of the natural resources. Researchers are searching for alternative sources of energy to meet this growing demand. Renewable energy sources (RES) can be a good option for gradual switching from a top-down to a bottom-up electrical system in future. The abundant energy available in the nature such as solar energy, wind energy, biomass energy can be converted to electricity to supply necessary power to the consumer in both on-grid and off-grid regions [1], [2].

In a RES-based smart grid, the customer may face difficulties to monitor the system from the demand side because of the complex ICT integrated environment. In this circumstance, for increasing the user friendliness of the smart grid a smart meter can be introduced [3].

This paper presents modeling and the analysis of a smart grid system for community purpose in the offshore areas of Bangladesh. The paper mainly focuses on designing and analyzing a smart-grid for a small community of Chittagong city of Bangladesh, which is connected to the national grid of the country. A simulation based model has been developed in such a way that it can be used to optimize local power supply and demand for a small scale power system.

With available weather and technical data, the smart grid is modeled using HOMER Legacy (2.68 Beta). After developing the preliminary HOMER model, a MATLAB based model has been developed and a Graphical User Interface (GUI) based smart meter namely 'sMeter_v2015a' has been implemented.

II. Analysis of a Smart Grid

A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users. Smart grids co-ordinate the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimizing costs and environmental impacts while maximizing system reliability, resilience and stability. Smart grids are a set of evolving technologies that will be deployed at different rates in a variety of settings depending on local conditions such as existing technologies, regulatory frameworks and investment framework [4].

Smart grid is an automated, self-balancing and self-monitoring grid capable of accepting multiple energy sources. Smart grids possess demand response capacity to help balance electrical consumption with supply, as well as the potential to integrate new technologies to enable energy storage devices [5].

A smart meter appears to be very similar to traditional electricity, gas, or water meter located in a residence or business. Both smart and traditional meters provide metrology by measuring quantities of voltage, current, pressure, velocity, temperature, or flow rate, and communicate this information to the utility. It enables the integration of new technologies and innovations across the grid [6]. A smart meter can contribute to enhance the smart grid. Depending on the real time data smart meter is able to send the statistical data to the prosumer.

III. Architechture of the Model

Before modeling the smart grid, mainly three renewable energy sources have been used which are solar PV, wind and biomass energy. The system is designed considering a community having 30 apartments. In load calculations, it has been considered that each apartment has 8 lights, 4 fans, 1 TV, 1 freeze, 3 laptops, 1 iron, 1 blender and 1 pump. For each apartment, 2 lights and 1 fan have been considered to be fixed loads and for home appliances, others loads are assumed to be variable loads.

A converter is used which can be used both as a rectifier and an inverter. A battery is used as the storage system which stores the extra energy produced from the grid and supplies it back to the grid when needed. Figure 1 show the block diagram of the smart grid where monitoring and energy storage are used for design. Three resources, one bidirectional converter, one battery as a storage system are used along with two types of the load [7], [8].

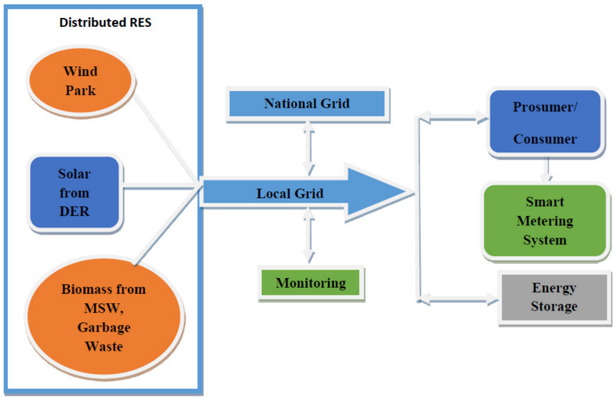

Fig 1 Block diagram of the proposed smart grid.

After designing, simulations are done firstly using software HOMER Legacy (2.68 beta). Solar and Wind data are collected from the NASA surface meteorology and solar energy website [9] and biomass data are taken from previous researches. The load calculations are done using standard forms of the utilities. The HOMER based analysis focuses on balancing as well as the maximization of power production and consumption. Figure 2 shows the HOMER implementation of the model.

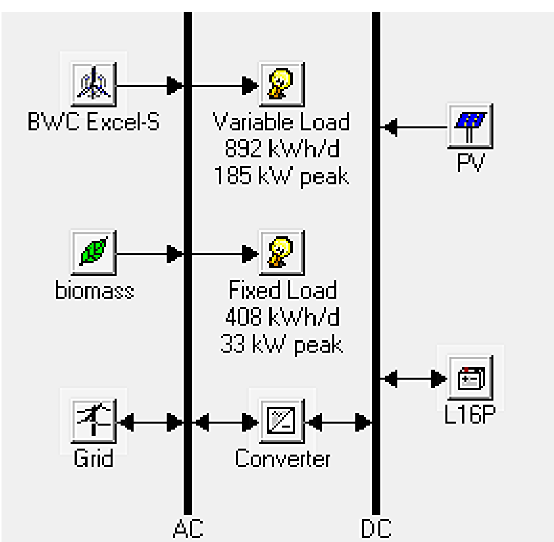

Fig 2 HOMER implementation of the smart grid.

The designed model is further analyzed using MATLAB. Then GUI is used to design a user friendly, smart meter simulation model. The developed GUI model - 'sMeter_v2015a' can take input time data variables and then show the total consumption, solar, wind, biomass output, total production, total sell and buy based on the real time data. Hence the user will have the flexibility to change the time and observe the response faster. The user will also have an approximate idea how much electricity can be stored or supplied.

IV. Data Collection

This section informs about data collection for different RES and instruments. Executable data were gathered for accurate simulation from different resources. Mainly three renewable energy resources are used to design the model: Solar, Wind and Biomass [9], [10], [11].

Data for solar resources for the Chittagong city are shown in Table I and corresponding graph is shown in Figure 3.

TABLE I. Daily Prevaling Solar Radiations for Chittagong City

Month	Daily Radiation ($KWh/m^2/day$)	Clearance Index
Jan	4.404	0.626
Feb	4.912	0.606
Mar	5.637	0.599
Apr	5.786	0.553
May	5.706	0.519
Jun	4.242	0.381
Jul	3.817	0.346
Aug	4.038	0.380
Sep	4.022	0.413
Oct	4.776	0.564
Nov	4.346	0.599
Dec	4.293	0.643

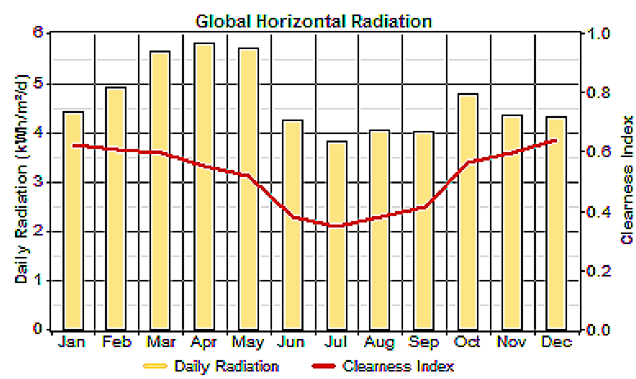

Fig 3 Solar data resources for Chittagong City (Latitude 22.3667°N /Longitude 91.8000° E)

Data for wind resources are shown in Table II and the corresponding graphs are shown in Figure 4.

TABLE II. WIND SPEED FOR CHITTAGONG CITY

Month	Wind Speed (m/s)
Jan	4.900
Feb	5.100
Mar	7.600
Apr	7.800
May	8.200
Jun	7.600
Jul	8.100
Aug	7.400
Sep	6.900
Oct	6.400
Nov	5.600
Dec	5.100

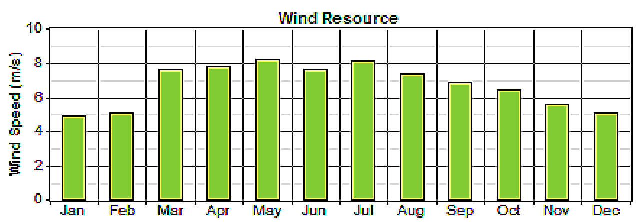

Fig 4 Daily Wind Speed Variations

Data for biomass resources are shown in Table III and the corresponding graphical representations are in Figure 5.

TABLE III. BIOMASS DATA FOR CHIITAGONG CITY

Month	Available biomass (tonnes/day)
Jan	4.000
Feb	4.000
Mar	4.000
Apr	4.000
May	4.000
Jun	4.000
Jul	4.000
Aug	4.000
Sep	4.000
Oct	4.000
Nov	4.000
Dec	4.000

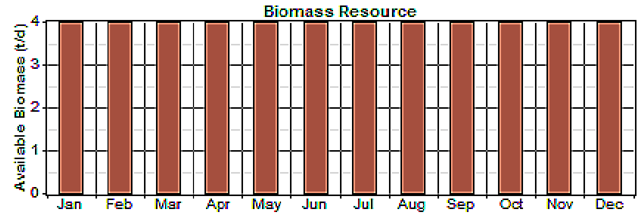

Fig 5 Available biomass resources

V. SIMULATION AND ANALYSIS

A. *Simulations using HOMER Legacy (2.68 beta)*

As mentioned in Section III, Figure 2 shows the HOMER implementation of the smart grid model. PV indicates photovoltaic cells, which are connected to the DC grid and Wind and Biomass resources are connected to AC grid. The Generator on the figure is the biogas generator used as a biomass resource which runs using biogas as fuel and BWC Excel-S is the wind turbine used to generate wind energy. A bidirectional converter is used which can be used both as rectifier and inverter. Trojan L16P is the battery used as storage system of the system connected to a DC grid, which can store extra energy produced from the grid and also send it back to the grid when needed. Two types of loads are connected: Fixed Load and Variable Load. Both the loads are connected to the AC grid [12]. Figure 6 shows the total PV output for a year. Figure 7 shows the wind turbine output for a year. Figure 8 shows the biomass output in a year.

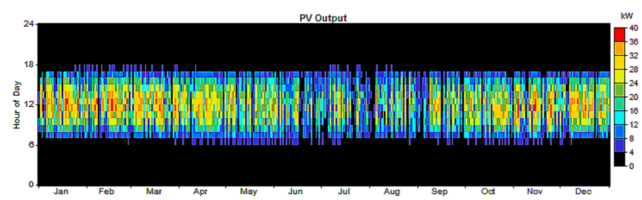

Fig 6 Solar Output

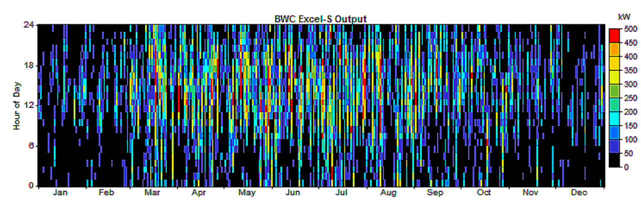

Fig 7 Wind Output

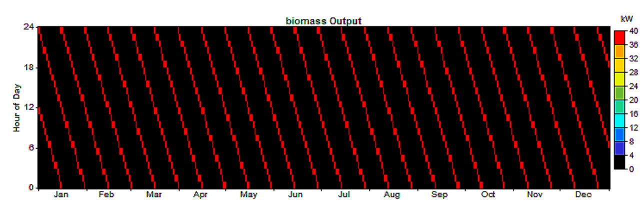

Fig 8 Biomass Output

Homer generates output power productions and power consumptions. Table IV shows the electrical production rates and Table V shows the electrical consumption rates. Figure 9 shows the electrical power production of this combination.

TABLE IV. ELECTRICAL PRODUCTION

Production	KWh/yr.	%
Photovoltaic array	59,172	6
Wind Turbines	690,829	72
Biogas Generator	30,160	3
Grid purchases	178,712	19
Total	958,873	100

TABLE V. ELECTRICAL CONSUMPTION

Consumption	KWh/yr.	%
AC Load	474,500	50
Grid Sales	478,457	50
Total	952,957	100

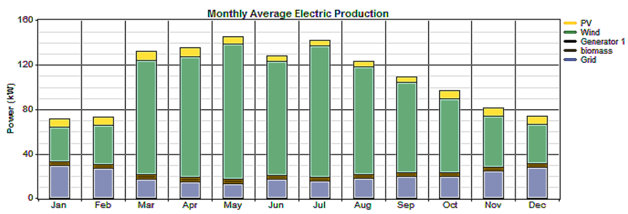

Fig 9 Monthly Average Electrical Production

The total energy production from the proposed smart grid yields 958,873 kWh/yr. where the consumption yields 952,957 kWh/yr. Residual energy that can be stored from the system is 478,457 kWh/yr. Total calculated system loss is 5,916 KWh/yr. Figure 10 shows the NPC (Net Present Cost) of this cost analysis.

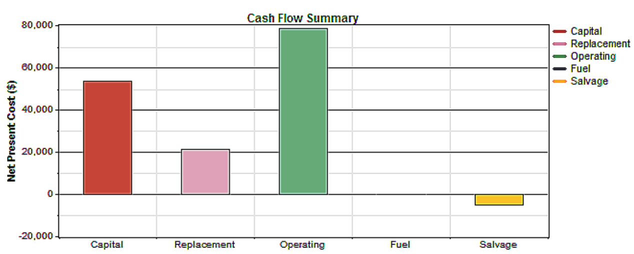

Fig 10 Net Present Cost

The system has been further analyzed using 40 KW PV, 40 BWC Excel-S Wind Turbines, 40 KW Biogas Generator, 1 Trojan L16P Batteries and a 218 KW inverter as 218 KW rectifier, which has a Net Present Cost of $148,909. Per unit cost of production becomes $0.012/KWh and operating cost is $7438 per year.

B. Simulations of Smart-Meter Using MATLAB with GUI

In order to increase the user friendliness of the system, a MATLAB based smart meter model has been implemented for the proposed smart grid. The initial interaction mechanism was programmed in MATLAB. Then the GUI based model ‘sMeter_v2015a’ has been developed. Figure 8 demonstrates the model using available data for Chittagong city, Bangladesh. The variable data input can be placed in the top pane by the user. The figure on the right side of the GUI show the total consumption, solar, wind, biomass output, total production, total sell & buy based on the real time data. Figure 11 shows the demonstration of ‘sMeter_v2015a’. The software model ‘sMeter_v2015a’ is able to show the amount of sell and buy data in real time, so that the prosumer can take the decision based on the results. Based on the output display, the user will also be able to see the load variation at different times of a day.

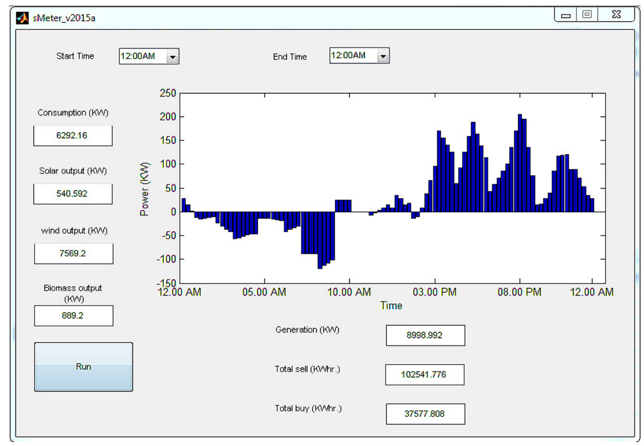

Fig 11 Demonstration of ‘sMeter_v2015a’

VI. Conclusion

The smart grid using renewable energy resources (Solar, Wind and Biomass) is modeled successfully using HOMER Legacy (2.68 Beta). Different combinations of the components are checked and analyzed using HOMER Legacy software. Finally, the system is designed using 40 KW PV, 40 BWC Excel-S Wind Turbines, 40 KW Biogas Generator, 1 Trojan L16P Batteries, 218 KW inverter as 218 KW rectifier. It has a Net Present Cost of $148,909 per unit cost for production COE of $0.012/KWh and operating cost of $7438 per year. A smart meter is programmed for the proposed system using MATLAB. A Software model, namely ‘sMeter_v2015a’ is designed using MATLAB GUI. The model can take input time data variables and then show the total consumption, solar, wind, biomass output, total production, total sell and buy based on the real time data. This type of smart grid based power plant can solve the supply demand balancing problem in small scales in Bangladesh. For extensive research in the future, more weather and RES data should be taken into account. An agent based model for customer interaction can provide a refined solution for local power supply-demand matching [13]. Moreover, analysis should be performed for other off-grid and semi-off grid regions of Bangladesh.

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Simulation of Standalone 80kW Biomass Fueled Power Plant in Sailchapra, Bangladesh

Muktadir Ahmed, Md. Salahuddin Parvez, Md.Mozammel Hossain
Dept. of EEE, Mymensingh Engineering College (University of Dhaka)
Mymensingh, Bangladesh
muktadir220@gmail.com

Md. Maksudur Rahman
Dept. of EEE, American International University, Bangladesh (AIUB)
Dhaka, Bangladesh

Abstract—**In this era of globalization to keep pace with the world Bangladesh is also going forward, but the people of rural areas being deprived from modern facilities & our country's economy is falling apart. For development of rural place of Bangladesh electrical power is necessary. Scientists are working desperately to power up the whole rural areas. Energy generation from biomass will be revolutionary system to power up rural areas of Bangladesh like Sailchapra. In every season about thousands tons of straw and two hundred tons of husk are produced from paddy in Sailchapra, which is a good source of biomass fuel. The Sailchapra can generate a large amount of electric power by gasification of this biomass fuel. The aim of this paper is to power up Sailchapra by implementing a biomass power plant.**

Keywords- biomass; power-crisis; HOMER pro

I. INTRODUCTION

The village Sailchapra is about 13Km away from Muktagacha. Sailchapra's geographical coordinates are 24° 42' 0" North, 90° 11' 0" East. People of Sailchapra do not always get benefit from the grid-connected electricity for power supply. They gets electric supply from 'Palli Bidyut', but the supply of 'Palli Bidyut' is not uninterrupted. Only 44 of 367 family having electricity connection in this village (from our survey), another 323 do not have the electricity connection because of their poverty, also the connected families suffers a lot because of load-shedding.

Figure 1. Location of Sailchapra village.

It's very important to power up the whole village because a major step for the development of Bangladesh is to ensure electric power for each habitation. We are surveyed 38 families and have seen that their individual load is approximately 0.23KW. If we power up the whole village we need to generate approximately 80KW. The implementation of 80KW biomass power plant will be most economical because of fuel source. Biomass fuel like Straw, Rice Husk and dry Cow Dung is available in this village.

II. BIOMASS

Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities. It is derived from numerous sources including the by-products from the timber industry, agricultural crop, raw material from the forest, mayor parts of household waste and wood [1]. Biomass is biological material derived from living or recently living organism. In the context of biomass for energy this is often used to mean plant based material, but biomass can equally apply to both animal and vegetable derived material [2].

A. Biomass and Bangladesh

As an agricultural country, Bangladesh possesses the potential for power generation from biomass sources. To tap the unharnessed potential of biomass energy sources, IDCOL financed the first and only biomass gasification based commercial power plant at Kapasia of Gazipur district. The project, which has an installed capacity of 250kW, was initiated in 2005 by Dreams Power Private Limited (DPPL) and gained commercial go-ahead in December 2007. Constructed in an off-grid area, this plant utilizes locally available agricultural residue like rice husk as a raw material and is capable of serving 395 households. Though the plant has successfully served the customers since its commencement, meagre electricity demand during evening hours results in a per capita consumption of 130W only, a value much lower than projected [5]. Biomass is the most significant energy source in Bangladesh which accounts for 70% of the total final energy consumption [6].

B. Biomass Gasification

The chemical composition of biomass varies among species, but plants consist of about 25% lignin and 75% carbohydrates or sugars. The carbohydrate fraction consists of many sugar molecules linked together in long chains or

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polymers [1]. Biomass gasification is the process of converting solid fuels (wood/wood-waste, agricultural residues etc.) into a combustible gas mixture. This is achieved by reacting the material at high temperatures (>700 °C). The power derived from gasification of biomass and combustion of the resultant gas is considered to be a source of renewable energy. The calorific value of this gas varies between 4.0 and 6.0 MJ/Nm3 or about 10 to 15percent of the heating value of natural gas [3].

C. *Combustion of Biomass*

Generating plant fuelled by biomass uses conventional steam turbine electricity generating plant as used in coal fired power stations with modifications to the combustion chamber and fuel handling systems to handle the bulkier fuel [4].

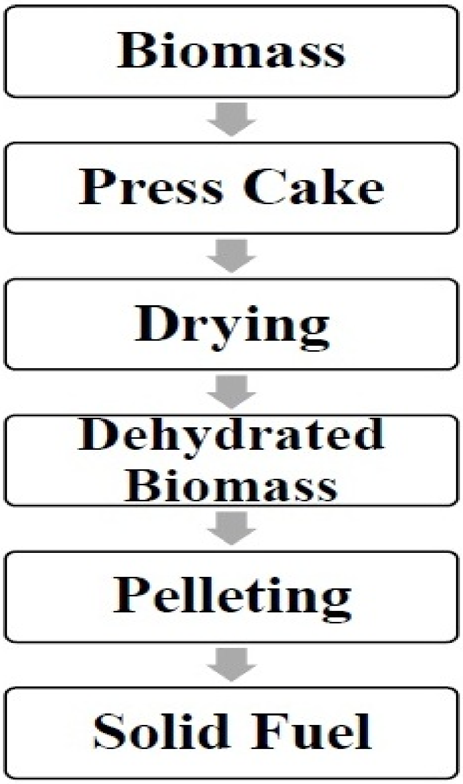

Figure 2. Biomass-solid fuel conversion.

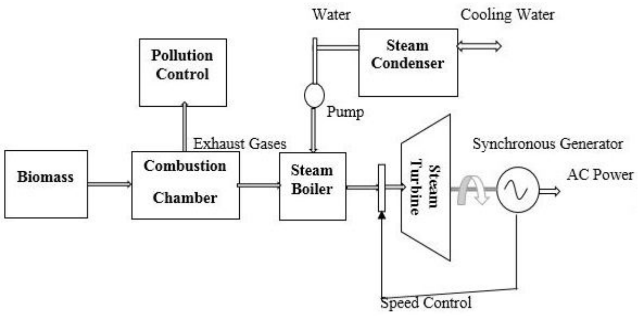

Figure 3. Electric power generation by combustion of biomass fuel.

III. PROPOSAL OF BIOMASS FUELED POWER PLANT

The village Sailchapra has huge source of biomass fuel. From the survey it's seen that the villagers cultivate their land twice a year. In 'Buro' season (April-10 to May-30) the farmers of the village produce about 710 tons of paddy from which 1014.4 tons of straw and about 213.23 tons of husk are produced. In 'Amon' season (October 25 to November 25) the farmers produce about 507 tons of paddy from which 811 tons of straw and 152 tons of husk are produced. Also we can get about 2.7 tons of dry cow dung per day.

If we preserve the straw and rice husk from every season, it will be possible to implement the 80KW combustion based biomass fueled plant every day. Total calculation of biomass fuel of Sailchapra is given below.

TABLE I. CALCULATION OF BIOMASS FUEL OF SAILCHAPRA

SL.	Biomass Fuel	Amount/year
1	Straw	1825.4 tons/year
2	Rice Husk	365.23 tons/year
3	Dry Cow Dung	985.5 tons/year
Total		3176.13 tons/year
Total biomass fuel per day		8.7 tons/day

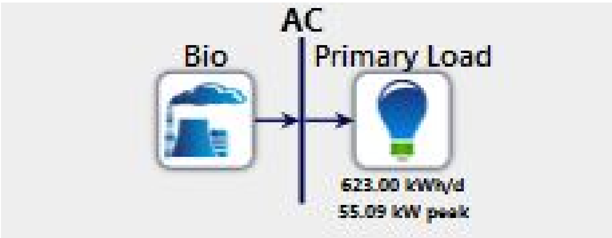

Figure 4. Schematic diagram of proposed biomass fueled power plant.

Figure 5. Biomass resource of Sailchapra.

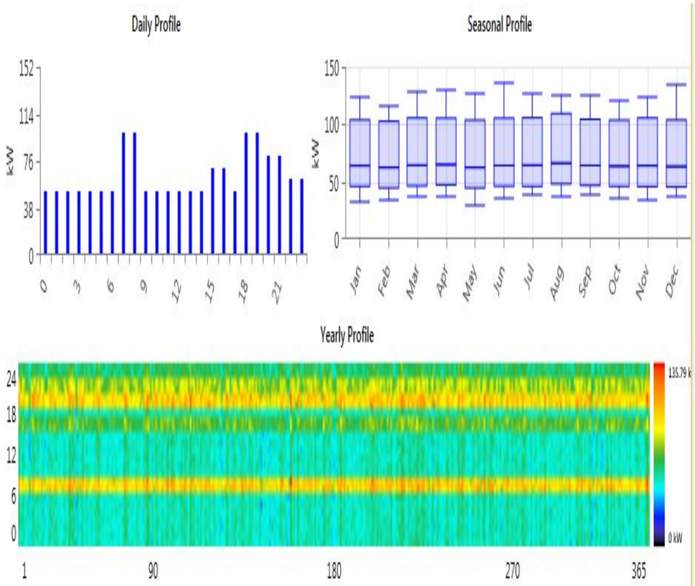

Figure 6. Daily, seasonal and yearly load profile of Sailchapra.

A. Costing of Biomass Fuel and Power Plant

The 80KW biomass fueled power plant cost is USD 60,000 and its maintenance cost is USD 1 per hour. The fuel is free of cost because the villagers said, if we light them up they will give the fuel free of cost.

B. Simulation Result

HOMER pro (v3.1.2) is used to simulate this model. The results are given below.

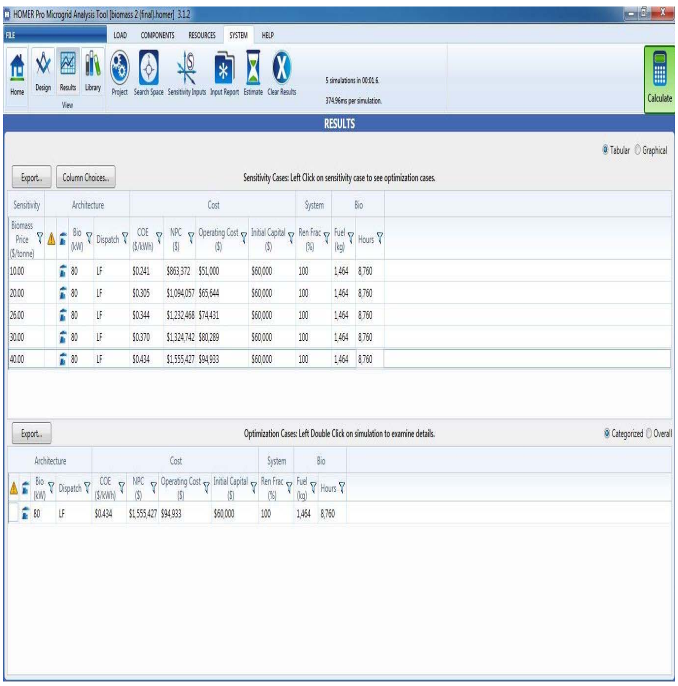

Figure 7. Overall simulation result.

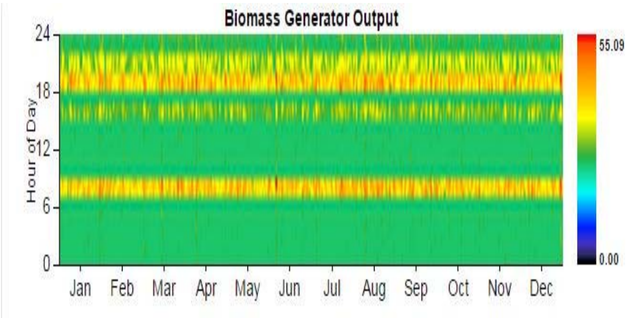

Figure 8. Biomass generator output.

TABLE II. OVERALL RESULTS

Quantity	Value	Units
Hours of operation	8,760	hrs/yr
No. of starts	1	Starts/yr
Operational life	2	yr
Fixed generation cost	1	$/hr
Electrical production	244,432	kWh/yr
Mean electrical output	28	kW
Min. electrical output	24	kW
Max. electrical output	55	kW
Fuel consumption	1,464	L/yr
Specefic fuel consumption	4	L/kWh
Fuel energy input	1,566,142	kWh/yr
Mean electrical efficiency	16	%

TABLE III. EMISSIONS

Pollutant	Emission	Units
Carbon dioxide	92	Kg/yr
Carbon monoxide	10	Kg/yr
Unburned hydocarbons	1	Kg/yr
Particulate matter	1	Kg/yr
Sulfur dioxide	0	Kg/yr
Nitrogen dioxide	85	Kg/yr

C. Outcome of the Proposal

If we implement this model, it will be possible to light up the whole sailchapra village. The cost will be 0.036 USD (approximately TK. 2.8) per kWh (Electricity production is 244,432kWh/yr and maintainance cost is 8760 US$/yr) because of the possibility of getting fuel free of cost.

IV. CONCLUSION

The proposed system has been designed and optimized using HOMER pro for a biomass fueled power plant in Sailchapra. Although the plant will not eliminate the power crisis of Sailchapra, it may reduce the power crisis. Biomass fuel is less costly than other fuel, so government and high officials should be concerned about biomass energy to reach their goal "Digital Bangladesh"

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I would like to express my sincere gratitude and profound indebtedness to Md. Ali, Tara Bro, Md. Saiful Islam, Md. Saqibul Amin, Dr. Rotan Kumar Nondy, Md. Khairul Islam Sohan, Mridha Shihab Mahmud for constant guidance, insightful advice, helpful criticism, valuable suggestions, commendable support, and endless patience towards the completion of this thesis. They rendered me enormous support during the whole tenure of my study. Last but not least we would like to thank H.M. Imran Hassan who taught me the value of hard work by his own example. I feel very proud to have worked with him. Without his inspiring enthusiasm and encouragement, this work could not have been completed.

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Minimization of Power Shortage by Using Renewable (Solar) Energy through Smart Grid, Perspective: Bangladesh

Muktadir Ahmed, Md. Salahuddin Parvez,
Md. Mozammel Hossain, Arup Kumar Pal
Dept. of EEE, Mymensingh Engineering College
(University of Dhaka)
Mymensingh, Bangladesh.
muktadir220@gmail.com

H.M. Imran Hassan, Md. Shahid Iqbal
Dept. of EEE, Khulna University of Engineering and Technology (KUET)
Khulna, Bangladesh

***Abstract*—A smart grid is an electricity network based on digital technology that is used to supply electricity to consumers via two-way digital communication. This system allows for monitoring, analysis, control and communication within the supply chain to help improve efficiency, reduce the energy consumption and cost, and maximize the transparency and reliability of the energy supply chain. The term "smart grid" is not familiar to Bangladesh. It will be good if it can be implemented in Bangladesh because of having load-shedding problem. The power system of Bangladesh is very complex and antique. If we want to reduce the complexity and eliminate load-shedding problem, there is no better way without smart grid. The regular grid system can easily be replaced by "smart grid". The main theme of this paper is to implement smart grid in Bangladesh and to integrate renewable (mainly solar energy) energy with it to increase production of power and eliminate power shortage in Bangladesh.**

***Keywords*-smart grid, smart meter, load shedding.**

I. Introduction

At present the generation of power is less than our huge demand so load shedding occurs when the electricity falls short of its demand. It is high time for Bangladesh to introduce with smart grid for reducing load shedding problem. Smart grid may be the revolutionary solution of a century old centrally-controlled electrical grid, bearing the aspects of smart central generation, smart transmission, smart substation, smart distribution feeders and smart metering. Both theoretically and practically smart grid is more complex, larger and effective than its old counterpart. This paper addresses the Perspective of smart grid in Bangladesh using renewable energy (solar energy). The key target of this paper is to provide current condition of the electrical grid of Bangladesh as well as to discuss the possibilities of smart grid in this developing country. It is anticipated that this paper will provide a positive way to address the challenges of the energy sector of Bangladesh by implementing smart grid technology using solar energy. In this paper we only considered Dhaka city of Bangladesh.

II. Smart Grid

According to DOE smart grid book, "A smarter grid provides chances to make the transformation from a centralized, producer-controlled network to one that is less centralized and more consumer-interactive, by bringing the philosophies, concepts and technologies that enabled the internet to the utility and the electric grid. More importantly, it enables the industry's best ideas for grid modernization to achieve their full potential".

According to European Regulators' Group for Electricity and Gas, "A Smart Grid is an electricity network that can cost efficiently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety is" [1].

A modern smart grid system has the following capabilities:

- It can repair itself.
- It encourages consumer participation in grid operations.
- It ensures a consistent and premium-quality power supply that resists power leakages.
- It allows the electricity markets to grow and make business.
- It can be operated more efficiently [2].

TABLE I. Comparision Between Existing Grid and Smart Grid [3]

Existing Grid	Smart Grid
Electromechanical	Digital

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Existing Grid	Smart Grid
One-way communication	Two-way communication
Centralized generation	Distributed Generation
Few sensors	Sensors throughout
Manual monitoring	Self-monitoring
Manual restoration	Self-healing
Failures and blackouts	Adaptive

III. Present Power System Status of Bangladesh

The total generation of power is 10264 MW (December 2013). Different types of power plants generate electricity and synchronize it with the national grid. There are some isolated diesel power stations at remote places and islands which are not connected with the National Grid. Terminal voltages of different generators are 11 KV, 11.5 KV and 15.75 KV [4]. In the Eastern Zone (eastern side of river Jamuna), electricity is generated from indigenous gas and a small percentage through hydro power. In the Western Zone, Coal and imported liquid fuel is used for generation of electricity. The fuel cost per unit generation in the Western Zone is much higher than that of the Eastern Zone. Therefore, as a policy, low cost electricity generated in the Eastern Zone is transferred to the Western Zone through the 230 kV East-West Inter connector transmission line.

IV. Benefits of Smart Grid For Bangladesh

1. Smart grid technology can recover the fault automatically. It can reduce additional transmission lines.
2. It is atomized and it process real-time information from sensors and meters for fault location, automatic configuration of feeders, voltage and reactive power Optimization [5].
3. Smart grid can reduce the reactive power flow and maximize the amount of real power to minimize transmission losses.
4. Smart grid required digital radios to wirelessly control the distribution network. Under this system the area will be divided in two very small regions and if fault occurs then whole area will be not victimized.
5. Most of the meter is digital .It can detect non-working meters and bypassed meters.
6. It can integrate renewable energy and distributed sources.
7. It can eliminate billing error, detect nonpayment of bills, remotely disconnect for non-paying consumer and reconnect after payment.
8. Theft detection of transformer level is possible.
9. Communication system is present and it is two way and real time.

V. Scope of Smart Grid in Bangldesh

The initiative of smart grid will create a scope to make the present electricity market a deregulated market. Thus new competition, business and research areas will be created. Big cities are over populated with very less options available for establishing required facilities in due time in aright space. Application of GIS, one of the components of Smart Grid will ease the procedure of decision making for a network planner [6]. Steps to implement Smart Grid by the Govt. of Bangladesh will be a strong approach to make a “Digital Bangladesh”. The government has declared the “Vision 2021” which targets establishment of a resourceful and modern country by 2021 through effective use of information and communication technology. The customers want a reliable, cheap and quality power supply in an environment friendly manner. Considering all the technical, economical, geographical, environmental and social aspects, it can be stated that smart distribution system is an inevitable choice for Bangladesh.

VI. Smart meter

The smart meter is an advanced energy meter that obtains information from the end users’ load devices and measures the energy consumption of the consumers and then provides added information to the utility company and/or system operator for better monitoring and billing. With smart meter, electrical data such as voltage and frequency are measured and real-time energy consumption information is recorded. Smart meter supports bidirectional communications between the meter and the central system. Also, smart meter has the built-in ability to disconnect-reconnect certain loads remotely and can be used to monitor and control the users’ devices and appliances to manage demands and loads within the “smart-buildings” in the future. From the consumer’s perspective, smart meters are offering a number of potential benefits; for example consumers are able to estimate bills from the collected information and thus manage their energy consumptions to reduce their electric bills [3].

A. Feature of smartmeter

A smart meter system employs several control devices, various sensors to identify parameters and devices to transfer the data and command signals. In future electricity distribution grids, smart meters would play an important role in monitoring the performance and the energy usage characteristics of the load on the grid. Collection of energy consumption data from all customers on a regular basis allows the utility companies to manage electricity demand more efficiently and also to advise the customers about the cost efficient ways to use their appliances. In light of this, smart meters can be used to control light, heat, air conditioning and other appliances [7].Smart meters can be programmed to maintain a schedule for operation of the home appliances and control operation of other devices accordingly. In addition, integration of smart meters helps utility companies in detecting unauthorized consumption and electricity theft in view of improving the distribution efficiency and power quality [8].

B. How Smart Meter Works

Smart meters have a digital display and are similar in size to regular meters. Various types and models of smart meters are available, but all of them have the same basic functionality. Using a communications network, the internal antenna present in smart meters sends electricity consumption data to the utility. An external antenna may be required in some cases for improving signals over longer distances and ensuring reliable data transmission. This antenna can be attached on or near the meter box. Smart meters can also record the energy that feedback into the distribution network from co-generation sources, such as wind turbines and solar panels. Smart metering communication technology enables centralized meter reading, so meter readers don't have to visiting individual premises for data collection [9]. However, your meter may need to be examined occasionally for testing and maintenance.

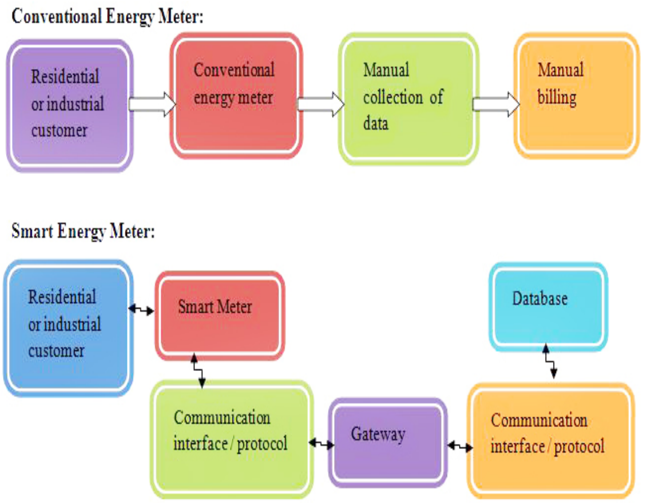

Figure 1. Line diagram of a conventional and smart meter system [7].

VII. LOAD SHEDDING PROBLEM IN BANGLADESH

According to the official statistics, the country's electricity shortage gone up 1000 megawatts (MW) to 1259 MW with the demand of 4806 MW on 2006. Authority said in year (2009) the country's electricity shortage gone up 1400 MW to 1800 MW which was almost twice more than last year and the country need about 5000 MW. In Bangladesh electricity power is not generate as much as our demand. So every summer we face huge load shedding and people are suffering, but in winter there is almost not load shedding. In summer temperatures goes up to around 40° Celsius. So in this situation if there is load-shedding of electricity people face uncertain condition.

VIII. PROPSED MODEL OF IMPLEMENTATION OF SMART GRID

Since smart grid technology allows consumers to interact with grid that's why we have proposed to install PV cell in residential (roof top), institutional, industrial and other consumers area. This model proposed to install solar panels in sunny areas (area which get maximum sunlight).

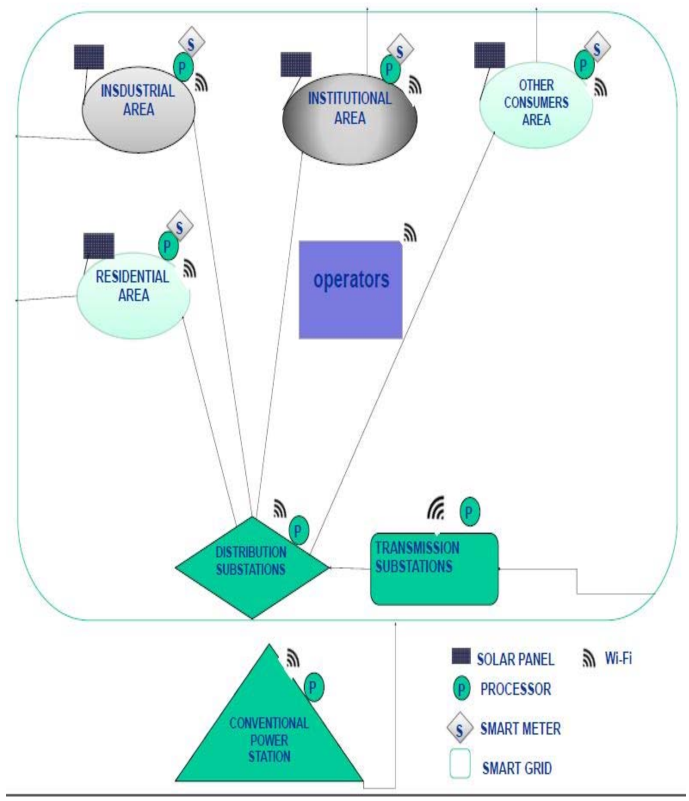

Figure 2. Block Diagram of Proposed Model.

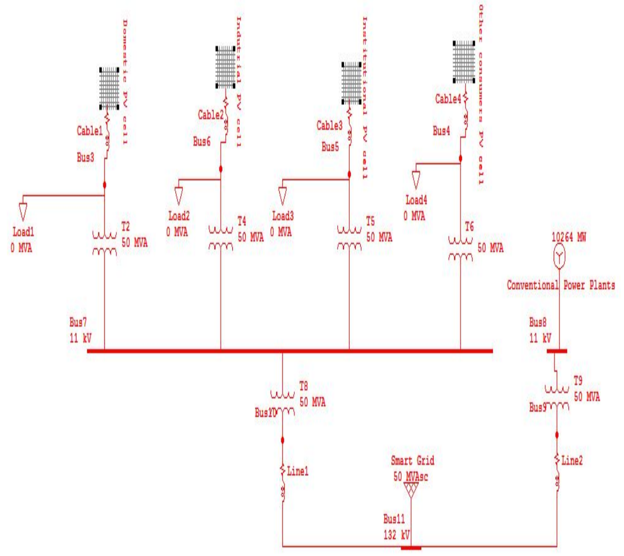

Figure 3. Proposed Model of implementation of smart grid using ETAP (v4.0).

The consumers will consume power from PV cell (as consumer want) and the rest power consumer will give to the smart grid. Consumer will also consume power from the

Smart Grid (because in winter and rainy season the sun is hardly be seen). By this way we can easily overcome our load shedding system and can improve our capacity. In this proposed model all consumers, generating stations, transmission and distribution substations and operators are connected through WAN and all are having processor to do the process easily.

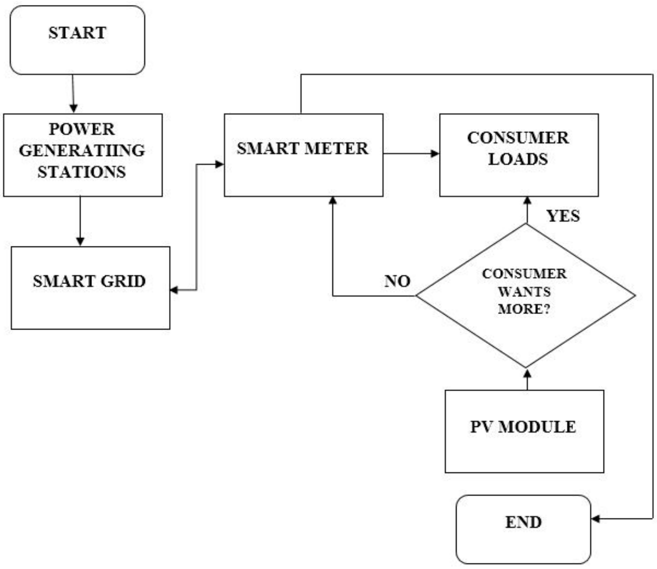

Figure 4. Flow chart of proposed model.

As we consider only dhaka city so the figure 5 shows the climate data sheet of Dhaka city, figure 6 represents the daily solar beam radiation in Dhaka and figure 7 shows the Demand and Load-shed curve as on 17/04/2014 to 27/2014 (Dhaka). From table 2 we get the actual area of PV panel installation of some major areas of dhaka and from table 3 we get calculation of power.

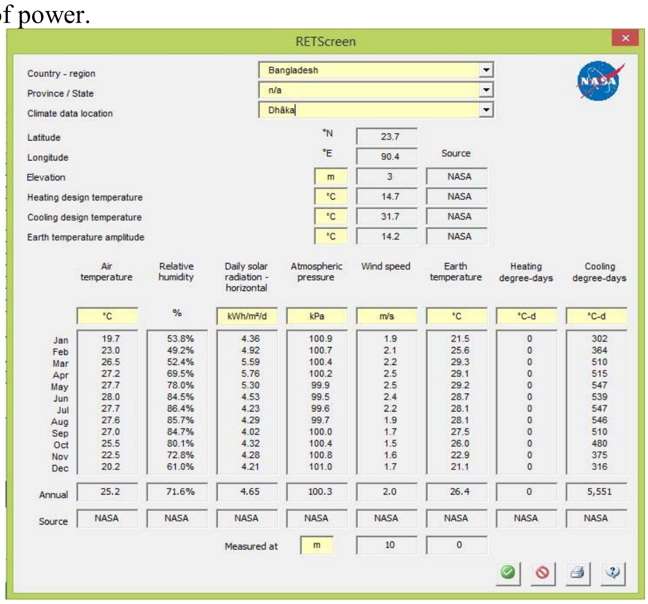

Figure 5. Climate data sheet for Dhaka (software: RETScreen v 4.0).

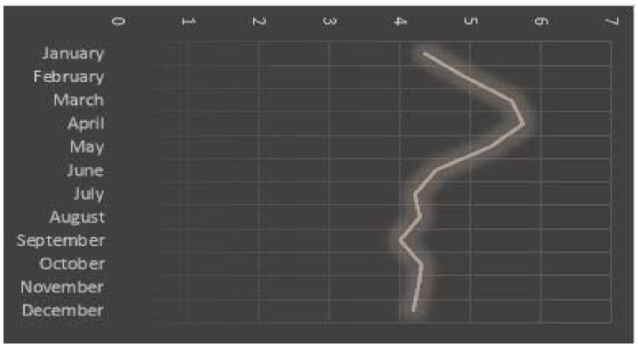

Figure 6. Daily solar beam radiation in Dhaka (Y-axis: months; X-axis: kWh/m^2/d).from the curve average solar radiation is 4.65 kWh/m^2/d.

TABLE II. AREA CALCULATION AREA CALCULATION OF ROOFTOP PV PANEL INSTALLATION IN DHAKA [10]

Area	Total area	Bright rooftop area	Actual rooftop area for PV cell installation
Dhanmondi	3,346,008 m^2	232,721.62 m^2	116,360.81 m^2
Kakrail	1,660,574.089 m^2	398,783.91 m^2	199,391.95 m^2
Kawranbazar	2,539,521.258 m^2	406,852.51 m^2	203,426.25 m^2
New Ramna	2,285,882.631 m^2	466,399.26 m^2	233,199.63 m^2

Figure 7. Demand and Load-shed curve as on 17/04/2014 to 27/2014 (Dhaka).Total loadshedding of April is 742 MW in Dhaka city.

TABLE III. ACTUAL SOLAR POWER GETTING FROM DIFFERENT AREAS OF DHAKA

Area	Actual rooftop area for PV cell installation	Power from the rooftop area
Dhanmondi	116,360.81 m^2	(116,360.81m^2×150W)= 17.454MW
Kakrail	199,391.95 m^2	(199,391.95m^2×150W)=29.909 MW
Kawranbazar	203,426.25 m^2	(203,426.25m^2 ×150W)= 30.51MW
New Ramna	233,199.63 m^2	(233,199.63m^2×150W)= 34.980MW

We know a typical "150 watt" solar module is about a square meter in size [11]. Total power from the areas = 103.703 MW.

A. *Outcome of the proposed model*

Total power shortage in September'14 was 408 MW [4]. From some areas like Dhanmondi, Kakrail, Kawranbazar, New Ramna we can get 103.703 MW solar power. So it can be said that if we can implement this proposed model, it will easily be reduced the load shedding.

IX. CONCLUSION

Dhaka, the capital of Bangladesh is top listed among the polluted cities in the world. Smart grid technology is environment friendly. It can reduce carbon gas emission because smart grid system gives continuous feedback on electricity use. It can also reduce greenhouse gas emission. It is proven that Smart grid technology is beneficial from all respect of technical, economical &environmental point of view for Bangladesh. This technology can create a field of opportunities for Bangladeshi engineers, teachers, researchers and young professional's .so government and high officials should be concerned about smart grid & should take action for training programs and workshops where consumers will be taught about the use of smart grid, associated benefits and the potential implementation issues.

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An Automatic Monitoring and Control System Inside Greenhouse

Niamul Hassan, Shihab Ibne Abdullah, Ahmad Shams Noor,
Department of Electrical and Electronic Engineering
BRAC University
Dhaka, Bangladesh
nhleon.17.nl@gmail.com, shihab.bu@gmail.com, shamsnoor13@gmail.com,

Marzia Alam
Department of Electrical and Electronic Engineering
BRAC University
Dhaka, Bangladesh
marziaalam@bracu.ac.bd

Abstract— **In this work, we have proposed a framework that can gather the data identified with greenhouse environment and yield status and control the system automatically in view of the gathered data. By throatily observing periodic conditions, this study has the reason for securing connection between sensors flags and reference estimations. Control programming will give information finding of the ongoing show. Through long time running and functional utilizing, the framework has been demonstrated that it has numerous points of interest. To monitor the environment inside greenhouse different parameters have been considered such as light, temperature, humidity, soil moisture etc. using different sensors like DHT22 temperature and humidity Sensor, LDR, grove-moisture sensor etc. which will be interfaced with microcontroller. It is a closed loop system that will execute control action to adjust temperature, humidity, light intensity and soil moisture if any unwanted errors (high/low) occur.**

Keywords- greenhouse; sensor; environment; microcontroller

I. INTRODUCTION

Bangladesh is an agrarian economy. Agribusiness is the single biggest delivering area of economy since it comprises around 30% of the nation's GDP and utilizing around 60% of the labor force. Till now our agricultural systems are followed by conventional method whereas developed countries use automated system to control their agrarian economy to grow more products than before using same lands and weathers. Though moderate weather condition always helps us to grow different plants at different seasons, it does not help us to escalate crops production without impeding crops from natural destruction. In addition, dry spells are connected with the late arrival or an early withdrawal of monsoon rains furthermore because of discontinuous droughts agreeing with cultivated phases of different harvests in the north-western and northern areas of Bangladesh. Another downside of climate change is inability to produce a wide range of items like fruits and crops. So we have considered something which will bring arrangement by presenting some controlled framework that will control the temperature and feed the plants in dry session to deliver yields. If we can utilize mechanized framework in development process, we can produce a wide range of harvests in every season which will chop down import expense and besides work expense will decrease maintenance cost considerably as by controlling temperature we keep up immaculate climate for plants. Moreover, the greenhouse configuration gives light access, and when this light is consumed by items inside the greenhouse and swings to warmth vitality, it is not allowed to get away. The air temperature in the greenhouse will surpass the outside temperature. In the event that it gets excessively hot, all you have to do is open up a portion of the ventilation boards or simply open the entryway, contingent upon the outline and the temperature will drop [1-2].

Greenhouses have the capacity to direct temperatures; temperature variances can push plants and moderate development. The impenetrable covering on a greenhouse makes it get to be very hot and moist inside amid the daylight. The dampness vanishing from the dirt and the dampness given off by photosynthesizing plants fills the air. When the air is extremely damp, it gets to be harder for plants to lose water through vanishing, and moreover with the dirt. This serves to continue everything from drying out on a hot sunny day. Subsequently, it is vital to have air course to fumes over the top moistness and control air trade. In a nutshell we believe our project will bring the change to our conventional agriculture. It is nothing but a small initiative of a huge upcoming success of our agricultural and scientific sector.

Similar work has been done in this area which involve computer based system or sms based and wireless system which are much complex and somewhat expensive. In this paper, we have proposed a framework that can gather the data identified with greenhouse environment and yield status and control the greenhouse consequently in view of the gathered data to foresee and follow up on circumstances for splendidly controlled climatic conditions. By thickly observing climatic conditions, this exploration has the reason for making relationship between sensors flags and reference estimations, breaking down the development, advancement of yields and the natural variables to which they are uncovered. Moreover, control programming will give information procurement and control, genuine time graphical show, dates and time labels the data and stores it for present or later utilize. Also, by

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consistently observing various natural variables without a moment's delay, an agriculturist has the capacity see how development conditions are fluctuating, and respond to those progressions with a specific end goal to expand effectiveness [3-9].

II. SYSTEM OVERVIEW

The proposed framework is an implanted framework which will nearly screen and control the small scale climatic parameters of a greenhouse on a usual premise. For the development of products or particular plant species which could enhance their creation over the entire yield development season and to fight with the challenges included in the framework by falling human negotiation to the best feasible degree. The framework contains temperature; humidity; light and moisture sensors; Arduino micro controller easily and actuators (Relay module).

At the point when any of the above-mentioned climatic parameters cross a security limit which has to be kept up to secure the yields, the sensors sense the change and the micro controller reads this from the information at its data ports in the wake of being changed over to an advanced frame by the ADC. The micro controller then performs the required actions by utilizing transfers until the strayed-out parameter has been taken back to its ideal level. Since a micro controller is utilized as the heart of the framework, it makes the set-up minimal effort and compelling all things considered. As the framework likewise utilizes a LCD show for constantly alarming the client about the condition inside the greenhouse, the whole set-up gets to be easy to use.

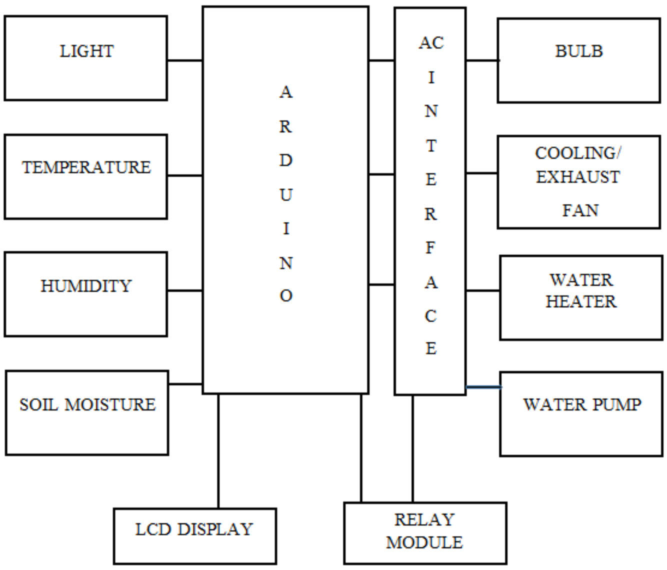

Figure 1. System overview

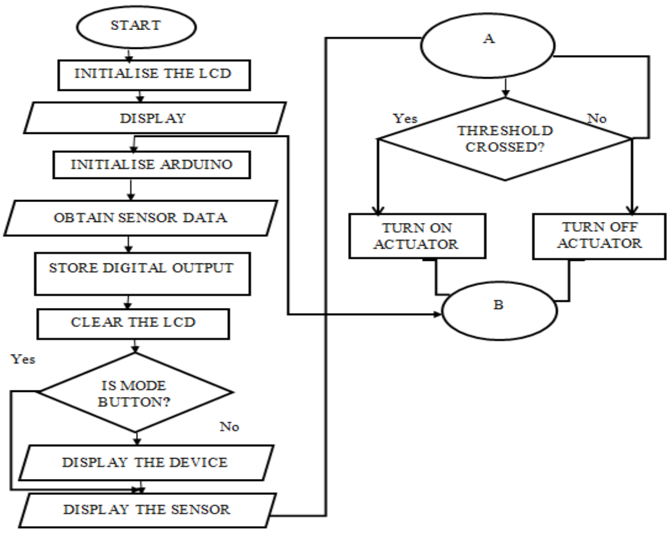

Figure 2. System flowchart

An imperative component in considering a control framework is the control technique that is to be taken after. The most straightforward procedure is to utilize edge sensors that straightforwardly influence incitation of gadgets. For case, the temperature inside a greenhouse can be influenced by controlling warmers, fans, or window openings once it surpasses the most extreme permissible farthest point. The light force can be controlled utilizing four edge levels. As the light power diminishes one light may be turned on. With a further decline in its force a second light would be controlled, et cetera; accordingly guaranteeing that the plants are not denied of sufficient daylight apart within the winter season or an overcast day.

III. TEST RESULT AND ANALYSIS

It is essential to effectively recognize the parameters that will be measured by the controller's information procurement interface, and how they are to be measured. Outputs of various sensors are shown below.

A. *DHT11 Temperature and Humidity Sensor*

The sensor builds up a relation between voltage and relative humidity. It can work over a 4-5.8 supply voltage range. At 5V supply voltage, and room temperature, the sensor output voltage ranges from 0.8 to 3.9V as the mugginess changes from 0% to 100% (no condensing).

Figure 3. DHT11 Temperature and humidity sensor

The output voltage is converted to temperature by a simple conversion factor. The general equation used to convert output voltage to temperature is:

$$Temperature(°C) = \frac{(V_{OUT} * 100)}{5°C} \qquad (1)$$

Sensor output voltages is obtained according to the formula:

$$RH = \frac{\left(\frac{V_{out}}{V_{\sup ply}}\right) - 0.16}{.0062}; \text{typical at } 25°C \qquad (2)$$

TABLE I. DHT11 HUMIDITY SENSOR READINGS

Relative Humidity	**Transducer Optimum Range**
30.8% to 40.5%	1.75-2.05V
41.3%to50.3%	2.075-2.35V
51%to 60.02%	2.375-2.65
61.6%to70.5%	2.7-2.975V

TABLE II. TEMPERATURE SENSOR READINGS

Temperature range	**Sensor output (V_{out})**
20°C to 25°C	1.0-1.25V
25°C to 30°C	1.25-1.5V
30°C to 35°C	1.5-1.75V
35°C to 40°C	1.75-2.0V

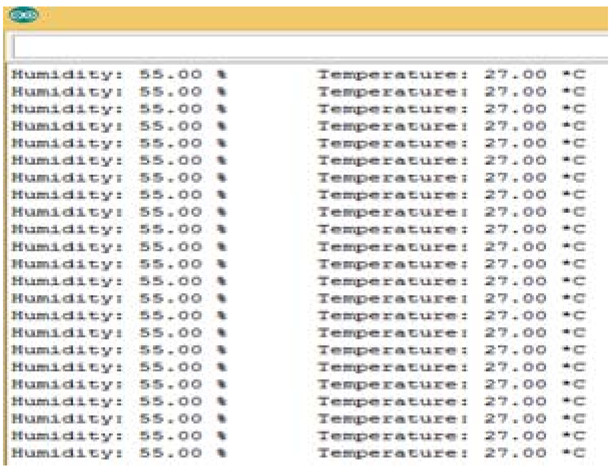

Figure 4. Arduino output for DHT11 temperature and humidity sensor

B. Controlling method for temperature and humidity

Exhaust fans can move a substantial volume of the hot plant outlet and pull outside air in through the back vent. This is useful for a reason. As full sun on a hot summer day can bring about temperatures inside the nursery to superheat. A fumes fan must have the capacity to drag this excess heat, or the temperatures will keep on rising.

Overhead infrared warming gear joined with soil link warmth gives a limited plant environment, which permits plants to flourish despite the fact that the encompassing air is at a lower than typical temperature. Electric resistance-sort warmers are used as space radiators or as a part of a constrained air framework**.**

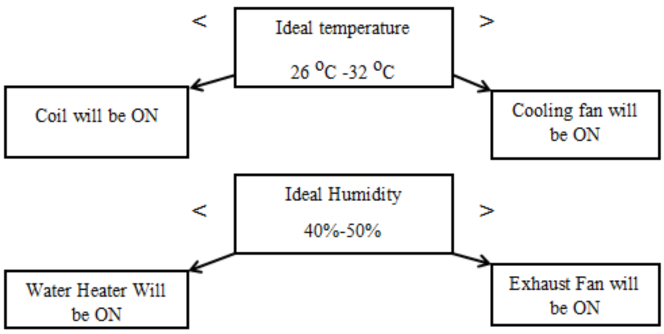

Figure 5. Relay condition for temperature and humidity

C. Light Sensor

The circuit used for sensing light in our system uses a 10 kΩ fixed resistor which is tied to +5V. Hence the voltage value in this case decreases with increase in light intensity.

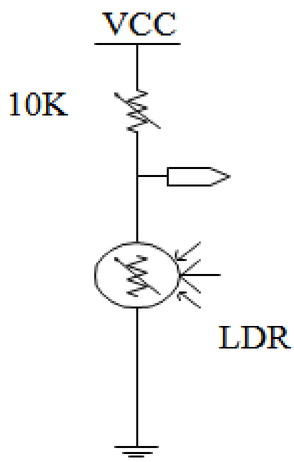

Figure 6. Circuit diagram of LDR

TABLE III. LIGHT SENSOR READINGS

Illumination Status	Transducer Optimum Range
Optimum Illumination	0V-0.69V
Dim Light	0.7V-2.5V
Dark	2.5V-3V
Night	3V-3.47V

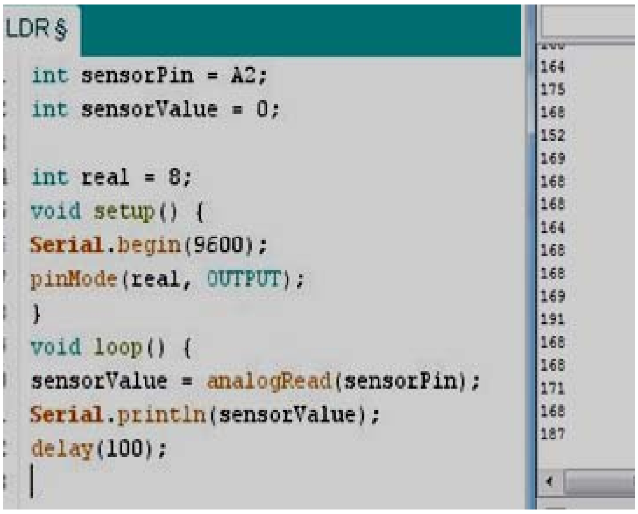

Figure 7. Arduino output of LDR (dim light condition)

D. Controlling method for light

Here we can see from TABLE III, the condition for dim light situation is 0.7V-2.5V and corresponding light intensity was found from arduino was around 187 lumen. When light intensity is 500 lumen, it means there is presence of light. If the light intensity is below than 500 then our automated system detects it and turn ON the relay module. The artifical light will shine untill the sunrises. If there is any existance of cloudy weather or rainy our automated system will work if the intensity of the light does not match with the set value (500 lumen).

E. Soil Moistiure Sensor

The elementary idea behind using soil moisture sensor to control irrigation is simple: when plants use water, they take it up from the substrate, so the water content of the substrate decreases. Soil water sensors detect these changes and can be used to open an irrigation valve when the substrate water content drops below a user-determined set-point. This results in frequent applications of small amounts of water, and the frequency of irrigation is adjusted automatically based on the rate of substrate water depletion. This irrigation approach automatically replaces water that is used by plants or lost

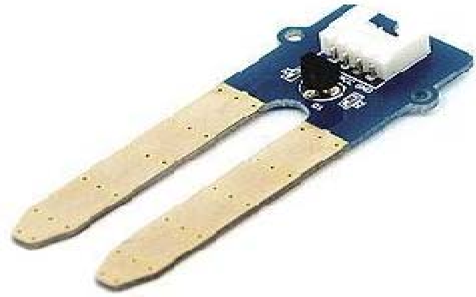

Figure 8. Grove moisture sensor

through evaporation and assures that plants are never exposed to drought stress. By irrigating with the amount of water actually needed by the plants, water use and leaching can be reduced greatly. This minimizes pollution without using expensive recycling irrigation systems or large ponds to capture runoff.

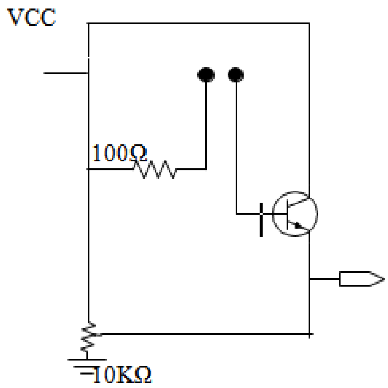

Figure 9. Circuit for grove moisture sensor

TABLE IV. SOIL MOISTURE SENSOR READINGS

Soil Condition	Transducer Optimum Range
Dry	0V
Optimum Level	1.9-3.5V
Slurry Soil	>3.5V

F. Controlling method for soil moisture

Soil condition is very important for the plant. As far as we can see moisture of soil is depending on the water level of the soil. So in this paper we prefer a soil moisture sensor to sense the condition of soil whether it is dry, humid or watery. If the soil condition is dry it automatically on the servo motor to on the water supply. When the soil becomes humid it will close the water supply automatically.

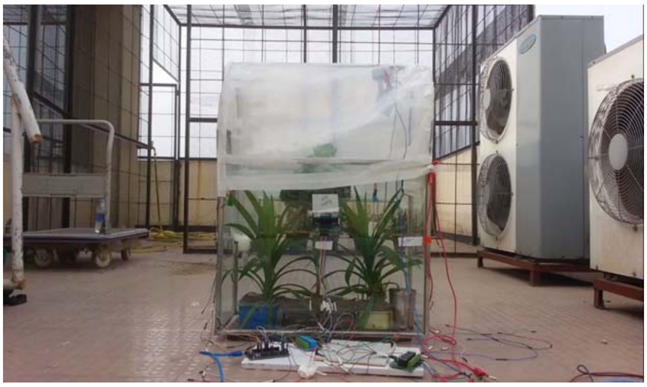

Figure 10. Completed project with automatic control

IV. Conclusion

It is our great pleasure that we have successfully completed our project which we dreamed of previously. In addition, we want to build a wireless remote control system with more parameters such as CO2, pH factor detection etc. To be confirmed, we have tested our greenhouse project in different places whether it works without any error or not and we found it worked successfully. We are delighted that we got positive feedback regarding our project to be implemented in Botanical Garden. In addition, Botanical Garden authority showed their huge interest to assist us in every aspect for our further research, which is a massive opportunity for us to move forward.

Acknowledgment

To start with, we would like to thank Almighty Allah for helping us in achieving the fruitful end of the project. We would like to express our gratitude to our regarded supervisor, Ms. Marzia Alam, Senior Lecturer, Department of Electrical and Electronics Engineering, BRAC University for her continual direction and support.

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Harvesting Green Energy from Wastage Energy of Human Activities Using Gymnasium Bicycle at Chittagong City

Md.Thuhid Ullah
Dept. of Electrical & Electronic Engineering
Chittagong University of Engineering & Technology
Chittagong, Bangladesh
thuhidullah@gmail.com

Muhammad Helal Uddin
Dept. of Electrical & Electronic Engineering
Chittagong University of Engineering & Technology
Chittagong, Bangladesh
helaluddin089@gmail.com

Md. Atif Bin Karim
Dept. of Electrical & Electronic Engineering
Chittagong University of Engineering & Technology
Chittagong, Bangladesh
atifcuet09@gmail.com

Giasuddin Muhammad Tauseef
Dept. of Electrical & Information Technology
Technical University Darmstadt
Hessen, Germany
gmtauseef@gmail.com

Abstract— **Energy crisis is the most critical infrastructure constraint in Bangladesh's economic growth. Limited resources for generation of electricity is one of the major reason behind that. It is happening because of the limitation of technology in the field of electricity. Though renewable energy is introduced, the impact of this new technology is not significant. This is why this paper introduces a mechanism to produce green electricity from human wastage energy. In this mechanism the pressure energy from the movement of human body is used to harvesting electricity using gymnasium bicycle. This paper also presents a field survey on the human and gymnasium at Chittagong city to find out the feasibility of this mechanism. A hardware implementation has been done to produce electricity through the use of gymnasium bicycle. A detailed cost analysis has also been done to find out the economic generation of electricity. Actually the authors are trying to introduce such a mechanism through which the electricity problem of Bangladesh will be reduced significantly.**

Keywords- power, Bicycle Exercise, Gymnasium, Battery charging

I. INTRODUCTION

Energy is everywhere in the environment surrounding us and is available in many forms. Capturing this energy and converting it to electrical energy has been the subject of many research investigations. To meet the worlds increasing energy needs, many companies around the world are investing in the research and development of environmentally sustainable technologies. Due to continuous growing need of clean sustainable energy, many countries and universities have invested time and money in Energy Harvesting (EH). The term Energy Harvesting, is also known as energy scavenging or power harvesting [1]; is the process of capturing small quantities of energy from any number of naturally occurring energy sources, which would otherwise be dissipated or lost (e.g. as sound, heat, light, movement, vibration); collecting them and storing them for later use. Energy Harvesting (EH) is made up of 3 key components namely; energy conversion, harvesting and conditioning circuit and energy storage. This research has progressed in the fields of solar, wind and nuclear energy. However, there exists a large untapped source of dissipated energy that has potential to help solve this energy problem. Every day, gym goers produce lots of energy just by doing their daily workout on exercise equipment. This energy, if used as an alternate to fossil fuels could supply clean sustainable energy. However, this energy is produced in mechanical form rather than electrical form, but slight modifications to the exercise equipment would allow the energy being produced to be converted to electrical energy which can be harvested, and stored for a later time. The concept of harvesting energy from an exercise machine had been introduced by a Hong Kong gym called "California Fitness" [2]. Since then, there have been three establishments in the United States that have been working to commercialize this technology [3]. Pedal power generation techniques are presented in [4-7]. This paper focuses on large scale power generation from the gymnasium stationary bicycle and also finds out its commercial probability as a secondary power source in local gyms. A field research is done on different gymnasiums at Chittagong city on the basis of number of member, working hours, number of bikes available in the gymnasiums, secondary power sources used during load-shedding, monthly electric bill, average members per day, daily load shading time and members uses the bike etc. Detailed design and construction of the system has been done to convert the people muscle power into electrical power. Generally the output power generated in this mechanism is alternating, so to store this energy in batteries for later use it is necessary to convert the ac current into dc currents. This is done by using a charge controller circuit which is also another research presented in this paper. Performance analysis of the system has been done in terms of individual component efficiency. Cost analysis for implementation of the complete

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system and feasibility to setup this system in gymnasium is also presented in this paper.

II. Hardware Implementation

The bicycle is one of the most efficient uses of the human body's existing musculature and the ergonomic position allows for nearly everyone to utilize. Generally human are going to gym to burn their calorie to make their body fit. To convert the burned calorie of human body into green electricity a complete system has been developed as shown in Fig.1. Firstly, the mechanical energy is translated into

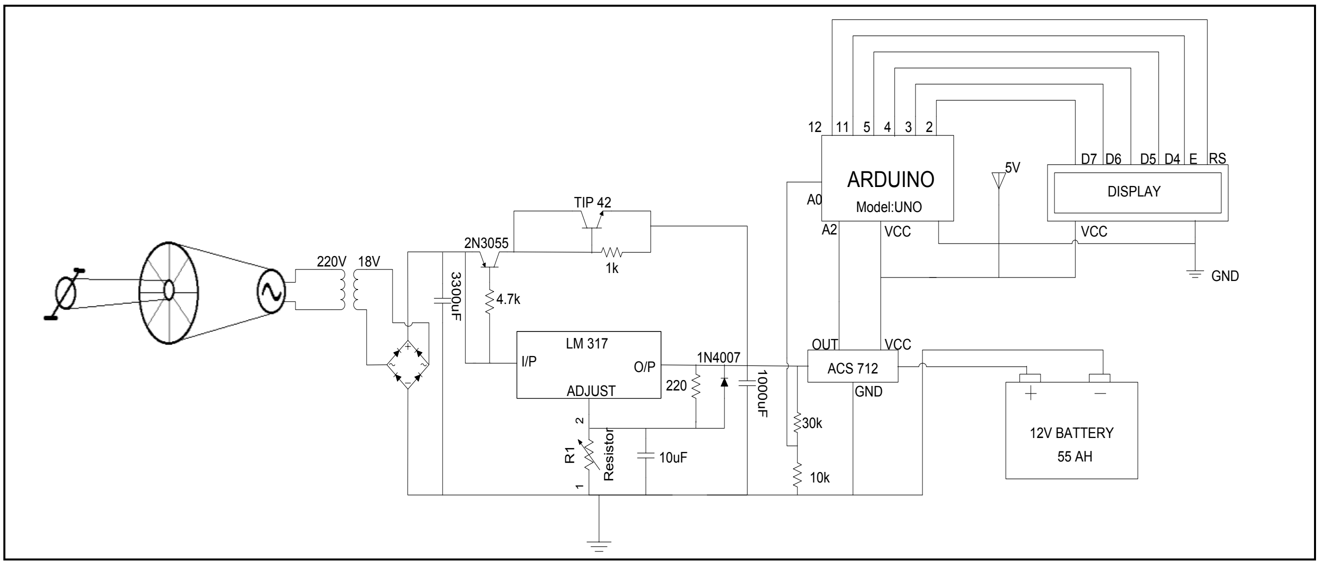

Figure 1. Charge Controller Circuit Diagram

Electrical energy through the use of coupling belt turning an alternator. The coupling belt is rubber made to prevent slip loss. The stationary bike have gear system that can adjust the range of RPMs and makes initial pedaling easier. The user is able to start softly and increase the resistance as momentum is gained. Secondly, a three phase 500W, 220V, 50Hz permanent magnet alternator is used for power generation due to low loss and less complexity. A transformer with several tapings at both high and low side is used to step down the generated voltage. In this system 220/18V tapping is used. A bridge rectifier circuit is used to convert AC input power into DC output power. Thirdly, a charge controller circuit is used to convert the dc power into a precise form to be stored efficiently. The designed and implemented charge controller circuit is shown in Fig. 2.

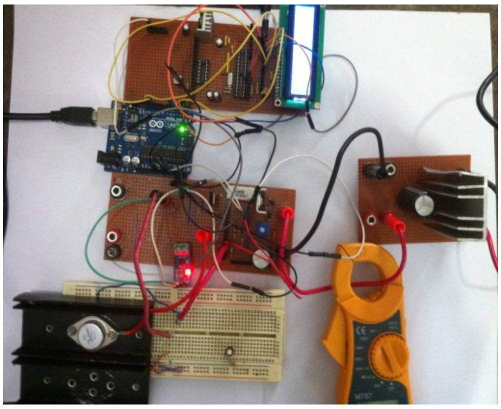

Figure 2. Implemented Charge controller circuit

Finally a 12 Volt Lead acid battery is used to store the generated electrical power. An ACS712 current sensor and a voltage divider are used to measure current and voltage respectively. The large current is drawn by the 2N3055 power transistor. The values are calculated by an ARDUINO, and then it shows the voltage, current, pedaling time and the calorie burned by the user into a LCD display. Thus extra instrument is not required to measure the calorie burned by the user.

III. Performance Analysis

To evaluate the overall system performance, design optimization and sizing of cooling systems, it is necessary to determine the efficiency of the individual systems.

The output voltage and current on the secondary side of a 240VA, 220/18V step down transformer are 18V and 7.07A respectively. The output power of the transformer is 127VA. The output power is (127/240) = 0.52 times of the rated output. Thus transformer is running at half of its rated full load with unity power factor as the battery is considered as an almost resistive load (except the smoothing capacitor) [8].Copper loss, W_{CU} = 12.5Watt and core loss, W_i = 6.5Watt are measured from short circuit test and open circuit test respectively. As the transformer is running at half of its rated output, the efficiency is 92.78%. The overall loss of the transformer is 7.22%.

To measure the efficiency of the alternator 750 watt dc motor was used as the prime mover. To measure the coupling loss speed and torque of both dc motor and alternator is measured.

DC motor and generator coupling efficiency is 97.42 %. DC motor and generator coupling loss is 2.58%.
Coupling belt loss is 1.64%. At a gear ratio of 3.33 the gear has an efficiency of = 93% [9]. Gear loss is 7%.
The efficiency of the rectifier circuit and charge controller circuit is measured at different input and output condition and average efficiency is found equal to 7.74%. The complete efficiency of the system is found by subtracting all losses and it is equal to 48.02 %.

A good coupling may have an efficiency of above 98% [9]. From this setup the coupling belt efficiency is 98.36% and

IV. OUTCOMES OF GYM SURVEY

Outcomes of the gym survey in the Chittagong city are presented in Table 1. From the survey chart it is found that the average pedaling time per person is about 20 minutes. The average number of member's per day at the gym is about 100.The average number of members per day pedal the bike is about 50.So, daily pedaling time per gym is 1000 minutes.

TABLE 1. GYMNASIUM SURVEY TABLE

Name	Number of members	Working hour (hour)	Number of bikes	Secondary power source	Monthly electric bill (primary+secondary)tk	Average members per day	Daily load shading time(hour)	Members uses the bike	Average cycling time (minutes)
1.Fitness Zone	400	15	1	Generator	5000+2000	120	4	50	20
2.Muscle Blast	300	14:30	0	Battery	5000	65	2		
3.Lift &Life fitness center	33	13:30	2	Battery	40000	22	0	22	20-25
4.The Life style	416	16	2	Battery	5000	40		15	20
5.Power Fitness	100	16	0	Generator	3000+300	80	3-4		
6.Saikot gym	170	12	1	Generator	3000	45	3-4	15-20	20-25
7.Chitttagong multi-sport	160-170	16	0	Battery	4000	60	1		
8.Universal Fitness Zone	300	15:30	3	Battery	2500	100-110	4-4.5	30-40	30
9.Exercise Zone	800	15	0	Battery	3000+400	200-250			
10.Alvira's	300	15	8	Generator	88000	170	3	120	20-30

From experimental setup, the output voltage stays constant at, V = 14.4V.The output average current, I = 4.4A.The average output power, P = V× I = 14.4×4.4 = 63.36 Watts. From this output power daily a gym can harvest 1.056 kWh energy having a market price of Tk. 9.58 [10]. So from the proposed setup the monthly saving is Tk. 303.3. According to Body Building Association of Bangladesh there are more than 100 gymnasiums in the Chittagong city. From whole Chittagong city the monthly savings is Tk. 30349.4.

V. CONCLUSIONS

The bike, the stand is already available in the gyms. Again most gyms use IPS as their secondary power source, so they already have the battery. These three items are already available at the gyms. These items cost 71% of the total system cost. Considering from this point of view a gym having these items will have to spend Tk. 12030 for the complete set up and this money will return in something more than in 3 years. This research aimed to design and implement a human exercise power system using gymnasium bicycles. The research goal was to charge a 12V, 55AH battery. This goal was accomplished within the constraints of a low production cost and high safety. The conversion efficiency was less than 50% due to huge loss in alternator. By changing this alternator the efficiency can be increased. In short, the research was a success in proving the concept that electrical energy can be harnessed from human power, specifically in the gymnasiums. This prototype was successfully able to meet most of the requirements established at the beginning of the research and therefore proves the concept of generating electrical power from a stationary exercise bike. This method may also be implemented by trade mill in gymnasiums. Thus a large amount of electrical power can be generated from a city like Dhaka or Chittagong. Thus electrical power generated due to calorie burn of people using gymnasium bicycles not only saves money but also provides safe, green and reliable power to the consumers and also reduces pressure on the national grids. If this system is setup through the entire Bangladesh, then huge amount of money can be saved as well electricity crisis in Bangladesh can be minimized significantly.

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Prospect of Green Power Generation by using Nuclear Energy in Bangladesh

Rajon Bhuiyan [1], Hafez Nasim Bin Jasim [2], Mahamudul Haque Taluckder [3], Sourav Sarker [4]

[1,2,4] Department of Mechanical Engineering, Rajshahi University of Engineering and Technology, Rajshahi 6204, Bangladesh

[3]Department of Electrical & Electronic Engineering, North South University, Dhaka 1229, Bangladesh

E-mail: [1] rajonbhuiyan@gmail.com, [2] nasim@nasimbinjasim.com

***Abstract*—Bangladesh is said to be one of the biggest energy starved countries, with the present demand for electricity at 9000 plus MW (Mega Watt) as opposed to the production of 6500 to 7500 MW. Access to electricity in Bangladesh is one of the lowest, about 40 percent of the total population are without access to adequate, cheap and quality energy. At present, we have to depend on indigenous energy resources, which are finite as well – gas, oil, furnace oil and coal to produce electricity. And about 55 per cent of our natural gas is used to produce this power. The reserve of gas is not infinite and will soon run out and before that happens, we must adopt alternative energy sources, be it renewable with a bio ecological/ green revolution or build nuclear power plants (NPP). Hence, the government recently decided to join the world's 30strong nuclear power club, signing an intergovernmental agreement (IGA) with Russia on November 2, 2011 for a nuclear power plant at Rooppur, Ishwardi of Pabna district, in the country's northwest region. This paper discusses about the prospect of green power generation in our country by using nuclear energy and find out if it is a proper decision to build a nuclear power plant in Bangladesh.**

Keywords-Nuclear power; Green Power; Nuclear Power plant; Economic Feasibility; Future plan of Bangladesh; Safety

I. INTRODUCTION

Electricity is the main ingredient for socio-economic development of any country. Often per capita consumption of electricity and energy is considered as one of the development indication of a nation. But, in Bangladesh (in August 2014) only around 62% of the population has access to electricity, and per capita commercial energy consumption is 321kWh, the lowest in the world [1]. In this context, Bangladesh is in the immediate need of manifold increase of existing electricity generation capacity. At present, electricity production in Bangladesh is mostly based on existing reserve of conventional energy sources (such as fossil fuel like gas, coal, oil etc.) which will not be available in the future if power is generated only from conventional sources. Moreover, generation of electricity from conventional sources is costly and more significantly polluting the environment and exacerbating global climate change. Again, power generation from renewable energy sources like solar and wind will not be enough to fulfil the huge shortage of power in our country as they cannot produce energy in huge scale. It is thus essential for Bangladesh to give major concentration on large scale power generation which is renewable in nature and also can ameliorate the huge power crisis apace. In this context, Nuclear Power Plants could be the best option for Bangladesh for huge amount of power generation [2].

II. ENERGY SCENARIO IN BANGLADESH

The energy infrastructure of Bangladesh is quite small, insufficient and poorly managed. The per capita energy consumption in Bangladesh is one of the lowest (321 kWh) [1] in the world. Non-commercial energy sources, such as wood fuel, animal waste, and crop residues, are estimated to account for over half of the country's energy consumption. Bangladesh has small reserves of oil and coal, and medium amount of natural gas resources. Commercial energy consumption is mostly natural gas (around 66%), followed by oil, hydropower and coal [3].

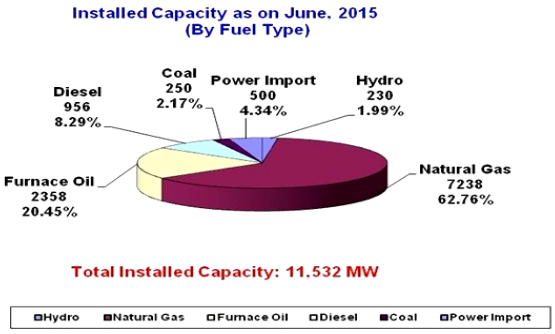

Figure 1. Present Installed Generation Capacity (MW) by fuel type as on June, 2015 [4].

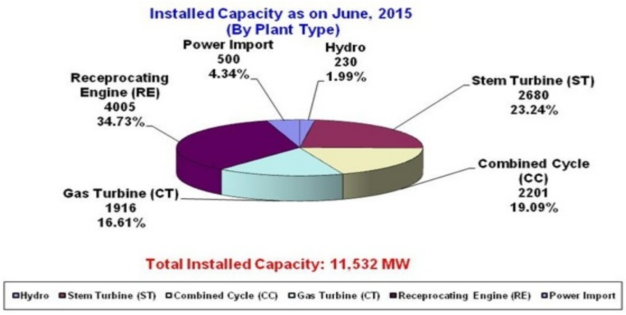

Figure 2. Present Installed Generation Capacity (MW) by plant type as on June, 2015 [4]

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III. Problems with present electricity scenario

A. Production shortage

The production curve has always lagged behind the demand curve of electricity in Bangladesh. The insufficient electricity production of this country has always pulled back this developing country.

TABLE I. THE DEMAND AND PRODUCTION DATA OF THE PAST FEW YEARS DESCRIBES THE SCENARIO BEST. [5][6]

Fiscal Year	Peak Demand (MW)	Maximum Generation (MW)
2010	6454	4698.5
2011	6765	5174
2012	7518	6350
2013	8349	6675
2014	9268	7418

B. Decreasing stock of primary resources

Bangladesh has very few natural resources which are being used excessively to produce electricity, such as- coal, natural gas, furnace oil, diesel and hydro. Coal is harnessed from coal mines situated in the northern portion of Bangladesh and there are several gas fields lying all around the country. But it is not possible to harness enough coal from the mines because of negative effects of it on the nature and gas fields have limited balance of gas left in them. Bangladesh has to import furnace oil and diesel from abroad. At the current rate of natural gas use in Bangladesh the current estimated proven reserves would last only 45 years. Even if the present rate of use increase at 10% per year, these reserves would last about 17 years .Power sector ranks the highest (44%); fertilizer sector ranks the second (28%); and industry, domestic, commercial and other sectors together rank third (22%) in natural gas consumption. Currently 12gas fields under public and private sectors are in production with gas supply between 900 and 930mmcfg per day. [7]

IV. Why Nuclear Power is necessary ?

Nuclear power plants use nuclear fission reaction to produce heat, which is in turn used to produce electricity. In nuclear fission, atoms are split apart to form smaller atoms, releasing energy. Usually in commercial production of nuclear energy, special isotopes of Uranium and Plutonium are used. The general reaction is figured out below-

235 U+ neutron fission →fission fragments +2.4 neutrons+192.9 MeV

239 Pu+ neutron fission →fission fragments +2.9 neutrons+198.5 MeV

This massive energy is not produced in open places like the burning of fuels. This production needs an isolated and controlled environment. A nuclear power plant has its own cooling system and such a facility is generally established near big natural water reservoirs e.g. rivers, sea.

V. Advantages of Nuclear Based Energy Production

A. Production Capacity

This country needs a stable and powerful source which will be able to supply energy continuously for a very long period of time in a sustainable manner and without harming the environment. Here Nuclear Energy can be the best solution to this problem. Primary sources of energy can't provide that much of energy as Nuclear Energy. Also the lifespan of a typical nuclear power plant is much higher than any other plant.

TABLE II. A COMPARISON BETWEEN HEATING VALUES OF DIFFERENT FUELS ARE GIVEN BELOW: [8]

Type of Fuel	Heat Value (MJ/kg)
Firewood	16
Brown Coal	9
Black Coal (low quality)	13-20
Black Coal	24-30
Natural Gas	39
Crude Oil	45-46
Natural Uranium in light water reactor	500000

B. Effect on Environment

Nuclear reaction does not produce greenhouse gases during production of energy. Though small amount of greenhouse gases are produced in a nuclear power plant due to the use of supporting machineries like turbine and cooler, it is far less compared to the produced greenhouse gases in other power plants. Thus a nuclear power plant is sustainable in nature and saves the earth from the harmful effects of these toxic greenhouse gases.

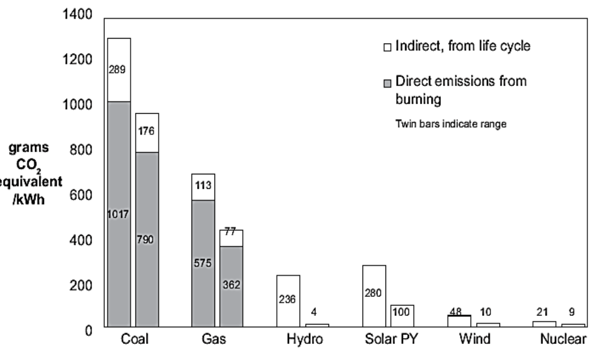

Figure 3. Grams of CO2 equivalent/kWh [9]

C. Safety Features

In the past, the disposal of radioactive waste was difficult and harmful to the nature to some extent. Besides, operating nuclear power plant machineries and the cooling procedure were very difficult. But presently due to the improvement of the power plant up to 3rd Generation, the use of pressurized water reactor and the fully automated power plants make the nuclear based power production very secured and sustainable.

Besides the in- built safety features reduces the chances of accidents significantly. These safety features consist of multiple layers of protective walls and emergency core cooling system.

VI. ADVANCEMENTS REGARDING NUCLEAR ENERGY IN BANGLADESH

In 1963 the Rooppur site was selected for the establishment of the first nuclear power plant of this country. In 2001 Bangladesh adopted a national Nuclear Power Action Plan. On 24 June 2007, Government of People's Republic of Bangladesh announced plans to build a nuclear power plant to meet electricity shortages. In May 2010, Bangladesh signed a civilian nuclear agreement with the Russian Government. Bangladesh also has framework agreements for peaceful nuclear energy applications with the US, France and China. In February 2011, Bangladesh reached an agreement with Russia to build the 2,000 megawatt (MW) Nuclear Power Plant with two reactors, each of which will generate 1,200 MW of power. The nuclear power plant will be built at Rooppur, on the banks of the Padma River, in the Ishwardi sub district of Pabna, in the northwest of the country. The RNPP (Rooppur Nuclear Power Plant) is estimated to cost up to US$2 billion, and start operating by 2021. The inter-governmental agreement (IGA) was officially signed on 2 November 2011.On May 29, 2013 honourable Prime Minister of Bangladesh declared that a second nuclear power plant will be constructed in an inland river island in southern region of the country. [10]

TABLE III. THE INFORMATION OF THESE NUCLEAR POWER PLANT PROJECTS ARE SUMMARIZED BELOW: [11]

Station/Project Name	Type	Capacity	Expected Construction Start Year	Expected Commercial Year
1.Rooppur Nuclear Power Plant (Unit-I)	VVER	1000-1250 MWe	By 2016	By 2021
2.Rooppur Nuclear Power Plant (Unit-II)	VVER	1000-1250 MWe	One year after the first unit built	--------

VII. ECONOMICS & SUSTAINABILITY OF NUCLEAR POWER GENERATION

Nuclear power plants typically have high capital costs for building the plant, but low fuel costs and low external costs, namely carbon tax [14]. Assessing the relative costs of new generating plants utilizing different technologies is a complex matter and the results depend crucially on location. Coal is, and will probably remain, economically attractive in countries such as China, the USA and Australia with abundant and accessible domestic coal resources as long as carbon emissions are cost-free. Gas is also competitive for base-load power in many places, particularly using combined-cycle plants, though rising gas prices have removed much of the advantage. Nuclear power plants are expensive to build but relatively cheap to run. In many places, nuclear energy is competitive with fossil fuels as a means of electricity generation. Waste disposal and decommissioning costs are included in the operating costs. If the social, health, sustainability and environmental costs of fossil fuels are also taken into account, the economics of nuclear power are outstanding.

TABLE IV. COMPARISON AMONG DIFFERENT ENERGY GENERATION TECHNOLOGIES [14]

Tech-nology	Unit Size	Lead Time	Capital Cost	Oper-ation Cost	Fuel	Sustain-ability
CCGT	Medium	Short	Low	Low	High	No
Coal	Large	Long	High	Low	Medium	No
Nuclear	Huge	Long	High	Low	Low	Yes
Hydro	Huge	Long	Very High	Very Low	Nil	Yes
Wind	Small	Short	High	Medium	Nil	Yes

VIII. FUTURE PLAN OF BANGLADESH GOVERNMENT FOR NUCLEAR POWER

Bangladesh plans to have two 1000 MWe Russian nuclear power reactors in operation in the near future and at least one in operation by year 2021. This is to meet the rapidly increasing demand of energy and reduce dependence on natural gas reserve. Bangladesh produced 38 billion kWh gross electricity in 2009 from some 6.1 GWe of plant, giving per capita consumption of 250 kWh/yr. About 88% of electricity comes from natural gas. Electricity demand is rising rapidly, with peak demand 7.5 GWe, and the government aims to increase capacity to at least 7 GWe by 2014, meanwhile importing some 250 MWe electricity from India. New small coal-fired plants are envisaged for 2 GWe of that, and for 3 GWe more by 2016. However, about half the population remains without electricity, and the other half experience frequent power cuts. Some 5.0% of government expenditure is being allocated to 'power and energy'. The capacity target for 2021 is 20 GWe.

Building a nuclear power plant in the west of the country was proposed in 1961. Since then a number of reports have affirmed the technical and economic feasibility. The Rooppur site in Pabna district about 200 km north of Dhaka was selected in 1963 and land was acquired. The government gave formal approval for a succession of plant proposals, then after independence a 125 MWe nuclear power plant proposal was approved in 1980 but not built. With growth in demand and grid capacity since then, a much larger plant looked feasible, and the government in 1999 expressed its firm commitment to build this Rooppur plant. In 2001, it adopted a national Nuclear Power Action Plan and in 2005, it signed a nuclear cooperation agreement with China. In 2007 the Bangladesh Atomic Energy Commission proposed two 500 MWe nuclear reactors for Rooppur by 2015, quoting likely costs of US$ 0.9-1.2 billion for a 600 MWe unit and US$ 1.5-2.0 billion for 1000 MWe. In April 2008 the government reiterated its intention to work with China in building the Rooppur plant and China offered funding for the project. The International Atomic Energy Agency (IAEA) approved a Technical Assistance Project for Rooppur Nuclear Power Plant to be initiated between 2009 and 2011, and it then appeared that an 1100 MWe plant was envisaged. Russia, China and South Korea had earlier offered financial and technical help to establish nuclear power, and in March 2009 Russia made a formal proposal to build a nuclear power plant in the country. In May 2009 a bilateral nuclear cooperation agreement was signed with Russia. In April 2009 the government approved the Russian proposal to build a 1000 MWe nuclear plant at Rooppur for about $2 billion, and a year later this had become two such reactors by 2017. A nuclear energy bill was introduced into parliament in May 2012, with work to begin in 2013, and setting up a Bangladesh Atomic Energy Regulatory Authority. Parliament was told that 5000 MWe of nuclear capacity was envisaged by 2030, and a second plant would be built in the south once Rooppur was operating. In May 2010 an intergovernmental agreement was signed with Russia, providing a legal basis for nuclear cooperation in areas such as siting, design, construction and operation of power and research nuclear reactors, water desalination plants, and elementary particle accelerators. Other areas covered included fuel supply and wastes. An agreement with Rosatom was signed in February 2011 for two 1000 MWe-class reactors to be built at Rooppur for the Bangladesh Atomic Energy Commission. In line with standard Russian practice this included fuel supply and return of used fuel to Russia. Another intergovernmental agreement was signed in November 2011. In February 2012 the Ministry of Science and Technology signed an agreement with Russia's Rostechnadzor related to regulation and safety "and the provision of advisory support to the Bangladesh Nuclear Regulatory Commission on regulation, licensing and supervision". Staff will be trained in Russia. A further agreement will be for Russian finance. Construction of the first unit is expected from 2016, with operation in about 2021. In August 2012 a financing agreement was finalized under which Bangladesh would borrow $500 million for a 2-year technical and economic study together with design, documentation and training, at not less than 4% interest. Russia will then fund 85% of the estimated $1.5 billion for the first unit's construction. The $500 million loan will be repaid in 12 years with five years grace period, and the final construction cost will be repaid in 28 years with 10 years grace period. The IAEA continues its close involvement with the project [15].

IX. RESULT & DISCUSSION

Electricity production from nuclear energy with modern technology is safe, reliable, sustainable and on the context of Bangladesh capable of reducing the huge gap between demand and production significantly. The 3rd Generation Pressurized Water Reactors with automated and in-built safety features make Nuclear Energy a reliable source of massive electricity production for Bangladesh and moreover it is also environment friendly. On the basis of present energy and climate scenario of Bangladesh and above mentioned discussions in this paper, nuclear energy based power production should be the best solution for solving the overall energy crisis.

X. CONCLUSION

Bangladesh is a poor and densely populated small country. It is very important for the development of Bangladesh to supply electricity for the people at reduced cost .Also, the demand of electricity is now increasing rapidly. Most of power plants are now depending on natural gas, furnace oil and diesel. Using these kind of fuels increases the bad impact on climate change. Moreover, these resources are now decreasing apace. Now, taking into account the knowledge of Nuclear Power and the experience gained during a tenure of about fifty years of functioning of nuclear power stations across various parts of the world, it is obvious to say that power generation from nuclear sources is a sustainable development. One can conclude that with the present state-of-the-art technology in this field, it is quite competitive as compared to other ways of energy production on the large scale. So, it is necessary for Bangladesh to use nuclear energy as an alternative, safe and cheap source for producing electricity at large scale.

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Scope of Geothermal Potential of Bangladesh: A Review

Kamruzzaman Khan
Dept. of EECS
University of Toledo
Ohio, USA
kamruzzaman.khan@rockets.utoledo.edu

Muktadir Ahmed, Md. Salahuddin Parvez, Md. Mozammel Hossain
Dept. of EEE
Mymensingh Engineering College (University of Dhaka)
Mymensingh, Bangladesh
muktadir220@gmail.com

Abstract—**Bangladesh is facing a lot of drawbacks to acquire sustainable development owing to lack of electricity. Now a days the demand of power is increasing day by day in Bangladesh. Now Bangladesh needs a reliable green energy source to meet the demand. To improve the power crisis in our country geothermal energy can be a vital & useful alternative. Bangladesh is one of the largest deltas and having a large sedimentary basin. It has many abandoned gas wells (temperature: more than 100°C in the depth of 3 km to 4 km). The main theme of this paper is to discuss about geothermal energy and its prospects in Bangladesh.**

Keywords-geothermal energy; geothermal resources; geothermal gradient; renewable energy.

I. INTRODUCTION

Energy Resources are most important element in sustainable industrialization of a country. Industrialization is a prerequisite for attaining or securing rapid advancement in technology, sustainable and revolutionary development of economy through various sector of developed countries all over the world [1]. Geothermal Energy is a thermal energy which is produced from the hot earth core. It is environment friendly and the production cost of this energy is very low. The steam and hot water produced inside the earth surface is used to generate electricity for geothermal energy. The production of geothermal energy in the beneath of earth is about 400 miles away from earth periphery [2]. In the context of geothermal water utilization, Bangladesh is still very naïve. Until now, there has been a little thorough systematic analysis that has been implemented to investigate scope of the geothermal resources of Bangladesh. However, in a few articles [3], it has been implied that Bangladesh could a region to have great potential for using geothermal energy. In Bangladesh many deep abandoned wells, drilled for natural resources (e.g. oil and gas) exploration, have been used to extract valuable information about the subsurface geology and temperature of areas of interest. Survey and study of the temperature variable of these investigated wells indicates that geothermal gradient along the southeast part of the Bengal for deep region and along the northwest stable shelf is from 19.8 to 29.5°C/km on average and from 20.8 to 48.7°C/km on average respectively [3].

II. GEOGRAPHICAL LOCATION OF BANGLADESH

Bangladesh is located in the north-eastern part of south Asia. India and Myanmar are the two neighboring countries of Bangladesh. It shares its longest three geographical borders(4000km)with the nearest country India with a 24° 0' 0″ N latitude in the north (N) and 90° 0' 0″ E longitude to the east(E).Myanmar is the extreme south east and the Bay of Bengal is the southern margin. Geographically, it is mostly covered by a low-lying land delta by the river zone of Brahmaputra and Ganges and has occupied a land of 147,570 sq km [1].

III. PRESENT ENERGY SCENARIO OF BANGLADESH

There are varieties of power plant (e.g. combined cycle power plants, hydraulic power plant, engine based power plant, steam power plant and gas power plants etc.) that generate and give electricity to the National Grid. There are some off grid diesel power stations at remote places. Terminal voltages of different generators are 11 KV, 11.5 KV and 15.75 KV [4]. Most of the electricity generation in Bangladesh is from natural gas. Electricity produced from natural gas and coal is currently about 79%. 6.36% of power and energy comes from renewable green energy sources (e.g. solar, hydro and wind) whereas 93.64% of power and electricity is from fossil fuels gas, coal and oil in Bangladesh [5]. At present, Power generation of Bangladesh from the public and private power plant is 53% and 47% of the total electricity generation of Bangladesh, respectively [2].

IV. GEOTHERMAL ENERGY

The term geothermal comes from two Greek words: geo and thermos. The meaning of geo and thermos is 'earth' and 'heat', respectively [6]. Geothermal energy originates from heated rocks and fluid that fills the fractures and pores within the earth's crust. The origin of the energy is from radioactive decay deep within the Earth and can stay as hot water, steam, or hot dry rocks [5]. There are four types of geothermal resources and these are: geopressured, hot dry rock, magma, and hydrothermal [16]. Geothermal (meaning "earth heat")

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energy uses the high temperatures generated beneath the earth to produce electricity from heated water [5]. The thermal energy which is produced and stored inside the earth surface is called geo thermal energy. It is very much cost effective and environmentally friendly. With appropriate technology, steam and hot water that is inside the earth surface, can be used to produce electricity. Geothermal energy is generated about 4,000 miles below the surface, in the earth's core [7]. Geothermal systems can be divided into various classes. These classifications are based on temperature, enthalpy, physical state or their nature of fluid and utilization as well as geological settings. The geothermal system are classified into two kinds on the basis of geothermal field. These are low-temperature (LT) and high-temperature (HT). This classification is mostly used all over the world. In the continental areas of the earth surface, low-temperature (<150°C) sedimentary geothermal resources are extensive.

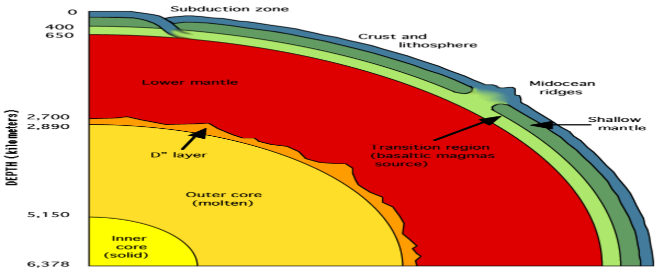

Figure 1. Earth interior [8].

With Low-temperature system, geothermal water or subsurface hot water (temperature ranges from 40°C to 150°C) is utilized directly as various purposes (e.g. space heating, greenhouse, aquaculture, horticulture, industries and bathing along with electricity production (power plant ranging from 10MW to 20MW). These are volcanic/intrusive in origin with regards to happening and heat source and associated with the plate boundaries and their temperature are more than 150°C at the depth of 1 km. This system is perfect for the electricity generation and always affiliated with the eruptive system [9]. According to Subir K. Sanyal [20] geothermal system can be classified into 7 major classes: Class 1 (less than 100°C), Class 2 (100°C to less than 150°C), Class 3 (150°C to less than 190°C), Class 4 (190°C to less than 230°C), Class 5 (230°C to less than 300°C), Class 6 (greater than 300°C), Class 7 (Steam fields). Geothermal energy extraction rate should be greater than the natural heat loss rate from the earth's surface and this is a prerequisite for its renewability[10]. With regards to random wind and solar energy capacity(estimated around 20-35%), geothermal energy has a capacity factor of 70% with continuity [11].

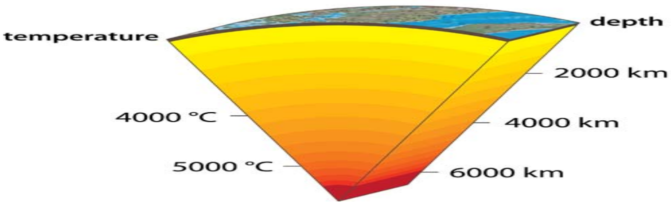

Figure 2. Temperature of earth [6].

A. Use of Geothermal Energy

Geothermal energy can be used in both direct and indirect way. The choice of way is decided by the available temperature, the availability of resources, the objective and the economic context.

Direct use of geothermal energy: Thoughts based on direct use are given below:

1. By using drill holes hot water is soaked from subterranean. [6]
2. Heat exchanger exchanges the heat from hot water to the application. [6]
3. The water after application pumped back to subterranean via drill holes to make the water reusable [6].

Indirect use of geothermal energy: The Indirect use of geothermal energy generally refers to converting geothermal energy into electricity. This is executed by using heat exists in the deeper subsurface at depths of 3 to 5 km. However, in specific areas (e.g. Island), the drilling that deep is not necessary. Such geothermal applications have been implemented in approximately 24 countries like USA, Australia, Philippines, New Zealand, Costa Rica [15] and various places in Europe [6].

B. Geothermal Power Plant

Geothermal power projects convert the heat energy stored in hot rock under the earth surface into electricity by using water to absorb heat from the rock and crust. After that the water is transported to the earth's surface to convert it into electrical energy through turbine-generators. Figure. 3 shows the production wells, separator, scrubber, turbine, condenser, and cooling tower. After being separated from steam, brine is injected back into the reservoir. Before entering the turbine, steam is transferred to the plant where it passes through a scrubber. The steam is then condensed. Condensed steam is used in the cooling towers, where roughly 80% evaporates and the remainder is injected back into the reservoir [12].

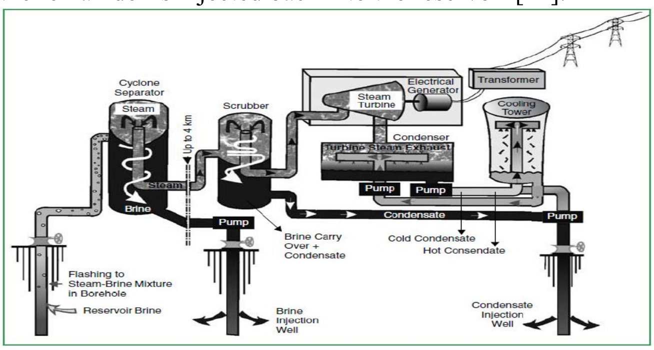

Figure 3. Geothermal power plant [12].

The power output for this turbine is calculated using the following equation,

$$W_{st}=\eta t\times\eta g\times\square_s\times\Delta h$$

Where W_{st} is the steam turbine power output (MW), η_t is the turbine efficiency, η_g is the generator efficiency, $\square_s$ is the total mass of steam (kg/s), Δh is the enthalpy difference between inlet and outlet enthalpy (kJ/kg) [13].

C. Advantages of Geothermal Energy

a) Geothermal energy is pollution free. [14]
b) Geothermal plant does not need fuel. [14]
c) The energy is almost free after building the plant [14].

D. Disadvantages of Geothermal Energy

a) There are very few places to produce geothermal energy. [14]
b) A perfect type of hot rock is very important for easy drilling. [14]
c) Dangerous gases may come from subterranean region [14].

V. WORLDWIDE GEOTHERMAL ENERGY

As on 2015, worldwide install capacity is 12,635 MW and total produced energy is 73,59 GWh [15]. Geothermal electricity production in the United States began in 1960 [16]. USA generates largest amount of geothermal energy across the world. Table I shows the worldwide condition of geothermal energy and Table II shows continent wise install capacity and production as on 2015.

TABLE I. WORLDWIDE AMPLE SIZED INSTALL CAPACITY AND PRODUCTION WELL AS ON 2015 [15].

Country	Installed (MW) in '15	Production (GWh) in '15
USA	3,450	16,600
Indonesia	1,340	9,600
Mexico	1,017	6,071
New Zealand	1,005	7,000
Philippines	1,870	9,646

TABLE II. CONTINENT WISE INSTALL CAPACITY AND PRODUCTION WELL AS ON 2015 [15].

Continent	Installed in '15 (MW)	Production in '15 (GWh)
ASIA	3,756	22,084
EUROPE	2,133	14,821
AFRICA	601	2,858
AMERICA	5,089	26.353
OCEANIA	1,056	7.433
TOTAL	12,635	73,549

VI. GEOTHERMAL ENERGY AND BANGLADESH

Owing to several geo-tectonic status, geothermal resources of Bangladesh may be classified into: the northwest part and the deep sedimentary basin. The northwest and deep sedimentary basin of Bangladesh is acquainted as shield areas and Bengal Foredeep region of the country, respectively. The deep sedimentary basin is made up of several basement highs and lows as well as the hill ranges of the Chittagong-Tripura folded belt, where a few thermal springs are present. In the northwest part of the country, in the Thakurgaon district, thermal expositions and shallow aquifers indicate the availability of a geothermal resource [3]. In the northwest part of the country, in the Thakurgaon district, thermal expositions and shallow aquifers indicate the availability of a geothermal resource [3].

A. Geothermal Resources of Bangladesh

The NW tip of Bangladesh the basement occurs at 2500 m depth at Shalbanhat with a temperature about 79°C. The approximate boundary of the Rangpur Saddle at the northern and the southern slopes has been seismically defined by the approximately 700m depth contour. The basement of Madhyapara area lies at only 130 m depth. In the western part of the Rangpur Saddle,the The coal mine of Barakupuria has a temperature of 50°C at a depth of 400 m [17]. These areas are also attracted by researchers for geothermal exploration [3]. At Thakurgaon warm water, up to 36°C, has been observed in irrigation wells at depths of ca 80 m. Here Madhupur Clay (ca 20 m) is an insulating layer [17]. Singra, Kuchma and Bogra areas are observed as powerful zones for geothermal exploration in the Bogra shelf region [3]. The width of Bogra Shelf is 60-125 km [17].

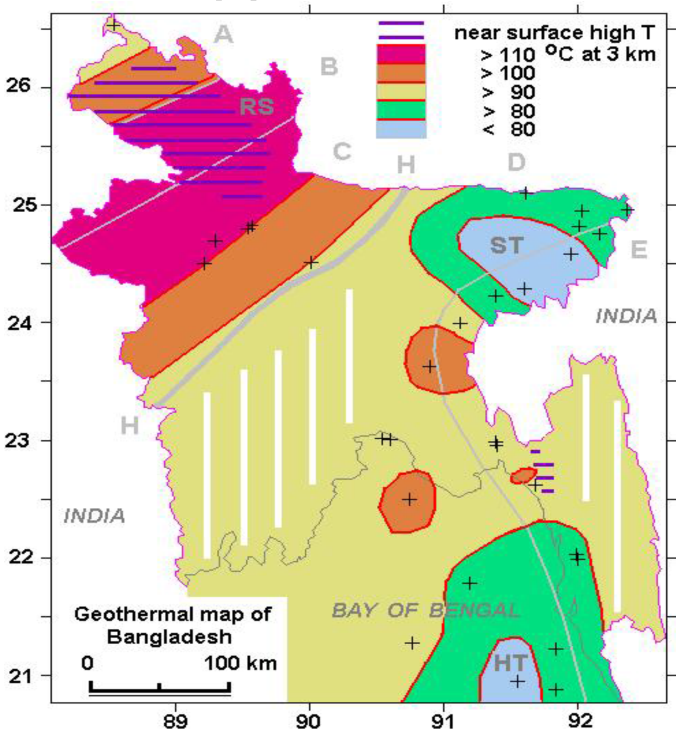

Figure 4. Geothermal map of Bangladesh showing the temperatures at 3 km depth [17].

TABLE III. GEOTHERMAL GRADIENTS FOR THE DEEP WELLS ALONG THE BENGAL FOREDEEP REGION [3].

SL/No.	Well Name	°C/km	SL/No.	Well Name	°C/km
1	ARCO A1	26.1	16	Kailashtila 1	19.8
2	Atgram 1	20.1	17	Kamta 1	23.5
3	Bakhrabad 1	23.9	18	Kutubdia 1	26.4
4	Beani Bazar 1	19.8	19	Muladi 1	26
5	Begumganj 1	25.4	20	Muladi 2	24.4
6	BINA 1	25.2	21	Patharia 5	20.4
7	BODC 1	25	22	Rashidpur 1	21.7
8	Chattak 1	21.1	23	Saldanadi 1	27.2
9	Cox's Bazar 1	25.6	24	Semutang 1	27
10	Fenchuganj 2	20.7	25	Shabajpur 1	29.5
11	Feni 1	23.8	26	Sitakund 5	24.7
12	Feni 2	23.5	27	Sylhet 7	19.9

13	Habiganj 1	20.5	28	Titas 11	23.1
14	Jaldi 1	20	29	Hazipur 1	24.2
15	Jaldi 3	22.5	30	Bangora 1	21.2

B. Geothermal Prospects of Bangladesh

The northern districts of Bangladesh have an immense possibility to explore the geothermal resources. The demand of natural resources for electricity in urban as well as in the rural areas is increasing, but our production of electricity is not increasing with respect to demand increase. The geothermal energy can compensate the rural demand of electric power. It is also possible to fulfill the demand of urban areas by the saved power from rural areas. Geothermal energy can balance the electricity consumption in these two areas [18]. The first geothermal power plant of Bangladesh has been planned to set up in Thakurgoan by a company named Anglo MGH. The capacity would be 200 MW of this plant [19]. So it's clear that geothermal energy can be a huge source of power for Bangladesh.

VII. CONCLUSION

The power crisis of Bangladesh is increasing day by day. It is high time that renewable energy started to explore in our country. Geothermal energy is one of the most promising renewable energy sources in Bangladesh. It may play an important role to minimize power crisis of Bangladesh.

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Distributed Storage based DC Micro Grid:

A Reliable PV based Solution for Rural Electrification of Bangladesh

Shahid Jaman
Institute of Energy
University of Dhaka
Dhaka, Bangladesh
shahid.jaman.aust@gmail.com

Minar Mahmud Hossainy
Institute of Energy
University of Dhaka
Dhaka, Bangladesh
minarmahmud100@hotmail.com

Md. Saiful Huque
Institute of Energy
University of Dhaka,
Dhaka, Bangladesh,
saifulh.ire@du.ac.bd

***Abstract*— this paper proposed a conceptual design and economic analysis of a distributed storage based DC micro grid system for rural area electrification of Bangladesh. In this design we has taken an average load consumption about 34.3kWh including the rural household load and irrigation facility with seasonal load variation. After that we have estimated required specification of DC micro grid components such as solar PV, micro grid charge controller, battery, distribution system etc. Moreover, we have also shown the cost analysis of our proposed micro grid system. Cost analysis estimated about 17.80 BDT/kWh electricity cost with seasonal irrigation facility. It is argued that the developmental activity should be chosen in such a way that it matches with the seasonal variation in insolation and load demand may keep the energy cost to a minimum.**

Keywords*— DC Micro Grid, Distributed Storage,, Irrigation, Solar PV, Micro grid Charge Controller,, Battery, Cost Analysis.

I. Introduction

Development of DC micro grid technology is ever increasing all over the world. A low cost DC nano grid proposed in [1]. There has shown the possibility to fulfill the consumer demand (1.9kW) with PV based nano power system with low cost. In Energy management, control strategy and power electronics area there are different kind of invention and development took place for DC micro grid quality enhancement such as a smart wireless DC micro-grid suitable for efficient utilization of energy available from Distributed Renewable Energy Generators (DREGs) is described. [2] This concept is experimentally demonstrated using a 40 W solar photovoltaic (PV) array delivering power to fluorescent lighting; other DC loads such as Light-Emitting Diodes (LEDs) and DC ceiling fans can be easily integrated into the proposed hybrid micro-grid. Then, a droop control for power electronic converters connected to battery storage is developed and tested. DC micro-grid has different control strategies according to different operating modes (grid connected, islanded). Then its control mode is designed and investigated by MATLAB/Simulink models in [3]. The simulation results verify the validity of the mathematical model and the feasibility of the proposed control strategies. In the grid connected mode, the transfer energy can flow in bi-directional modes, and DC bus voltage level can be stabilized by DC/AC converter. In the islanded mode, the battery converter serves as a voltage source to ensure a stable DC voltage.

So it's high time to adapt with DC micro grid system for livelihood enhancement. Many developing country like India, Malaysia, and many region of Africa has already oscillating this concept. In case of Bangladesh, peoples are fascinated to Solar Home System (SHS). In the context of our country, particularly when one considers the growing identification of the limitations of the SHS even amongst those household's where it is more or less affordable. Despite all the positive features of the SHS, it has a very serious limitation in terms of its potential to directly affect an individual households ability its income generation and overall quality of life [3,4].

In this paper we propose a community based small sized centralized solar PV system with distributed storage, termed 'micro-grid' for its small size (in contrast to the larger networks envisaged under terms such as mini-grids and nano-grid), that can provide energy to 50-60 households and can support small scale developmental activities like irrigation.

Irrigation is one of the major energy-demanding activities carried out in rural Bangladesh as Bangladesh is predominantly an agricultural country. Bangladesh has a monsoon climate where there is plenty of rainfall during the months from June to September. Indeed, sometimes there is too much rainfall and flooding takes place. Seasonal cultivated item in Bangladesh has shown in TABLE I below. However more than 60% of the rural area is not connected to the national electricity grid and irrigation mainly depends on diesel based engines in these areas. [1, 5].

TABLE I. SEASONAL CULTIVATION ITEM IN BAGLADESH

Season	*Cultivated Item*
Boro (January – May)	Boro and Jute
Amon (June – September)	Amon, Cattle vegetetion
Robi (October – January)	Chili, Onion. Potato

However more than 60% of the rural area is not connected to the national electricity grid and irrigation mainly depends on diesel based engines in these areas. The cost of diesel in the city areas is about Tk. 61 per liter and it is at least 20% higher in the rural areas due to the incidence of transportation and storage costs. Bangladesh imports USD 1bn worth of diesel for use in the agricultural sector alone [1, 4]. The cost of diesel based irrigation at the field level is Tk. 21 per kW-hr equivalent of electricity. The irrigation pump owners charge about 25% of the value of the crop produced for irrigating the land for a season. It has also seen that [1] 12858 L/day or 11250L/hour or 187.5L/min water discharge is enough for 1 acre of land. Summarized irrigation trend which already adopted by rural area has shown in TABLE II below-

TABLE II. IRRIGATION TREND IN RURAL AREA OF BANGLADESH

Pump usage per Day	8 hours
Required Energy for Pump	6400-8800W-hr/day
Total Electricity Cost/day	164-185 BDT/day
Size of Plot irrigated	10 acres (1,000 decimal)
Diesel required per hour	0.75L
Diesel Required Day	6L
Total Diesel cost	366BDT/day
Water Discharge Rate	188L/min
Water depth	6-7m

From the above discussion, we can see that monthly total irrigation cost is around 16550 BDT which is very difficult to afford for a rural family. For this reason solar PV based irrigation system is most cost effective system for rural development.

II. DC MICROGRID: A RELIABLE CONCEPT FOR RURAL BANGLADESH

Conventional SHS has some limitation for which many researcher decided to continue his research for DC micro grid development with some new concept. Distributed storage based DC micro grid is such a concept which has sufficient advantages that can replace the older one. This kind of grid is simpler due to dc system, reliable for absence of large solar charge controller. Moreover, it is a energy efficient system due to reduction of energy conversion stages. For a bunch of utilities, this type of micro grid is attracted the researcher interest.

DC micro grid uses array of solar panel connected in series/parallel to generate power at 230 Volt DC, which can be transmitted over distance of 1-2 km similar to 230 V, AC distribution line using a 2 core cable and supporting poles. Houses are connected to the distribution line through junction boxes mounted on poles. The micro grid controller installed in each house steps down 230 V, DC to 12 V, DC which is used to charge the storage battery and power the energy efficient DC loads in house.

A. Advantages of DC Microgrid with Distributed Storage

Due to absence of centralized higher capacity solar charge controller, battery bank and higher capacity inverter the system is highly reliable. In DC micro grid, each household has their own lower capacity controllers and storage battery. The lower capacity controllers are more reliable to due to lower number of components. The technology is very simple as this system uses an array of solar panel connected in series to generate power at 230 V, which can be transmitted over a distance of 1-2km. The controller at each household steps down the voltage to 12V to power the load and charge the battery. Unlike AC micro grid, this system does not require centralized higher capacity solar charge controller, battery bank and higher capacity inverter. Due to use of LED Lamps, DC Fan and DC TV in each household, the power requirement for each family is less compared to conventional grid supply and AC Micro grid. So the DC micro grid requires less solar panel and storage battery compared to AC micro grid for same number of households.

B. Block Diagram of Distributed Storage based DC Micro Grid System

This concept takes advantage of the fact that houses in Bangladesh are usually clustered together in rural areas in a group of 55-60 houses (within a diameter of less than 1000m). A schematic diagram (bird eye view) depicting the concept is shown in Fig. 1. In the proposed distributed storage based DC micro grid system, something like a 5.8kW PV system is installed in a large area of households within a radius of 400m-500m and power is distributed to 5 types of consumer from this system.

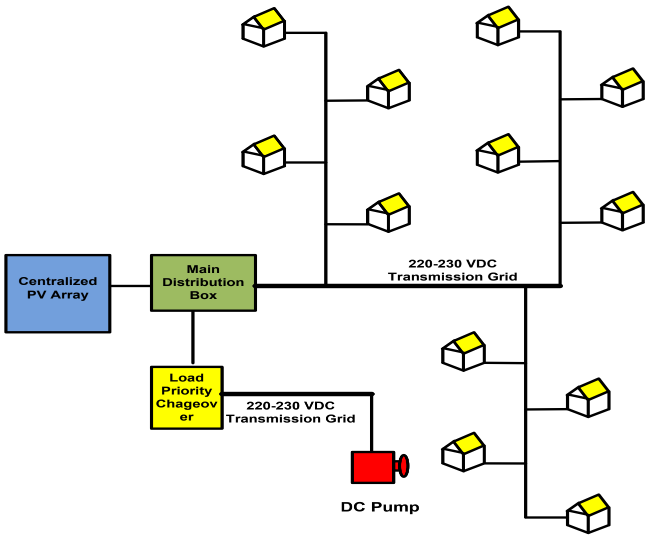

Figure 1. Bird eye view of proposed distributed storage based DC micro grid system.

The PV panels and the battery used in the proposed micro grid will be connected in series in such a way that the grid voltage is 220V DC (nominal) and the households are supplied with this voltage. There are already strong voices being raised regarding the advantages of DC grids [6]. As described in the later part of this section, the main household loads for this system are likely to be lighting, TV, fan and mobile phone. These days, brushless DC fans are widely available in the market. Although the brushless DC fans are more expensive, they are much more efficient (~80%) than the usual induction motor based AC fans (efficiency ~60%). The higher cost of the brushless DC fans is likely to be compensated within three years considering the lower power consumption of the fans. However, in case of irrigation pumps or some other income generating activities a separate inverter is likely to be needed. The advantage of the DC grid is its low cost, as no inverter is needed and at the same time this avoids inverter energy losses.

Additionally there several component may be used in our proposed system particularly storage system, junction box, prepaid energy meter etc. The storage system is obviously distributed among the consumer house. But a special type charge controller has to be used in dc micro grid system. It can be capable to operate at high voltage input as well as convert in to 12V which is necessary for dc home appliances. It also has to protect the battery from overcharge and over discharge. The cross sectional view of our DC micro grid with assumable distance has shown in Fig.2 below-

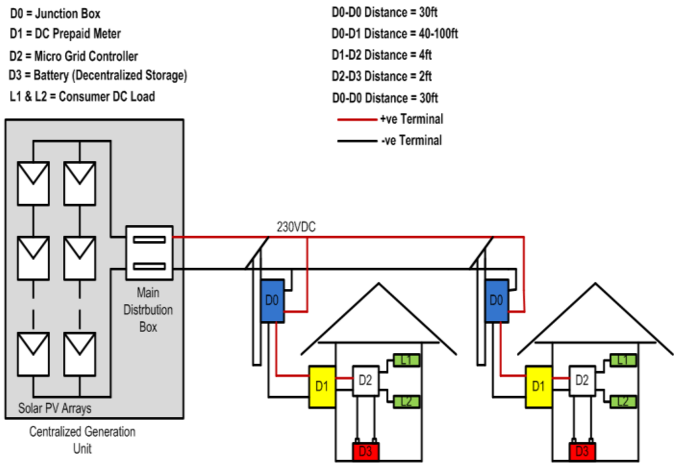

Figure 2. Proposed DC Micro grid with local consumer

C. System Cost Analysis Methodology

Cost Analysis of a project is very important factor to realize the practical viability of that project. It has a systematic methodology which helps us to calculate the system unit energy cost [7]. First of all we have required some base parameter to calculate that costs. Total project installation cost, inflation rate and discount or bank interest rate is the major parameter needed for that task. In a PV system there are some components which has to be replaced such as battery. Present worth of components can be calculated by following equation-

$$C_{PW} = C_{comp}\left(\frac{1+i}{1+d}\right)^{N} \qquad (1)$$

Where N is the no of years. Additionally bank discount and inflation rate has denoted by d and i respectively. C_{comp} is the component cost. Similarly the present worth of operation and maintenance cost can be calculated by following equation where O&M cost per year is required.

$$C_{MPW} = (M/yr)\times\left(\frac{1+i}{1+d}\right)\times\left(\frac{1-\left(\frac{1+i}{1+d}\right)^{N}}{1-\left(\frac{1+i}{1+d}\right)}\right) \qquad (2)$$

After that the total life cycle cost of the project (LCC) has to be calculating by summing the individual present worth cost of every component including O&M cost. Then annualized LCC can be calculated easily by equation (4).

LCC = ∑ (present worth of each project component) (3)

$$ALCC = LCC\left(\frac{1-\left(\frac{1+i}{1+d}\right)}{1-\left(\frac{1+i}{1+d}\right)^{N}}\right) \qquad (4)$$

Finally we figure out the per unit energy cost by using ALCC and total energy generated by solar PV panel E_L.

$$UnitElectricalCost = \frac{ALCC}{365E_L} \qquad (5)$$

III. Components Design of Our Proposed DC Micro Grid System

Solar PV system design is a common practice for the engineers. This practice consists of several steps as solar irradiance utilization of particular area, consumer demand calculation, PV panel sizing, storage system sizing, charge controller sizing etc. For our proposed micro grid system design, these steps are very essential. The major components design has described in below-

A. Solar Irradiance

Average solar radiation profile has shown in Fig 2. Solar radiation is high between February to April. The average annual clearness index is 0.484 and the average daily radiation is 4.509 kWh/m2/d [1].

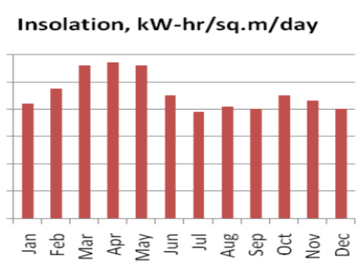

Figure 3. Solar irradiance variation throughout the year in Bangladesh

B. Average Load Consumption Scenario

In proposed PV system we developed a design that may provide power to 60 household. They can use various kind of load like LED light, DC fan and DC TV. So the total wattage and peak current were easily founded. Considering the typical load in a household which is describe in [1], the expected summer time (May to September) load is around 3 times the expected winter (November to March) household loads. This, as explained above, is due to the fact that there is expected to be high usage of fans in summer due to hot weather condition. The average typical household load in rural Bangladesh given below in Table III and Table IV. The demand for refrigerator is not considered at this stage as it goes beyond the affordability of the average households.

TABLE III. HOUSEHOLD CONSUMPTION IN SUMMER

	LED Light	Fan	TV
% Household(HH)	100	100	25
No./HH	3	2	1
Watt/unit	5	20	30
Usage hour	4.5	8	8
Diversity factor	0.8	0.8	0.8
Energy usage/day	54	256	48
Total energy required/day (Wh/day)			358
Avg load consume/HH (Watt/HH)			62.5

TABLE IV. HOUSEHOLD CONSUMPTION IN WINTER

	LED Light	Fan	TV
% Household(HH)	100	100	25
No./HH	3	2	1
Watt/unit	5	20	30
Usage hour	6	0	10
Diversity factor	0.8	0.8	0.8
Energy usage/day	72	0	60
Total energy required/day (Wh/day)			132
Avg load consume/HH (Watt/HH)			22.5

To sum up, total rural consumer demand is 34300 Wh/day and 63.6 W/day where 60 household consumption and a 1.1kW dc pump with 8 hour operation per day are included.

C. Solar PV Sizing

In case of solar PV sizing, we have to consider all losses associated with the components. Since it is a distributed storage based design, here each household has a dc micro grid charge controller and storage system (battery) and have to maintain 230V in dc transmission line. To calculate precisely we assume the combined efficiency of charge controller, wiring and battery is 85% and solar irradiance of the area is 4.509 kWh/m^2/day. Therefore the Solar PV has to generate around 35300Wh/day to serve the total demand. If we choose 250Wp panel for the design. The Solar PV Specification has given TABLE V below-

TABLE V. SOLAR PV SPECIFICATION

Parameter	Specification
Total No. of Panel	31
No. Of Panel in Series	8
No. Of Parallel String	4
Panel Wattage (Wp)	250
Voltage at MPP (V)	30.5
Current at MPP (A)	8.2
Open Circuit Voltage (V)	37.1
Short Circuit Current (A)	8.6

D. Battery Sizing

Since this is a distributed storage based power system, so the storage device will obviously located in each consumer house. From the above load calculation, we found that individual energy consumption is 360Wh per day and 62.5W power wattage. Moreover the voltage level of usable load in consumer side is 12VDC. Assume that battery DOD usage and efficiency is 75% and 95% respectively. Wiring efficiency is also 90% and day of autonomy is 2 days. So the battery sizing of each house has shown in TABLE VI below-

TABLE VI. BATTERY SPECIFICATION

Parameter	Specification
Minimum Ah required	100
No of Battery/HH	1
Battery Voltage (V)	12

E. Micro Grid Charge Controller Sizing

As we know that the power consumption of each house is 62.5W at 12V and 1100W at 12V DC pump side. Additionally the main transmission line as well as charge controller input voltage is 220-230 VDC. So we have to chose such a charge controller which is capable to convert high input dc voltage in to low 12VDC and control the charging, discharging cycle of a battery. Total drawing current by the each household load from the controller is 5.2A. The micro grid charge controller specification has shown in TABLE VII where 30% overload has assumed.

TABLE VII. CHARGE CONTROLLER SPECIFICATION

Parameter	Specification
Input Voltage(V)	220-230 VDC
Output Voltage(V)	12VDC
Output Current (A)	7-8
Output Wattage(W)	Above 80
No. Of CC/HH	1

F. Irrigation Pump Controller Sizing

A 1.1kW (~1.5HP) irrigation pump can run quite satisfactorily if the input power is within 1000-800W. A 1.1kW electric pump driven by an inverter, having an overall efficiency of 50%, can pump around 90,000 litres of water per day (4 hours of run time) from an average head of 7m. In the case of a submersible deep tube well the figure will be lower due to the higher head. TABLE VIII shows the pump specification for proposed micro grid.

TABLE VIII. IRRIGATION PUMP SPECIFICATION

Irrigation Pump Load	Rating
DC Pump	1.1kW, 1.5hp (3 nos)
Flow Rate	44-70m^3/hr
Voc	375VDC
Vmp	>230VDC

G. Distribution System Sizing

The distribution system designed for 2 wire DC power system at 230VDC. Total length of the distribution line is approximately 1km. Insulated cable with copper conductor will be drawn on electric poles. Spacing between two poles will be 20m. The feeder will be designed such that the voltage drop at the end point of any feeder will be less than 2.5% of the rated voltage at full load condition. The table below gives the basic design values for the transmission line. TABLE IX shows distribution system for proposed micro grid.

TABLE IX. DISTRIBUTION SYSTEM SPECIFICATION

Item Specification	Rating/description
Length of transmission line	1km
Number of electric pole (extra pole for sub distribution)	30-40 nos.
Junction Box	15 nos.
Overhead Conductor	3km
Insulator per pole	4 nos.
Transmission line cable size	1X35rm, Rating 30A
Cable size from Controller output to load	2X1rm, Rating 10A

IV. LIFE CYCLE COST ANALYSIS OF OUR PROPOSED DC MICRO GRID SYSTEM

The summarized result of our proposed system has given in Table X below-

TABLE X. RESULT OF DC MICROGRID DESIGN

Item	Design result
Number and types of load	About 60 Household
Load demand coverage of the area	Around 34.3kWh/d peak, 62.5W/day peak
PV Array Sizing	250Wp (31nos)
Battery Sizing	100Ah (for each HH)
Micro grid Charge Controller sizing	8A, 90W (for each HH)
Cable Sizing	Main Transmission Line : 1X35rm, Rating 30A, Cable from Controller to Load: 2X1rm, Rating 10A
DC Pump Sizing for Irrigation	1.1kW, 1.5hp, Vmp>230V

A. System Components Costing

To implement the proposed solar PV based micro grid, we need to have a clear concept on the implementation cost. In these consequences, we have calculated the approximate cost in Bangladeshi taka (BDT) all components cost that we have required implementing a solar PV system. These components are: PV modules, Micro grid charge controller, battery, wiring and other costs as protections, installation etc. We have considered the cost by visiting the market level. After doing calculation the total cost stands around BDT 18,72,000. The detail cost calculation has given TABLE XI below-

TABLE XI. RESULT OF DC MICROGRID DESIGN

Components	Unit Cost	Quantity	Total Cost
Solar PV Panel, C_{PV}	12000/-	31	3,72,000/-
Charge Controller, C_{CC}	5500/-	60	3,30,000/-
Battery, C_B	8000/-	60	4,80,000/-
Irrigation Pump Accessories	30000/-	1	40,000/-
Wiring Cost (Distribution System)	-	-	4,00,000/-
Other Cost (Installation, Civil)	-	-	2,50,000/-
Grand Total			**18,72,000/-**

B. Per-unit Electricity Cost Calculation

The entire life cycle cost analysis of a project has been discussed earlier. The lifetime N of all the items is considered to be 20 years, except that of the battery which is considered to be 5 years. Thus, an extra 3 groups of batteries (each of 60 batteries) have to be purchased, after 5 years, 10 years, and 15 years. Inflation rate of 7.5% and a discount or interest rate of 13%. By using above equations we can calculate the per unit electricity cost of our proposed DC micro grid system by TABLE XII below-

TABLE XII. PER UNIT COST CALCULATION

Title of Cost	Amounts	Remark
C_{B1PW} [Eqn (1)]	3,74,017/-	Replaced after 5 years
C_{B2PW} [Eqn (1)]	2,87,993/-	After 10 years
C_{B3PW} [Eqn (1)]	2,21,754/-	After 15 years
C_{MPW} [Eqn (2)]	`	Assuming 1,20,000/- per year
LCC [Eqn (3)]	28,51,200/-	Considering all associated cost in TABLE XI and XII
ALCC [Eqn (4)]	2,22,750/-	
Unit Energy Cost [Eqn (5)]	17.80/-	Generated power by PV is E_L=34.3kWh

Considering a monthly service charge of Tk. 100 electricity bill for an average household for summer months is Tk. 293 and that for winter months is Tk. 171 (including the monthly connection charge). The yearly average of the bill is Tk. 232 per month. Corresponding irrigation energy cost per season is Tk. 10, 000 (Equivalent to 14.28% of the crop produced for rice fields where 70000 BDT revenue per month).

V. CONCLUSION

This paper has proposed a conceptual design and cost analysis of a distributed storage based DC micro grid system. The advantages and reliability has also discussed here. The technical advantages and cost analysis has also shown in this paper. It is worth mentioning here that the average energy cost in a SHS under a similar financing model is close to Tk. 40 [6]. As SHS has only fixed load of light, mobile charger and/or TV, it cannot accommodate the seasonal variation of sunshine resulting in underutilization of the available PV energy. In contrast, this dc micro grid capable to provide power the extra load as fan, computer, refrigerator etc which is not possible for SHS system. In summary, the nano grid provides energy at a lower cost with more options for household gadgets. Apart from household use, it can incorporate a small sized irrigation pump that can have significant impact on agriculture.

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Designing of a 2kW Stand-alone PV System in Bangladesh Using PVsyst, Homer and SolarMAT

Md. Sifat Morshed, Shoaib Mohammad Ankon, Md. Tanzil Hoque Chowdhury, Md. Anikur Rahman
Department of Electrical and Electronics Engineering
Ahsanullah University of Science and Technology
Dhaka, Bangladesh
E-mail address: sifat19eee@gmail.com

***Abstract*—In today's world the demand of energy is incredibly high and non- renewable resource such as ore, fossil fuel and nuclear fuel are not sufficient to meet this demand. Eventually renewable energy is a better choice. There is an increasing trend of using solar cell in the industry as well as to household appliance because solar energy is expected to play a prominent role in future smart grid as a distributed renewable source. For optimal and large scale integration of solar energy several modeling software and computer program is used. In this paper a stand-alone solar system of 2kW with battery backup, being located in Dhaka, Bangladesh is designed by using a MATLAB program named SolarMAT and two popular software PVsyst v5.06 and HOMER. Both PVsyst and HOMER are versatile and renowned software in the field of solar system design and modeling. PVsyt and HOMER have to be purchased, unlike SolarMAT, which is a free tool and it is developed in MATLAB environment which can also accurately design a solar system but not that much like the other two. To check the acceptance of these software, the final result will be compared with the practical data. Another widespread photovoltaic solar system configuration known as grid tie system can also be designed by both of these tools.**

Keywords—solar cell; solar energy; stand-alone; PVsyst; grid-tie; MATLAB

I. Introduction

Increased energy utilization and global pollution awareness have made green/renewable energy more and more valuable. Among several renewable energy resources, photovoltaic (PV) effect is the most essential and sustainable way because of abundance and easy accessibility of solar radiant energy around the earth [1]. The conversion of solar energy into electric energy is performed by means of photovoltaic cells. One of the attractive features of the PV system is that its power output matches perfectly with the peak load demand. It produces more power on a sunny day when excessive load consumes more power from the grid.

More than 1,320,965 SHSs having capacity 36.5MW have been installed by different NGOs in Bangladesh up to February 2012 which are supported by IDCOL (Infrastructure development company limited) [2]. It is expected by the expert's that Bangladesh will meet 10% of its total electricity demand by renewable energy in 2020 [3].

There are three basic configuration of solar system [4]. Stand alone system, grid tie system and grid interactive system. At present, PV power is extensively used in stand-alone power systems in remote villages, particularly in hybrid with diesel power generators. It's major components are PV module, charge controller, battery and inverter.

Batteries store the energy and provide a constant power source. Charge controller is used to control the flow of current into and out of the battery. It prevents the battery from overcharging and completely discharging. As most of the appliances are AC-voltage devices, inverter becomes an inevitable component of a stand-alone system. Modern sine wave inverters exhibit low open-circuit loss, allow partial load operation and should have power surge protection, short term overload capacity for several minutes and low level of high-frequency interference in the output signal [5].

Grid-tie is gaining popularity in Europe and the United States [6]. In a grid-tie system, electrical appliance runs on solar power during the day. Any surplus energy produce is then fed into the grid. In the evening and at night, when solar energy system is not producing electricity, then consumer can buy their power from the electricity companies in the usual way. The benefit of grid-tie solar installations is that they reduce reliance on the big electricity companies.

In this paper a stand-alone solar system of 2kWp is designed by using PVsyst, HOMER and SolarMAT which is a novel tool developed by the authors. In recent days the computer modeling and analysis of solar system is extensively used because of its accuracy and reliability. As a result there are plenty of software exist and developed day by day.

II. Case Study

Here a stand-alone system has been studied. A small flat situated at Dhaka, Bangladesh having 2kW load is designed by PVsyst v5.06, HOMER and SolarMAT. The required data to complete the design by SolarMAT is listed in Table I. Not all data are required for PVsyst and HOMER as listed in the Table I.

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TABLE I. REQUIRED PARAMETER TO RUN THE SOFTWARE AND SOLARMAT

Parameter	Value
Load	2kW
Operating duration	3hr
Insolation	4hr
System voltage	48v
Inverter efficiency	80%
wire loss	3%
Battery autonomy	1
Battery voltage	12
DoD (depth of discharge) of battery	60%
Battery efficiency	95%
Battery Ah (given)	100Ah
PV module Isc	8.19A
PV module Imp	7.71A
PV module Vnm	24
PV module loss	5%
PV module length	1650mm
PV module width	992mm
PV module efficiency at STC	15%
PV module loss due to temp.	11.7%
Inverter efficiency	80-85%
Charge controller efficiency	95%

There are also some additional data of the project which are not required by any of the software or SolarMAT but it will be essential for later evaluation. They are shown in Table II.

TABLE II. ADDITIONAL PARAMETER OF THE PROJECT

Parameter	Value
No. of Battery	8
Battery in series	4
Battery in parallel	2
No. of PV module	10
PV module in series	2
PV module in parallel	5
Charge controller current	60A
Charge controller voltage	48V
Inverter size	2.25kW
Inverter input voltage	230V

III. DESIGN BY PVSYST V5.06

PVsyst [7] can provide almost everything that needs to design a solar home system. It shows the number of pv module, battery, inverter size, pv module loss factor, energy calculation, hourly profile, P-V curve, maximum power point and also the economical analysis. Based upon the location one sets PVsyst can also plot the performance ratio, normalized energy profile, loss diagram etc. PVsyst has a rich database of lot of popular battery and pv module company. Its vast geographical database can give precise information about the solar irradiance and insolation hour of a particular area of a country.

Providing the proper location, tilt angle and necessary data from Table I PVsyst gives the following result shown in Table III [8]. Loss diagram, normalized energy per month, daily input output diagram and hourly profile generated by PVsyst is shown in Fig. 1 to Fig. 4 respectively.

TABLE III. PVSYST OUTPUT RESULT

Parameter	Value
No. of PV modules	3
PV modules in series	1
PV modules in parallel	3
Module area	5.0m^2
Wiring loss	2.1% at STC
Module quality loss	0.8%
Module mismatch loss	2%
No. of battery	2
Battery in series	2
Battery in parallel	1
PV module size	690Wp
Available energy	1036kWh/year
Unused energy	695kWh/year
Excess energy	34kWh

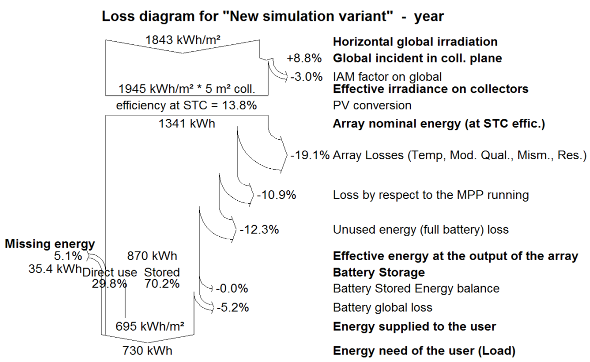

Fig. 1. Loss diagram.

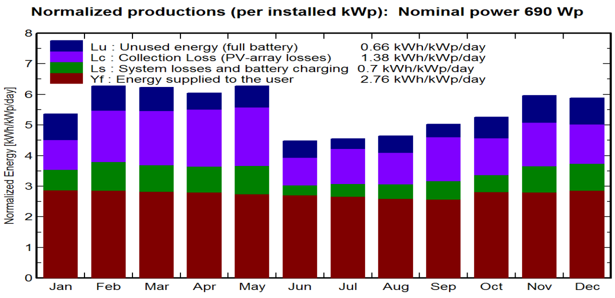

Fig. 2. Normalized energy per month.

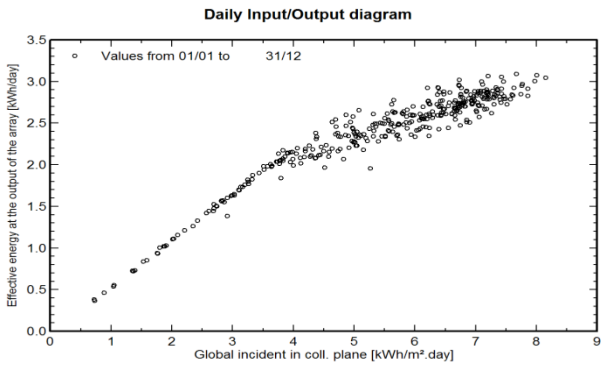

Fig. 3. Daily input/output diagram.

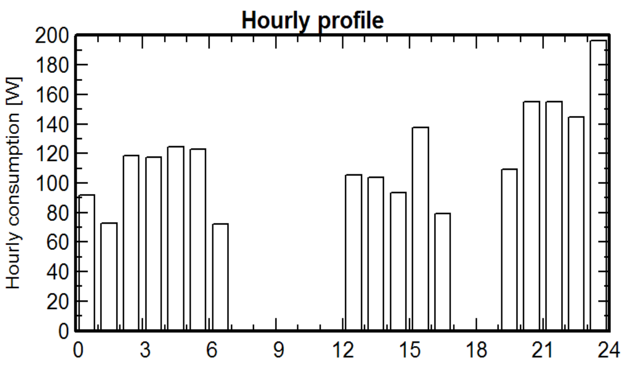

Fig. 4. Hourly profile.

As a dedicated software Pvsyst can successfully simulate and design this stand alone project though there are some ambiguity presents in the simulated result and practical result. This is because there are some mismatch in practical data. As a result though the no. of battery and PV module is 8 and 10 respectively according to Table II but PVsyst shows it 2 and 3 with a changed voltage rating. Based upon the PV module voltage-watt rating, total load and battery autonomy PVsyst finds the best configuration of PV module and battery. To make the project more economical and more optimal it automatically changes the battery voltage. It also warns if oversized battery, PV module or inverter are chosen by the user.

IV. Design By HOMER

HOMER [9] is another outstanding software developed by NREL (National Renewable Energy Laboratory) for the optimization, sensitivity analysis and simulation of hybrid renewable system. It can also provide economical analysis and feasibility of the system. The most unique feature of this software is to find all the possible optimum combination of a hybrid system which has wind turbine, PV, hydro and distributed generator connected. Moreover it can plot the output condition of every component throughout the year and fetches accurate monthly solar irradiance, global horizontal irradiation, azimuth angle etc of a specific region.

The following parameters shown in Table IV are given as input in HOMER to complete the design. The schematic diagram of the 2kW stand-alone system is shown in Fig. 5 after setting the latitude and longitude of Dhaka, Bangladesh. Homer gives the monthly average electric production and global horizontal radiation which are depicted in Fig. 6 and Fig. 7 respectively. Fig. 8 shows hourly profile.

TABLE IV. Input Parameter For HOMER

Parameter	Value
Total load	2kW
Size of PV panel	2.4kW
No. of Battery	6
Battery Ah	200Ah
Battery voltage	12V
Inverter size	3.125kW
Inverter efficiency	82%
PV panel derating factor	80%
Azimuth angle	23°

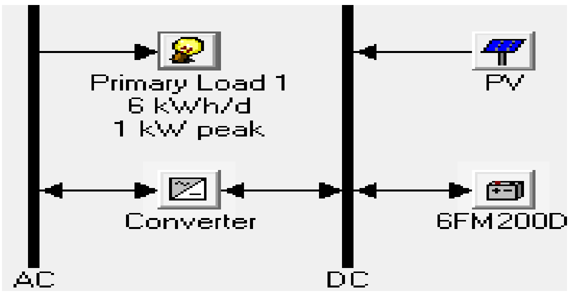

Fig. 5. Schematic diagram of the stand-alone system.

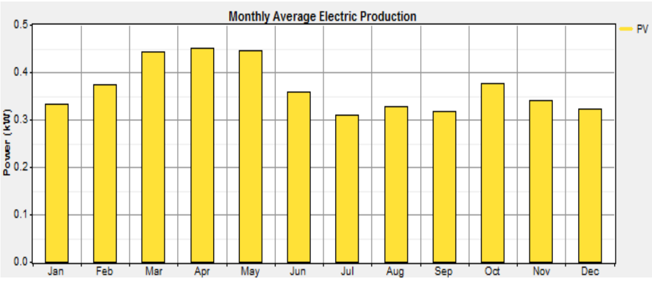

Fig. 6. Power vs monthly average electric production.

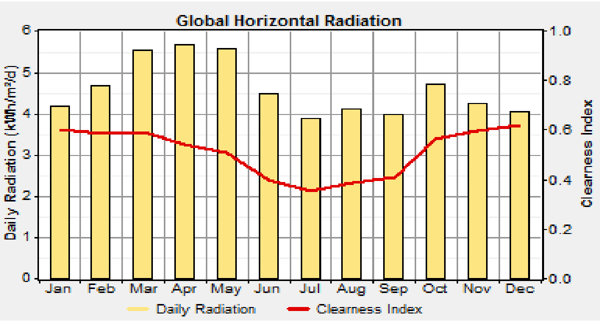

Fig. 7. Global horizontal radiation of Bangladesh.

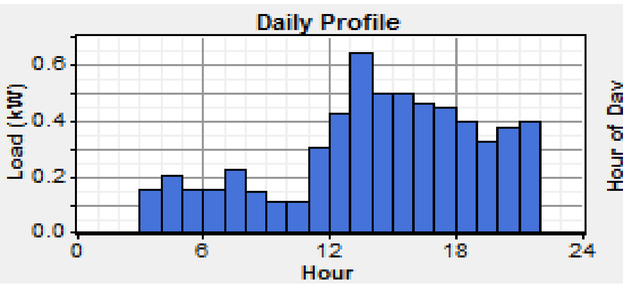

Fig. 8. Hourly profile.

Battery bank state of charge, PV output and inverter output are shown in Fig. 9 to Fig 11. All these figures show the real condition of battery bank, inverter and PV module output throughout the year on the basis of hourly load. From Fig. 8 it is clear that the battery is discharged heavily after the sunset and during the day time its discharge is pretty low.

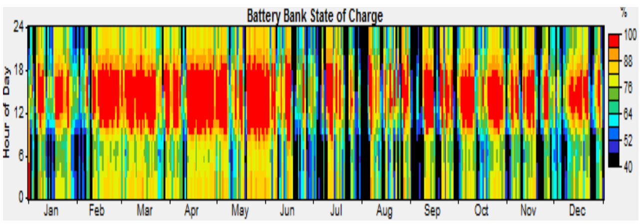

Fig. 9. Battery bank state of charge throughout the year.

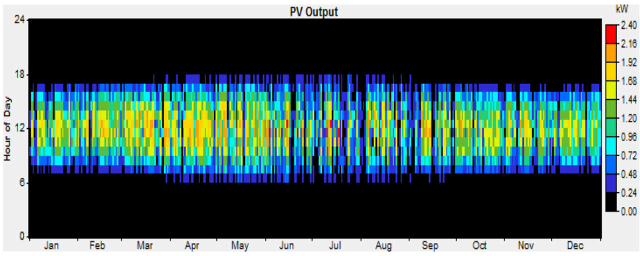

Fig. 10. PV output per month.

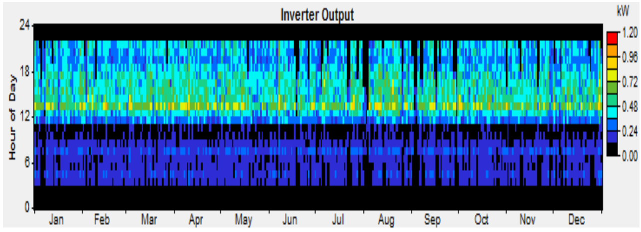

Fig. 11. Inverter output per month.

Beside these plots HOMER gives the following data of this stand-alone system which are given in Table V.

TABLE V. OUTPUT RESULT OF HOMER

Parameter	**Value**
PV mean output	9.11kWh/day
Capacity factor of PV	15.8%
Total production of PV	3324kWh/year
Nominal capacity of battery	14.4kWh
Usable capacity of battery	8.64kWh
Battery autonomy	34.6hr
Lifetime throughput of battery	5502kWh
Inverter mean output	0.23kW
Capacity factor of inverter	7.5%

V. DESIGN BY SOLARMAT

SolarMAT is a MATLAB oriented program developed by the authors of this paper. SolarMAT has a great ability to design the stand-alone and grid tie system. By providing the proper input data it gives the best series parallel combination of pv module and battery. It can also determine the appropriate inverter and charge controller size. Hourly profile can be obtained by analyzing the user load data. One can also get the loss diagram by defining the loss factor of PV module and battery which is similar to the PVsyst.

To design this project by SolarMAT all essential input is assigned to each variable of the program from Table I. SolarMAT gives the following result as shown in Table VI. Fig. 12 shows the loss diagram generated by SolarMAT. SolarMAT also gives the hourly profile and average solar irradiance VS month in Fig. 13 and Fig. 14 respectively. Loss diagram shown in Fig. 12 requires some explanation to make it discernable. Fig.12 shows the gradual loss of the stand-alone system. First bar labeled as “Global horizontal irradiance” of this plot is lesser than the second one which is unusual. But global horizontal irradiance is the measurement of the kWh received by the solar radiation per unit area throughout the year which is horizontal to the ground. For Dhaka, Bangladesh this value is 1843kWh/m^2/year. However “effective irradiance on collector” is calculated by (1945kWh/m^2/year) × Area of PV array. The value of effective irradiance on collector for Dhaka is 1945kWh/m^2/year according to the database of PVsyst [10]. For this project the area of PV array is 16.36m^2. This gives us the value of effective irradiance on collector equal to 3.17kWh/m^2/year as shown in Fig. 12. Array nominal energy is calculated by (1).

$$\text{Array nominal energy} = \text{Effective irradiance on collector} \times \text{Efficiency at STC} \tag{1}$$

TABLE VI. OUTPUT RESULT OF SOLARMAT

Parameter	Value
Total AC Wh/day	6000W
Total DC Wh/day	7543.3744W
Total ampere hour	157.1536Ah
PV module output	832.68W
PV module size	207Wp
No. of PV module	10
PV module in series	2
PV module in parallel	5
Short circuit array current	40.95A
Charge controller design current	51.1875A
Inverter size	3.048kW
Ah required by battery	275.7081Ah
No. of battery	12
Battery in series	4
Battery in parallel	3

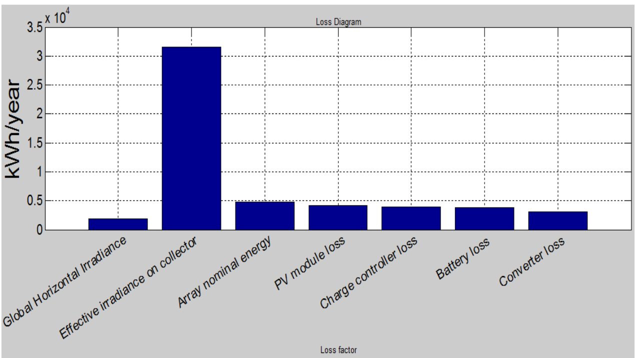

Fig. 12. Loss diagram.

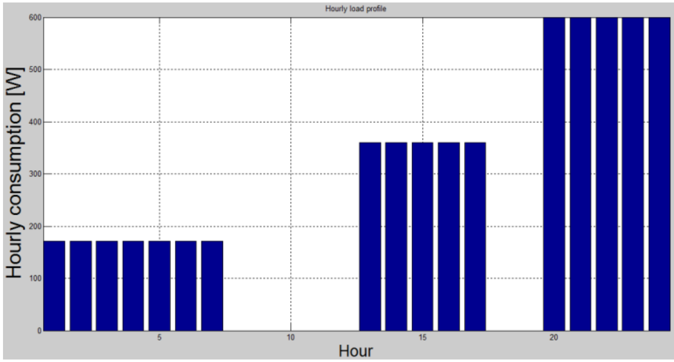

Fig. 13. Hourly profile.

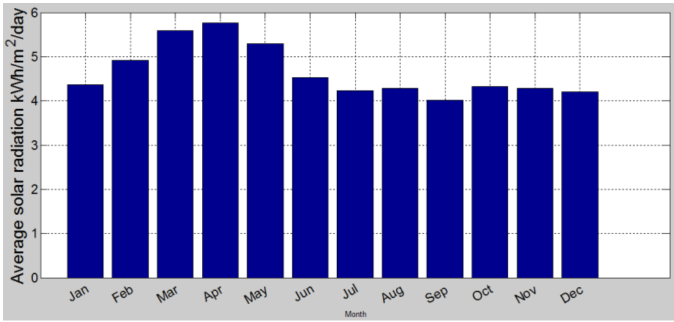

Fig. 14. Average solar irradiance vs month.

SolarMAT is a handy program to design stand-alone and grid- tie solar system in a short time. If the simulation data is compared with the practical data of Table I it will be seen that SolarMAT’s result is almost completely matched with the practical data. Series parallel combination of battery and PV module is matched with practical project and there amount is not differed much like PVsyst though the inverter size is a little bit higher. The economical feasibility of the result given by SolarMAT at the Table VI is checked by the RETSCREEN software in [4].

One of the great advantages of SolarMAT is it’s very simple to use and give all necessary information required to design a solar system. The program is written based upon some basic equation of stand-alone and grid tie solar system [11]. It has no copyright and anyone can use this for free.

SolarMAT is still under developing condition and it has some limitations. It has no database like PVsyst or HOMER and therefore user’s need to input a lot of data. If a solar project is to design which is placed outside of Bangladesh then loss diagram and average solar irradiance curve may not be accurate. But if one changes the GHI (global horizontal irradiance) in the code, will get the correct loss diagram for the new place. One should have the MATLAB R2007b or later version installed to run this program.

Although SolarMAT is developed in MATLAB, its web version is available which is also free [12]. A beta version is already available at [13]. It contains all the functions of the original tool with a user friendly GUI (graphical user interface). This gives this novel tool a new dimension. One can instantly access to this site and could get all the necessary results as shown in Table VI. for both stand-alone and grid tie system. User guide and MATLAB code is also available there.

VI. CONCLUSION

The design of a stand-alone system has been accomplished successfully by using PVsyst, HOMER and SolarMAT. In case of PVsyst it shows mismatch with practical data to a small extent. And output result generated by SolarMAT has a great similarity with practical data. The graphs and diagram obtained by PVsyst is highly informative whether SolarMAT gives a rather straight forward result and only contains the basic functionality. For a detailed design and economical analysis of a stand-alone or grid tie system PVsyst is a good choice. HOMER would be preferable for hybrid solar system design, optimization and sensitivity analysis. But SolarMAT as a freeware tool, can be a reliable choice for simple design. However SolarMAT will be more developed to meet the increasing demand of computer based design and analysis of solar system. There are a lot of scopes to make it better in future. Like economical analysis can be added with it. Adding geographical database for other countries, analysis of hybrid PV system along with stand-alone PV system and more user friendly GUI will make SolarMAT more effective.

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Prospect analysis of biofuel production and usage for transportation in Dhaka city, Bangladesh

A S M Monjurul Hasan
Department of engineering and management
Linköping University
Linköping, Sweden
monha041@student.liu.se

Sanjib Chakraborty
Technical Consultant
Go for Green
Sweden
sanjib@goforgreen.se

A S M Muhaiminul Hasan
Dept. of Electrical and Electronic Engineering
Ahsanullah University of Science and Technology
Dhaka, Bangladesh
a.s.m.muhaiminul92@live.com

Tousif Ashraf Niloy
Dept. of Electrical and Electronic Engineering
Ahsanullah University of Science and Technology
Dhaka, Bangladesh
tousif_niloy@yahoo.com

Abstract— **World is heading towards the crisis of fossil fuel. Energy crisis is more acute in Bangladesh, as there is no petro-fuel source but only natural gas. It has among the lowest per capita energy (240 kg oil equivalents) consumption in the world and is severely dependent on additional environmentally friendly renewable energy resources in the future. To cope up with present situation and to reduce dependency on imported fuel, Bangladesh government is encouraging the use of renewable energy sources. In this circumstances, biofuel can be a very good alternative fuel for transportation. This paper gives insight into biofuel production feasibility and it's usage for road transport can play an important role in the biggest metropolitan city of Bangladesh and contributes to knowledge on how to perform similar studies. Resource-focused assessment including feedstock from the waste sector, agricultural sector, forestry sector and aquatic environments partially considering technological and economic constraints. Sufficient evidence have been found for biofuel production and can met at-least 10% of energy demand for road transport of Dhaka city, Bangladesh. Without compromising with food security the study suggests that it is possible to significantly increase the biofuel production, and to do this as an integrated part of the existing society also contributing with positive societal synergies.**

Keywords-Biofuel, renewable energy, transportation, bio energy etc.

I. INTRODUCTION

Climate change is challenging almost all human endeavors, including the future ways in which energy will be generated and consumed. It could adversely affect water supplies and agricultural productivity, and the need to cut CO2 emissions to avoid harmful environmental degradation has made the transition from conventional fossil fuels to alternative and renewable resources a global priority.

The supply of fossil fuel will come to an end by 2050 considering a 5% flat increase in demand. With the rapid growth of technology and civilization spreading over the world, from 1955 to 2005 the emission of CO2 at atmosphere simply got twice from 3 billion tons of Carbon to 6 billion tons of Carbon, which certainly results in temperature increase, sea level hike, deviation of biodiversity and ecological imbalance. Most of the CO2 emission is caused by USA, China and EU countries, but the high risked counties of the impact of this phenomenon are underdeveloped countries like Bangladesh, where Bangladesh causes less than 0.1 tons of Carbon emission/Person compared to almost 6 tons of Carbon emission/Person of USA. Biofuel can be a strong and ultimate solution to overcome this problem for Bangladesh. In view of the current instability in oil prices, bi0-diesel stands as an attractive source of alternative energy. By adopting and increasing the use of biodiesel, European countries have reduced from her over-dependence on crude oil reserves. Beside of conventional fossil fuel has been reported as being finite. While it is worthy to note that biofuel will not completely displace petroleum diesel, biofuel has its place as an alternative fuel and can be a source of lubricity as an additive to diesel fuel. The emissions produced from biodiesel are cleaner compared to petroleum based diesel fuel. Bangladesh has the eighth largest world population of about 140 million in a small territory of 177,570 sq. km having the highest demographic density in this planet. About 80 % of the rural population has very limited access to conventional energy sources like gas, coal and electricity. They are mainly dependent on kerosene oil for lighting and biomass for cooking and for meeting other needs. The national energy policy is aimed at providing electricity to majority of rural people by 2020. Presently, electricity is mainly generated by natural gas, the principal nonrenewable energy resource of the country. Dhaka is located in central Bangladesh at 23°42′N 90°22′E, on the eastern banks of the Buriganga River. The city lies on the lower reaches of the Ganges Delta and covers a total area of 360 square kilometers (140 square mi). Dhaka District has an area of 1,463.60 square kilometer (565 square mi) with a population of 18,305,671 in 2012.

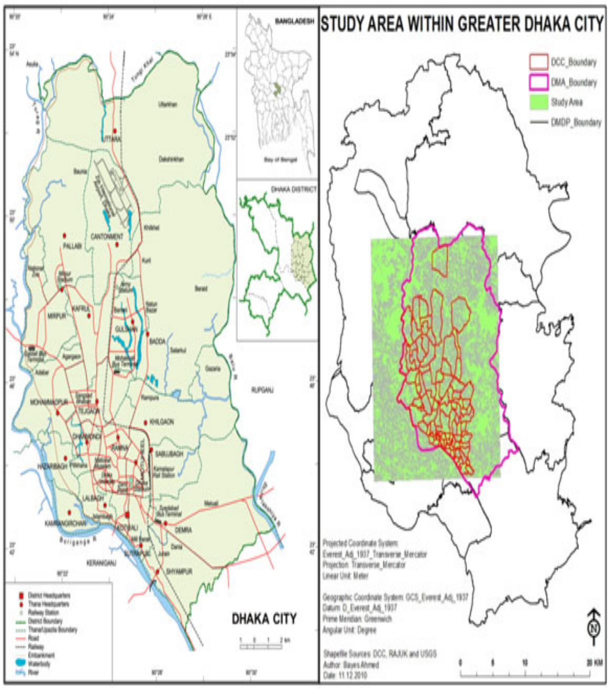

Fig.1 Dhaka city

II. ASSESSMENT OF BIOFUEL POTENTIAL AND SOURCES OF BIO ENERGY RESOURCES

Concerning biofuel potentials, there are several different types of potential in literature and the terminology is not always consistent. Based on a short overview, it can be relevant to have the following "perspectives" in mind:

A. Geography

What area is included, which could range from a global to a local level. It seems common to only focus on land areas, i.e., to exclude seas and sometimes also inland waters. As mentioned above, a specific type of land can be selected, such as surplus agricultural land. For different types of areas, a share can be selected, e.g., a share of arable land.

B. Biomass types

Bangladesh is an agricultural based country and having plenty of bio energy resources. What type of biomass is included, where some studies have a rather broad scope ,comprising all biomass produced through photosynthetic reaction, while others only focus on some selected crops or material flows.

C. Share of biomass

For the selected types of biomass it has to be decided what share to include. Here, competing needs may need to be considered, such as food production.

D. Energy:

There are different ways of assessing the energy potential, where some studies focus on the energy content for each feedstock while others apply a broader scope and to some extent include the use of energy in the value chain, for example, for collection, transport and production of biofuels.

E. Economy:

Ranging from a wider socio-economic perspective to the economy for individual actors such as biofuel producers. Focusing on producers, it can be defined as the potential that can be produced at economically profitable levels. Of course, the chosen time perspective can influence this potential.

F. Municipal wastage:

Municipal waste is the abandoned materials which have been thrown away after use in daily life in the urban area. Municipal waste generally compose of food scrap, packaging materials, used plastic materials, tire etc. Due to the increasing growth of urban population in Bangladesh this municipal waste is getting high concerns from the management perspective. Also the management of this huge amount of waste is a worth of large expense. A large amount of wastes is generated daily in the city of Dhaka. Power Cell, Ministry of Energy and Mineral Resources (MEMR), under the sponsorship of the World Bank, commissioned Bangladesh Centre for Advanced Studies (BCAS) in 1998 for quantity assessment and Institute of Fuel Research and Development (IFRD) of BCSIR for quality assessment of the city wastes. According to quantity assessment (BCAS, 1998), this city generated about 5000 tons of wastes daily in 2002 and the daily generation would increase to over 15,000 tons in 2025. This nuisance can be transformed into a resource if it can be processed to generate electricity.

III. DHAKA AND IT'S TRANSPORATATION SCENARIO

Bangladesh is mainly dependent on fossil fuel based energy generation. Recently there are some initiatives regarding sustainable energy but still they are not enough to fulfil the demand. Dhaka is the biggest city of Bangladesh and struggling to fulfil the demand for transportation fuel. Dhaka, the capital of Bangladesh and one of the major megacities in the world is the study area for this study. It is the 9th largest city in the world (World Bank, 2010). The geographic coordinate of the study area is 23°42′0″N 90°22′30″E with an area of 360km2. According to 2008 data base of Bangladesh Bureau of Statistics (BBS) the total population is 7 million with a density of 23,029/km2 . According to Detail area plan (DAP, 2004), Dhaka city has only 8% of land dedicated for the transport network. The city road network is characterized by chronic traffic congestion and delays, low quality of public transport service, lack of comfort and safety for pedestrians and growing air pollution (World Bank, 2009).

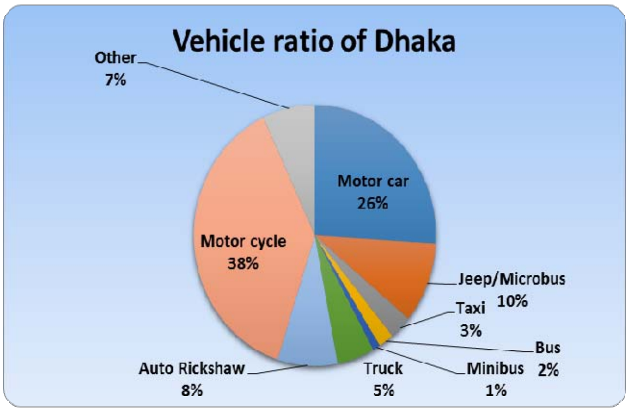

Fig.2 Transport ratio of Dhaka city

Below table we can see the fuel type and its usage pattern for vehicle in Dhaka city.

TABLE I. WASTE COMPOSITION IN DHAKA CITY

Fuel Type	Total consumption in year 2008
CNG	25,550,000,000cubic feet (cft)
Diesel	192,004,600 liters
Octane	64,229,050 liters
Petrol	8,438,800 liters

IV. BIOFUEL POTENTIAL OF DHAKA

A. Solid waste of Dhaka city

Dhaka City is now seizing with the troubles of sky-scraping volumes of wastes. But, these troubles have also afforded a window of prospects for city to find solution. The community and all the sectors have to involve their innovative technologies and disposal methods and concerning behavior changes and awareness rising.

TABLE II. WASTE COMPOSITION IN DHAKA CITY

Waste Composition	(Percentage by weight)
Food and vegetable Waste	70
Paper product	4
Plastic	5
Metals	0.13
Glass and ceramic	0.25
Wood	0.16
garden waste	11
Others	5

A healthy planned waste management process will not only help of pledge a cleaner atmosphere but it also cost-effective for citizens. Dhaka City Corporations are mainly maintaining this responsibility. DCC separated its area into 10 zones for supervision of solid waste production. Following table shows total waste composition in Dhaka city every day. Domestic waste can be one of the prime sources for biofuel production. Domestic waste is a big source of solid waste, which is about 1718 tons /day at a percentage of 49.08 %. These contain paper, vegetable peelings, onion seed coat, broken plastic and festal, spider net, soil and dust, pieces of thread, animal fasces, grasses, used shoes, pieces of cloth, small bottles, soot, used car parts, etc.

Fig.3 Vegetable market waste at Karwan bazar, Dhaka city

Mining the landfill can be very effective for biofuel resources. In Bangladesh landfilling of waste is a common tradition. Number of landfilling has been established around the Dhaka city.

Fig.4 Landfill sites at Dhaka city

B. Tannery waste of Dhaka city

The leather industries of Hajaribag area, Dhaka city, produce hundreds of metric tons of inorganic and organic wastes which pollute the adjacent water bodies including the river Buriganga. Leather manufacturers have now the chance to transform highly toxic tannery waste in what it seems to be a cheaper and a greener biofuel, the greener biofuel obtained is considered to be even cleaner than the biofuels that are available on the market now. Research is going on now a days to produce biofuel from waste water and gasification of tannery waste.

Fig.5 The fleshing machine is used to remove any fleshy matter from the leather and further used for biofuel production

V. Methodology

The methodology follows the general idea illustrated in the below figure

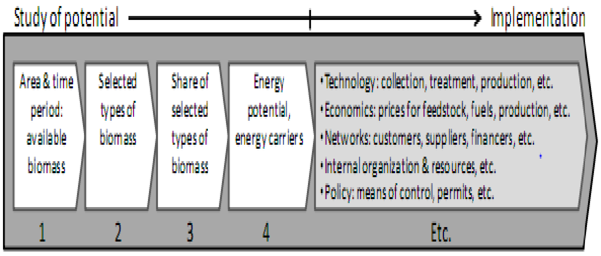

Fig.6 Main steps of the methodology employed in this study

From the figure 6, we can see that, in the first phase, need to focus on area and time period. In this article, Dhaka is the area for consideration. In the second phase need to specify the biomass sources. We have considered municipal wastage, agricultural resources for biomass sources. In phase three, we have focused on share on selected type of biomass. In the fourth stage, we have focused on energy potential and energy carriers.

Although the estimates of biofuel potentials vary considerably, it can be concluded that a large share of the existing potential is not yet implemented. Seen from the perspective of a biofuel producer, Figure 2 illustrates a schematic process from assessing biofuel potentials to implementation, meaning that biofuels are produced and sold on a market. It should be emphasized that even if some feedstock categories are promising based on the first four steps, the process is far from implementation. Of course, interlinked issues concerning technology, economy, organization, policy, etc. are often decisive, indicated in the box to the right in the figure.

The main supplying sector included are waste sector and agricultural sector. Within these two sectors, different feedstock categories are included. Materials from the agricultural and waste sectors are already used for biofuel production to quite a small extent. The potential of cultivated microalgae for production of biofuels and other valuable products has gained more interest in energy scenarios as well as for the bio-refinery concept. To produce biofuel, our main resource would be wastage of Dhaka city. It includes sludge from sewage treatment, food industry by products, kitchen waste, used cooking oil, garden waste, landfills and market waste. Handling the waste in an efficient manner is prior step for producing biofuel. After waste sector, agricultural sector can be considered as the second largest source for producing biofuel. It includes manure, agricultural waste, grains, straw etc. As Bangladesh is an agricultural based country, collecting bio energy resources would be convenient.

Multiple data collection methods were used to gather information about each type of feedstock, including the interviews mentioned. Most of the data was found in so-called grey literature, such as national reports from authorities, NGOs, research institutes, companies, international organizations and in legislative documents. Some information came from scientific articles. In addition, consultation with experts from industry and academia were necessary when relevant information was not found in literature. However, for the important feedstock categories the assumptions and choices had more impact on the result of the assessment than the actual year studied. Comparing the three selected biofuels, the land use efficiency for biogas production is higher due to the non-specificity regarding feedstock described above, but also because the whole crop can be used, not only the starchy or oil-rich parts. Biogas production based on energy crops have the potential to generate about twice the net energy yield per hectare per year compared to wheat ethanol or rape seed biodiesel. The land use efficiency of ley for biogas production contributed to the choice of ley as a dedicated energy crop in this study, but also important was that perennial ley has the potential to bring other benefits to agricultural areas such as improved soil and water quality. If only land use efficiency is considered there are other crops though that would have performed even better measured as biogas production per area of land, e.g. sugar beets.

In this study, biogas was generally chosen before other biofuels due to resource efficiency. However, existing plants, vehicles and infrastructure also have to be taken into consideration. Because of the existing ethanol plant, the choice was to continue to produce ethanol from wheat and ethanol was also considered as a reasonable choice for the straw feedstock assessed.

A. *Scenerio*

It is uncertain how the conditions for biofuel production and use will develop. In this study, two scenarios were developed from the present situation. Differences between the

Scenarios were determined by the availability of resources (feedstock), technological aspects and, to some extent, economic constraints. The construction of the scenarios was influenced also by some decisive parameters. The technology for biogas production from ley crop is already well known, hence the uncertainties are instead mainly coupled to parameters like agricultural policy, the global price development of agricultural products and environmental policies. The share of arable land used for biofuels was set at 30%. Existing wheat cultivation for ethanol production covers 15% and was assumed not to change. The additional share of arable land dedicated for cropping biofuel feedstock was assumed to be used for ley. Technology for using algae as feedstock for biogas is assumed to be close to implementation, but technical issues related to the collection of algae offshore, where the big potential is found, and the dewatering step prior to feeding a biogas digester with algae are the reasons for including only 10% of the algae potential.

VI. CONCLUSION

There are many different studies assessing biofuel potentials, applying different methodologies, focusing on different types of potentials and often covering large regions with a long term perspective. In addition to results about the studied case it is interesting to reflect upon the approach and methodology from a more general perspective. The approach in this study has been geographically limited and short term. Such a bottom-up perspective could make the results more relevant from an implementation perspective. Technical and economic aspects were considered. However, analysis of conditions for implementation was not included in this study. Obviously, a major challenge is the investments in new technology and production facilities that are needed for the realization of the assessed biofuel potential. Some of the cases data was not available and even there is a question of a reliability of data source as there is not authentic body for storage of the data in Bangladesh for this type of issues. Many actors within the industry face problems of profitability leading to a focus on existing raw materials, production efficiency, etc. The increased raw material potentials highlighted by this study provide opportunities in relation to economy of scale. Potential investors in biofuels require knowledge about the long-term policy conditions for the industry, which are not in place. Other external factors such as competition for feedstock, prices of fossil fuels and other competing products, investments in infrastructure, etc. may also hamper the development. The current article suggests that there is a large biofuel potential and that biogas technologies can play a key role in strengthening the sustainability performance of biofuels. What will happen however depends on the development of the complex networks of consistent policies, actions by companies and consumers, and technological development.

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An Objective Assessment of Walkability in Khulna City: A GIS Based Approach

Sourav Bhadra
Department of Urban and Regional Planning
Khulna University of Engineering & Technology
Khulna-9203, Bangladesh
sbhadra019@gmail.com

A. K. M. Tanbir Sazid
Department of Urban and Regional Planning
Khulna University of Engineering & Technology
Khulna-9203, Bangladesh
tanbirsazid26@gmail.com

Md. Esraz-Ul-Zannat
Department of Urban and Regional Planning
Khulna University of Engineering & Technology
Khulna-9203, Bangladesh
esrazuz@gmail.com

***Abstract*— Walking acts as an authentic link for intermodal transfer in major activity centers and helps to fulfil recreational and utilitarian trips in a city. To assess the condition and pattern of walking, walkability assessment is the primary option. In the last decade a large number of literatures in urban planning, public health and transportation have analyzed the role of the built environment on physical activity, typically walking. This study is the first approach of measuring neighborhood walkability for Khulna City which is the third largest city in Bangladesh. Different spatial analyses have been carried out to objectively assess walkability score for all 31 wards of Khulna City Corporation area using Geographic Information System (GIS). Final result shows the ranking of each ward based on their respective scores. The standard method of walkability measurement provided by IPEN (International Pedestrian Environment Network) has been followed in this study. Net residential density, net intersection density, land use mix and net retail floor area are selected as built environmental criteria. The result indicates that ward no 11 shows the highest standardized walkability score, where the lowest score was found for ward no 4. It was also found that 19.27% people live in high walkable area and 39.48% people live in low walkable area of the city. Outputs of the research will be very helpful for the decision makers, city managers etc. who are dealing with the development and environment of a city and finally the researcher to do research further on the given subject.**

Keywords- Walkability, Objective Assessment, GIS, Built Environment

I. Introduction

Walking is the oldest, most friendly and green transportation mode. However, rapid growth has made travel by foot a challenge in Bangladesh. Walkability analysis is a system to evaluate the situation of walkable areas among different neighborhoods and walkability index is a parameter to evaluate the walkability [1]. As being the 3rd largest city of Bangladesh, Khulna is facing increased population growth and consequently the rapid development of urban built up area day by day. But the physical environmental aspects of this city have been developed to support motorized vehicles rather than walking and physical activities [3]. This study objectively found out the walkability context of the city using different built environmental criteria. In developed countries various studies have been done to identify level of walkability for different places, but for developing countries like Bangladesh, it is unprecedented. The link between the built environment and human behavior has long been of interest to the field of urban planning, especially urban design and transportation planning [4].

In this study the status of walkability of Khulna City was vastly discussed. The output shows the walkability index score for each ward of Khulna City Corporation area. For this analysis the selected criteria were net residential density, net intersection density, land use mix and net retail floor area. The methods provided in International Pedestrian Environment Network (IPEN) have been followed here. Using other built environmental criteria could increase the accuracy of the results but due to data unavailability, only these four criteria have been selected. Outcomes of the study could be an appropriate guide for urban planners, city managers and decision makers to acknowledge a proper vision related to walkability. They can also incorporate the outcomes while preparing the development plan and can solve urban health problems. This study can also encourage measuring walkability for other big cities in Bangladesh.

II. Conceptual Framework of Walkability

Walkability is an important term in the context of transportation engineering and planning, urban planning, and health disciplines. So the definition of walkability have to support all the activities of these professional disciplines. Defining walkability is not an easy task because of its influence on various sectors. However various researchers, professionals and practitioners have been using and giving different kind of walkability definition. In the “Making London a walkable city:

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The Walking Plan for London" walkability is defined as the "… extent to which walking is readily available to the consumer as a safe, connected, accessible and pleasant activity…" In that walking plan walkability is broadly focused in the context of some terms i.e. Connected, Convivial, Conspicuous, Comfortable and Convenient [5]. P. T. Seilo defines walkability as "… a measure of the urban form and the quality and availability of pedestrian infrastructure contained within a defined area. Pedestrian infrastructure includes amenities developed to promote pedestrian efficiency and safety such as sidewalks, trails, and pedestrian bridges…" in his book entitled "Walkability and Urban Form: A GIS-based Analysis of Nodal Development Areas in the Eugene-Springfield Metropolitan Area" [6].

In this study walkability is defined as the ability of an area or community or neighborhood to promote walking, based on its built environmental attributes. More walkable area means that more number of walking is occurring in that area for its present urban built environment, in short, more people are walking in that area.

In the field of urban planning and transportation planning walking is an intense topic of discussion. Generally two types of walkability studies have been done for last three decades through different measures i.e. Subjective Approach and Objective Approach [7]. Urban designers, transportation researchers and health researchers have been using these approaches to assess walkability of an urban area. Subjective approach means the qualitative analysis of walkability i.e. peoples' perception for walking, sense of safety and security, aesthetics of footpaths etc. where Objective approach is the quantitative analysis of built environment i.e. net residential density, intersection density, land use mix etc. which are generally identified and analyzed using Geographic Information System (GIS) [8].

III. Methods

The built environment criteria used to measure walkability may vary between developed and developing countries. But Lotfi and Koohsari have used Net Residential Density, Net Intersection Density, Land Use Mix and Retail Floor Area to measure walkability for a developing country i.e. Tehran, and found the validity of these criteria [9]. So in Bangladesh as a developing country, these four built environmental criteria are considered in walkability measurement.

A. *Study Area*

The study area is Khulna City Corporation (KCC) Area which consists of 31 wards with a population of 657,798 and an area of 45.31 sq. km. Geographically, it lies between 22° 49′ north latitude and 89° 34′ east longitude and its average topographic elevation is 2 meters above the mean sea level. Figure 1 shows the key map of Khulna city.

B. *Relationships of Criteria with Walking Behavior*

The walkability index score for each ward were constructed using four basic built environmental criterion i.e. net residential density (NRD), net intersection density (NID), land use mix (LUM) and net retail floor area (NRFA) according to IPEN standard methodology.

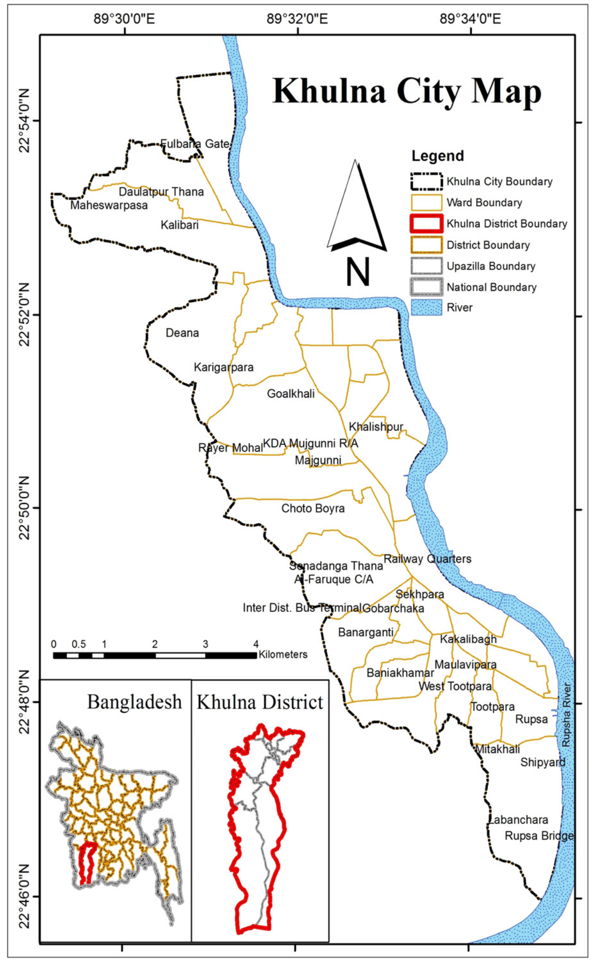

Figure 1: Location of the study area

1) *Net Residential Density (NRD):*

The ratio of residential unit to the land area devoted to the area of residential use per neighborhood. High density neighborhoods include mixed use development which improves accessibility to variety of complementary activities. High dwelling density creates retail and service variety which results in shorter walkable distances between complementary retail shops and services [14].

2) *Net Intersection Density (NID):*

The ratio of road intersection number per neighborhood area. Higher intersection densities are correlated with increased network connectivity which provides a variety of potential routes to people. It means access is easier to any major road where public transport is available. It represents the directness of path which facilitates walking behavior [14].

3) *Land Use Mix (LUM):*

The degree to which a diversity of land use types are present in a neighborhood. In this study nine types of land uses are selected i.e. Administrative, Commercial, Community Service, Education & Research, Industrial, Mixed Use, Recreational Facilities, Residential and Others. Agricultural use was excluded from this study because it has less influence in promoting walkability. An entropy equation acquired from previous similar walkability studies can be used to calculate the land use mix (LUM).

$$LUM = \frac{\sum_k p_k \ln p_k}{\ln N} \quad (1)$$

Where, k is the category of land use, p is the proportion of the land area devoted to a specific land use and N is the number of land use categories. The entropy equation results in a score of 0-1, with 0 representing homogeneity (all land uses are of a single type) and 1 representing heterogeneity (the developed area is evenly distributed among all land use categories). The more the land use mix, the more walking occurs. If a neighborhood contains diverse land use mix, it represents a large number of activities are occurring into that neighborhood which results in more walking behavior. It measures the heterogeneity or homogeneity of a neighborhood according to their land use types [14].

4) Net Retail Floor Area (NRFA):

The ratio of the floor area of retail buildings to the land area devoted to commercial and mixed user area per neighborhood. People who live near multiple and diverse retail opportunities try to make more frequent, more specialized and shorter shopping trips by walking. So a higher retail density represents higher walkability [14].

C. GIS Based Data Preparation

The required spatial data were first collected from Detailed Area Plan (DAP) of Khulna City and prepared for the assessment in GIS environment. To find the road intersection, road polygon data were converted into road centerline data using Arc Scan centerline vectorization. Retail floor area were calculated by multiplying each retail structures' area with their floor number using VBScript. To prepare the land use data of Khulna City, the mouza boundary data was intersected with the structure data of each building blocks. By this process, all the information of structural use was transferred into the attribute table of mouza boundary data. All the calculations were done in VBScript of GIS attribute table.

D. Calculation of Walkability Index (WI)

The walkability index was calculated using the above stated data sets in a walkability index equation. The four calculated values were normalized using a Z-score. The absolute value of Z represents the difference between the raw score and the sample mean in units of the standard deviation. When the raw score is below the mean, Z is negative and positive when above.

Since there is a considerable amount of environmental variation within cities, ideally the smallest available spatial units should be selected to minimize within unit variability and to maximize the variation between units [13]. In this study the smallest unit was considered as ward because of the data availability of spatial attributes for each ward.

The walkability index is the sum of the Z-scores of the four urban built environment measures as stated in the following expression:

$$WI = (2 \times Z_{NID}) + Z_{NDD} + Z_{LUM} + Z_{NRFA} \quad (2)$$

The Z value of intersection density was weighted by a factor of two in the walkability index. This is based on the evidence that among the other attributes street connectivity results in strong influence on non-motorized travel choice [10].

IV. Results and Discussions

To extract the level of walkability, selected built environmental criterion i.e. net residential density (NRD), net intersection density (NID), land use mix (LUM) and net retail floor area (NRFA) were measured. Data required to calculate net residential density was collected from the Population Census 2011 of Bangladesh Bureau of Statistics. The other data sets were derived from Detailed Area Plan 2010 (DAP) of Khulna City.

The raw scores of different built environmental attributes were normalized and using Equation 3, walkability index for each ward was found. Ward no 11 had the highest Z-score of 8.88 and Ward no 4 showed the lowest level Z-score of -6.37. Table 1 shows the raw scores, Z-scores and Walkability Index scores of all 31 wards and Figure 2 illustrates the final walkability Z-scores for each ward in a map.

The resulted walkability scores were ranked as Low, Medium and High using equal interval classification method. In Khulna City only 6.78% area is found as High Walkable. On the other hand Medium and Low walkability area is found as 36.27% and 56.95% respectively. The result shows that most of the area is relatively low walkable in Khulna city. According to the equal interval 19.27% people live in High Walkability Area, 41.26% people live in Medium Walkability Area and 39.48% people live in Low Walkability Area.

To validate the results, an extensive field observation for Ward 15, Ward 23 and Ward 11 were done. Ward no 11 contains Khalishpur Residential Area (east and north block), Platinum Jublee Labour Colony and Peoples New Colony. From an extensive field observation, it was seen that because of the locational importance of this area, people are walking more and more. The road pattern is also important here. The walkability index shows that, the most influential criterion for this ward is NID and it is true that the road pattern is almost grid iron, resulting a large number of road intersection & great connectivity. As it is a labor colony area, the NRD index also shows great influence in walkability because ward 11 has the highest population density. That's why, ward 11 resulted the highest walkability score. To analyze the context of a medium scored area, ward 23 was selected. In this ward, the most influential criteria are NRD and LUM. Ahsan Ahmed Para, Cemetery Road, Mirjapur Para, Dakbangla and Taltola Masjid Area are the important places in this ward. Here population density is relatively high because of its mixed use development and high commercial activity resulting a medium level of walkability. On the other hand, ward 4 was selected because of its low scored walkability index. Ward 4 is situated in the fringe area of Khulna City with a large number of agricultural area. Road network is too much dispersed resulting a lower connectivity between locations. It contains Deapara, Deyana and Krishi College. Moreover in this ward the land use mix is not much diversified and maximum areas are in agricultural use. These indicators resulted a lower level of walkability for this area. These field observations indicated a qualitative validity of the results found by objective analysis of four built environmental criteria.

The geographic distribution of walkability index scores are shown in Figure 2. High walkability was most concentrated in

Table 1: Descriptive statistics of applying walkability index in each ward

Ward No	Net Residential Density (NRD)		Net Intersection Density (NID)		Land Use Mix (LUM)		Net Retail Floor Area (NRFA)		Walkability Z-score	Level of Walkability[a]
	Raw Score	Z-score	Raw Score	Z-score	Raw Score	Z-score	Raw Score	Z-score		
1	0.01639	-1.129	0.00018	-0.384	0.48193	-0.655	0.01385	-0.972	-3.968	Low
2	0.01261	-1.329	0.00089	1.418	0.72282	1.688	0.02112	-0.790	-2.325	Low
3	0.01956	-0.961	0.00234	5.114	0.47917	-0.682	0.03806	-0.368	-5.573	Low
4	0.01534	-1.185	0.00007	-0.653	0.35722	-1.868	0.06423	0.284	-6.366	Low
5	0.03676	-0.051	0.00027	-0.151	0.55673	0.073	0.06845	0.389	1.258	Medium
6	0.02944	-0.438	0.00020	-0.326	0.57776	0.277	0.06417	0.282	-0.585	Medium
7	0.05619	0.978	0.00022	-0.262	0.59152	0.411	0.02498	-0.694	0.560	Medium
8	0.02564	-0.639	0.00023	-0.250	0.70163	1.482	0.02908	-0.592	0.218	Medium
9	0.02542	-0.651	0.00013	-0.493	0.52069	-0.278	0.03595	-0.421	-3.533	Low
10	0.05393	0.858	0.00031	-0.057	0.58763	0.373	0.06911	0.405	3.318	Medium
11	0.10061	3.330	0.00042	0.233	0.68030	1.275	0.05411	0.031	8.880	High
12	0.05405	0.865	0.00026	-0.184	0.59358	0.431	0.03513	-0.442	1.409	Medium
13	0.01716	-1.089	0.00007	-0.645	0.59008	0.397	0.01750	-0.881	-5.099	Low
14	0.02365	-0.745	0.00013	-0.499	0.49821	-0.497	0.02132	-0.786	-4.261	Low
15	0.02959	-0.431	0.00018	-0.365	0.56253	0.129	0.03311	-0.492	-1.844	Low
16	0.02005	-0.936	0.00023	-0.259	0.54020	-0.088	0.02388	-0.722	-1.852	Low
17	0.02444	-0.703	0.00016	-0.429	0.55172	0.024	0.10312	1.252	-1.045	Medium
18	0.02919	-0.452	0.00016	-0.436	0.54092	-0.081	0.03463	-0.454	-2.659	Low
19	0.05463	0.896	0.00036	0.075	0.44350	-1.029	0.15011	2.423	5.131	High
20	0.06667	1.533	0.00029	-0.101	0.66922	1.167	0.14923	2.401	6.385	High
21	0.04170	0.211	0.00025	-0.206	0.70414	1.507	0.17348	3.006	5.082	High
22	0.05390	0.857	0.00033	0.016	0.69499	1.418	0.05744	0.114	4.708	High
23	0.06173	1.271	0.00024	-0.222	0.67847	1.257	0.08416	0.780	3.529	Medium
24	0.03649	-0.065	0.00031	-0.055	0.49404	-0.537	0.04820	-0.116	0.974	Medium
25	0.04122	0.185	0.00031	-0.048	0.41287	-1.327	0.04438	-0.211	0.408	Medium
26	0.04314	0.287	0.00033	-0.002	0.44747	-0.990	0.02322	-0.738	0.718	Medium
27	0.04718	0.501	0.00030	-0.081	0.43583	-1.104	0.02579	-0.674	0.189	Medium
28	0.03577	-0.103	0.00026	-0.166	0.32735	-2.159	0.02279	-0.749	-2.295	Low
29	0.04421	0.344	0.00032	-0.021	0.59943	0.488	0.04094	-0.297	2.532	Medium
30	0.03817	0.024	0.00031	-0.035	0.42674	-1.192	0.04656	-0.157	0.545	Medium
31	0.01444	-1.233	0.00012	-0.528	0.55863	0.091	0.02021	-0.813	-4.441	Low

[a]Level of walkability is measured using Equal Interval Classification

south eastern area with progressively lower levels in northern area which are mostly suburban area. Medium walkability scores were randomly dispersed within the city boundary. Moran's I for the walkability index map is 0.28 ($Z = 2.85$, $p = 0.004$), which indicates walkability is highly clustered with wards having similar walkability more likely to be proximal than distal.

V. CONCLUSION

The study found the level of walkability for each ward of Khulna City, which is for the first in the context of a developing country like Bangladesh. Though the selected criteria were first considered for the developed countries i.e. Canada (Neighborhood Quality of Life Study - NQLS), South Australia (Physical Activity in Localities and Community Environments - PLACE) and Sweden (Walking for Well-being in the West - WWW) these criteria can affect walking in developing countries too [9]. These results can be considered to develop urban design policies for improving neighborhoods in a way supportive and encouraging for walking. Use of GIS in finding out the levels of walkability in a city could be a very useful and efficient tool. It would be less time consuming and less costly process for decision makers.

This is an objective assessment for measuring the level of walkability among each ward of Khulna City. The procedure depends on high availability of data. Having a comprehensive database related to the objective measures of built environment, such as commercial uses and quality of sidewalks could provide more accurate results. But these spatial data are very difficult to found in a city like Khulna in Bangladesh.

This study has several limitations. Firstly, the retail floor area ratio was needed to be considered as a built environment criterion. But because of the data unavailability, this criterion was replaced by net retail floor area. Secondly, purpose of walking is not considered in this study as validation measure. Future studies considering walking purpose could direct to

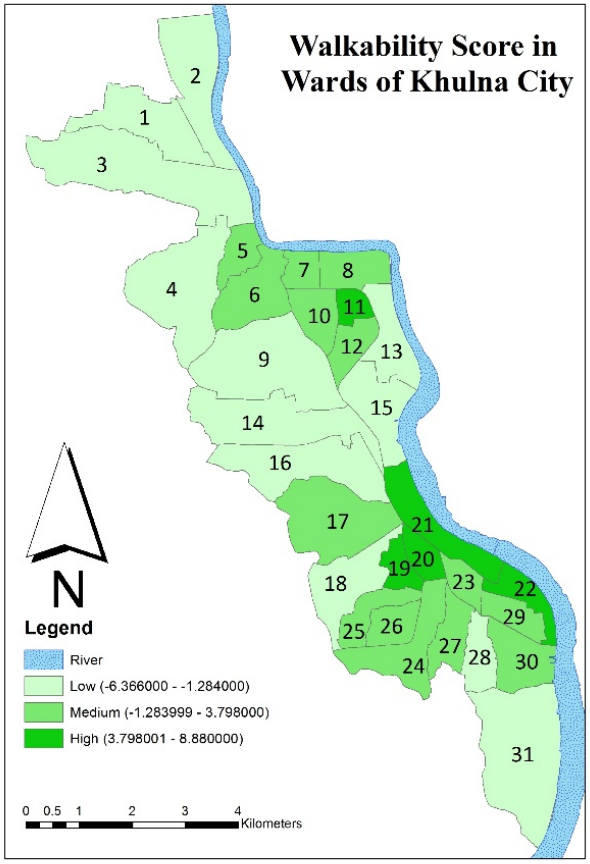

Figure 2: Geographic distribution of Walkability Score

more accurate validation. Thirdly, the validation is done in this study by a qualitative field observation. A quantitative observation could lead to more accurate validation.

In this study, the level of walkability is measured using objective assessment. In future further studies using both objective and subjective measures could be an appealing research topic. A number of criteria other than the selected four in this study could be used and tested in context of Bangladesh.

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Green Spaces: Assets or Liabilities?

An Economic Study on the Urban Residential Neighbourhood of Dhaka

Faria Sharmin
Stamford University Bangladesh
Dhaka, Bangladesh
faria_4297@yahoo.com

Bushra Nayeem
Stamford University Bangladesh
Dhaka, Bangladesh
bushra_nayeem_11@yahoo.com

Abstract— **Within the context of the economic valuation of open space, the presence and absence of green space has an effect on the residential property value in urban areas. This study only concerns with the valuation of open spaces; especially green parks and water bodies of different urban residential neighborhoods of Dhaka city in Economic terms. To analyze the impact of open space attributes on real price of residential properties, an empirical analysis is carried out by employing Hedonic Price Method (HPM). Together with a set of structural, location and socio-economic variables use to explain residential property prices; the study focuses on three amenity or environmental variables which include the existence of views of park, the distance from the housing unit to the nearest open space, and the size of that open space. The regression analysis results from the first stage hedonic estimation reveal that homebuyers are willing to pay only for scenic views and living in the closest proximity to open spaces especially green parks. In contrast results for the size of the nearest open space for houses do not show a significant relationship on nearby property values. This estimated valuation of open spaces and their amenity benefits will be useful for decision making in urban design, land use planning and green space preservation.**

***Keywords-** open space; economic valuation; residential property price; Hedonic Price Method*

I. INTRODUCTION

Open Spaces such as public parks, waterfronts, botanical gardens, playgrounds, reservoirs and forests, natural areas and golf courses provide numerous amenities for nearby residents including environmental, recreation opportunities and attractive views [1]. With the growth of the city green spaces are frequently transformed to make space for new buildings and roads needed to accommodate the increasing urban population. To ensure the contribution of green space, they must be sufficiently generated and well planned, designed and maintained. From an economic outlook, the valuation of urban open space is difficult to quantify because it is a classic public good, where there is no market price. Apparent lack of valuation in monetary terms prevents urban green open space from being properly evaluated in cost-benefit analyses. As a result, the people may ignore such benefits in their planning. The home sales price is one of the crucial catalysts for a country's economy as urban land value is determinative in both urban planning and real estate activities. An attractive environment is likely to influence house prices. If so, estimates of the monetary value of these benefits can be derived by careful analysis of home prices. Most of the developing cities have not yet realized the values that green open spaces can contribute in revitalizing communities. Often their importance is failed to consider in the debate of architectural built forms. This is particularly evident in the developing cities like Dhaka where urbanization sprawls extensively. Dhaka Statistical Metropolitan Area (SMA) accommodates 12715797 people, which is 46.3% of total urban population of Bangladesh [2]. As population is growing in this mega city, the numbers of dwelling places are very scarce. As a result residential areas of Dhaka city are turning into overcrowded, dirty, and unhealthy environment and lack of open spaces. Experts suggested that an ideal city needs to keep its 40%-50% of land green or free. However Dhaka structure plan urges to have 20% of green spaces for its future generation [3]. In Dhaka urban greenery, park greenery or tree-covered spaces constitutes less than 15% of the city landscape [4]. According to the DMDP'95, old Dhaka (organically developed neighborhood) has only 5% and new Dhaka (planned neighbourhood) has about 12% green open space [3]. Shortage of green space due to the population growth and urbanization is considered as the most alarming threat to the living environment of Dhaka. Dhaka has experienced, and will continue to experience, a very increased demand for housing. As a result, land is being consumed for housing sectors at rapid rates, often with little attention paid to the protection of the environmental amenities.

The development decisions of Dhaka city are frequently failing to consider the values of green spaces. As a result, development occurs in ways that greatly reduce these open spaces with negative environmental, economic, and social consequences. This study is concerned with the valuation of open spaces especially green parks and water bodies of different urban residential neighborhoods of Dhaka city in Economic terms.

The purpose of this study is to investigate the possible impact of public open spaces on the price of residential properties. Through the use of data from actual market transactions, the effect that housing has on the sale price of properties is determined. The aim of the method is to reveal how much of the differences in property prices depend on the differences of environmental quality, that is, the implicit price that individuals are willing to pay to consume environmental characteristics associated with the house [5].

In the first stage, fundamental concepts and approaches are evaluated by reviewing related literatures of urban design and environmental economics disciplines. In the second stage, to analyze the impact of open space attributes on rental price of residential properties.

II. MATERIALS AND METHODS

Hedonic Price Model is formulated, with the sample of 78 observations (owner occupied houses) and by using least square method, linear regression analysis are operated through E-views statistics package, SPSS. This study uses a typical hedonic equation of housing price in a semi logarithmic form as shown in "(1)" below:

$$Pi = \beta 0 + \sum \beta jSij + \sum \beta kNik + \sum \beta jAil + €i \ldots\ldots\ldots\ldots\ldots..(1)$$

Where in "(1)", Pi is the implicit price of the ith house, Sij represents jth structural variable, Nik is the measure of the kth neighborhood characteristics, and Ail represents the lth attribute of environmental attributes. Similarly β0, βj, βk, βl, represent the corresponding parameters to be estimated, whereas €i captures the error term.

The most popular indirect approach for estimating the monetary value of an environmental asset is hedonic price method. Estimates of the economic values or amenity benefits of urban parks and public open spaces have emerged recently [6]; [7]; [8]; [9]; [10]; [11] and [12]. At the first stage, implicit prices for different housing characteristics are estimated with formula given above [8]. This method obtains the economic value through the influence exercised by the environment on the market price of another good [9]; [10]; [8]. Applications of the method have focused on the analysis of the value of urban amenities and various land uses such as schools, open spaces [11]; [10], urban forests [8]; [6], urban wetlands [12], public housing projects, [13], shopping centers, office buildings [14]), and the neighborhood effects [15] on house prices. Previous research revealed that the price of a house increases with its proximity to nearby parks [6] [7]; [8]; [10]; [16]; [17]; [18]. Similarly, other studies indicated that increasing the size of urban parks increases the housing values nearby [6]. On the contrary, [19] and [10] reported that the size of urban parks or green areas did not have a significant amenity effect. Reference [20] measured the impacts of different categories of open spaces. The aim of the method is to reveal how much of the differences in property prices depend on the differences of environmental quality, that is, the implicit price that individuals are willing to pay to consume environmental characteristics associated with the house, and to infer what the social value of this difference is [5].

Regression is a technique that is used to investigate the effect of one or more predictor variables on an outcome variable. Within the context of regression analysis, an output table is generated. This table includes information about the quantity of variance that is explained by predictor variables. The first statistic, R, is the multiple correlation coefficients between all of the predictor variables and the dependent variable. The next value, R Square, is simply the squared value of R. This is frequently used to describe the goodness-of-fit or amount of variance explained by a given set of predictor variables.

III. DATA ANALYSIS

A questionnaire analysis is carried out by estimating the effect on 78 observations in the case of urban residential properties within two planned residential neighbourhoods (Dhanmondi and Gulshan) of Dhaka city. Using home transaction data in between the year of 2007 to 2010, the study analyzes the effect of proximity to open space (parks, and water bodies) on home sales price. Households and private developers are the main sources of information. Questionnaire survey is used to collect the data set featuring the price and environmental attributes. Further, some information about the open spaces and locality factors is drawn from maps provided by the Dhaka City Corporation, GIS and from literature review of some research papers.

Table I below presents the frequency analysis results for view of amenity characteristics, where view is the only categorical amenity variable in this study.

TABLE I

Variables	Category	Frequency	Percentage	Cumulative percentage
View (owned house)	No	40	50.6	50.6
	Field	5	6.3	57.0
	Park	7	8.9	65.8
	Lake	27	34.2	100.0

Frequency Analyses of Categorical Variables for Amenity characteristics

TABLE II

Variables	N	Mini mum	Maximum	Mean	Std. Deviation
Size	79	38794.000	6337108.80	2707074.600	2396614
Distance	79	00	1240.40	226.7906	282.64
Valid N (list wise)	79				

Descriptive Statistics results for Amenity variables used in the first- stage Hedonic model

Table II above presents the descriptive statistics results for amenity variables (Size & Distance) used to determine the price of housing unit.

IV. RESULTS

For regression analysis three sets of explanatory variables are used. These include a set of structural variables of the house, a set of neighbourhood characteristics and a set of amenity or environmental variables explaining the attributes of the nearest open spaces. In this study dependent variable is housing unit's implicit price. However, housing characteristics model include independent variables related to housing unit's structural, locality and socio- economic and amenity or environmental attributes.

In this regression model focus variable is housing unit's environmental attributes which includes **view** of green open spaces from housing unit (VCA1), **size** of nearest open spaces from housing unit (VCA2), **proximity** to the nearest open space from housing unit (VCA3).

TABLE III

Variables	Coefficients	Standard errors	t-statistic	P- value
Housing unit's Structural Variables				
VAS1 (Living area)	5757.734	669.716	8.579	0.000
VAS2 (Exterior)	10000000	3596750	2.811	0.006
VAS3(Bedroom)	6908865	1143144	6.044	0.000
VAS5 (Land area)	-160601	133013.2	-1.207	0.231
VAS6(Stories)	2610903	3700288	0.706	0.483
VAS7 (Age)	-1831205	587195.9	-3.188	0.003
VAS8 (Orientation)	1228212	549352.6	2.236	0.028
Housing unit's Neighbourhood Variables				
VBN1 (Population density)	87.236	25.682	3.397	0.001
VBN2 (Poverty)	163427.6	235966.5	0.693	0.491
VBN3(Median Age)	-0.006	0.009	-0.654	0.515
VBN4 (Vacancy rate)	48167.976	82371.248	0.585	0.560
VBN5 (Household income)	151.719	31.112	0.4.876	0.000
VBN6 (School Attendance)	148242.3	78687.398	1.884	0.064
VBN7 (Literacy)	-631167	320198.8	-1.971	0.052
VBN8 (School distance)	2766.355	899.876	3.074	0.003
VBN9(Housing tenancy status)	98759.707	47330.86	2.087	0.040
Housing unit's Environmental Variables				
VCA1(Park /Lake/ Field view)	1545181	494481.9	3.125	0.000
VCA2(Park or Lake size)	0.069	0.030	0.892	0.375
VCA3(Park /Lake/ Field proximity)	-5811.852	2483.569	-2.340	0.022
R- squared	0.744			
Adjusted R- squared	0.678			
F- statistics	11.247			
Number of observations	78			

Results of Regression Analysis model, significance of parameters at 1% and 5% level (marked as yellow)

Table III above represents R^2, F- statistics and coefficient values for each variable entered the model. The focus variables capturing the Environmental characteristics (for owned houses) are tested below; through hedonic regression model. Results revealed that, houses having the view of nearest park, lake or field – VAN1 have a positive and significant impact on implicit house price at 1% level. The co-efficient value for **view** is 1545181; Indicates that existence of view of open spaces for a particular house increases that house price by 1545181 BDT. That means houses with open space views specially lake or park views are sold by 1545181 BDT or 14% higher price than the houses without open space views (Table IV).

TABLE IV

Model	Unstandardized Coefficients		Standardized Coefficients	t	Significance
	B	Std. Error	Beta		
(Constant)	7427233.811	1310639.669		5.667	.000
VIEW	1545181.167	494481.858	.335	3.125	.003

Regression analysis results between price and view of nearest open spaces from owner occupied houses

TABLE V

Model	Unstandardized Coefficients		Standardized Coefficients	t	Significance
	B	Std. Error	Beta		
(Constant)	10199513.388	1087577.640		9.378	.000
SIZE	0.269	0.302	0.101	0.892	0.375

Regression analysis results between price and distance of nearest open spaces from owner occupied houses.

TABLE VI

Model	Unstandardized Coefficients		Standardized Coefficients	t	Significance
	B	Std. Error	Beta		
(Constant)	12246414.046	896526.186		13.660	.000
DISTANCE	-5811.852	2483.569	-.258	-2.340	.022

Regression analysis results between price and distance of nearest open spaces from owner occupied houses.

Size of the open space (park or lake) - VAN2 is positively related to house price. It means increase in size of open spaces nearest to the house increase the implicit price; but it does not indicate a statistical significant linear relationship (Table V).

The elasticity indicates that one unit (ft) decrease in **distance** from house to the open space increases the implicit price of the house by 5811.852 BDT on an average (Table VI). Or 1% increases in the distance of open space increase the price by 0.053%.

V. Discussion and Conclusion

In hedonic regression analysis by using 78 observations a price model has been developed where price of housing unit's is determined as dependent variable and housing unit's structural, neighborhood and amenity variables are determined as independent variables. This study focuses on the amenity or environmental characteristics of housing units, since it aims to determine the economic value of green open spaces. The amenity attributes of house include **view** and **size** of nearest open spaces and **distance** of those open spaces (parks and water bodies) from houses. From the test results it is found that view of open spaces for owner occupied houses have a positive and significant impact on house price. This indicates that existence of the view of open spaces increase the house price by 1545181 BDT (20,082.10 USD) or 14% than the houses without any scenic views. In terms of size of nearest open spaces, the results show a positive impact. But it does not indicate a statistical significant linear relationship. As the supply of open spaces far short of demand, less choice make it difficult to clearly determine the value of residential properties for size of open spaces. The distance of nearest open spaces from houses has a negative but significant impact. This means increase of distance of nearest open spaces from houses by 1 ft, decrease the house price by 5811.852 BDT (75.53 USD) or 0.053%. These test results summarize the findings of the study; which would provide suggestions for policy implications and further researches.

The findings of the research put forward that green open space has a relative measurable economic values. The empirical evidence concludes that open spaces within the residential neighborhoods have a positive effect on the property price. Homebuyers are willing to pay a premium for the open spaces when they purchase the properties. The results prove that presence of green open space has a significant impact on property prices of the two selected residential neighborhoods of Dhaka. Existence of open space views specially park or lake views increase the house price than the houses having no views within the same neighborhoods. Finally, the study revealed that the impact of open space on price differs depending principally on having views of open spaces and its proximity to the housing unit.

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Numerical Analysis of Deep Level Defects in Cu_2ZnSnS_4 (CZTS) Thin Film Solar Cells

Abu Shama Mohammad Miraz, Md. Mortuza Faruk and Muhammad Asad Rahman
Department of Electrical and Electronic Engineering,
Chittagong University of Engineering and Technology (CUET)
Chittagong-4349, Bangladesh
shamamiraz17@gmail.com, mfaruk1300@gmail.com, asad31@cuet.ac.bd

***Abstract*—Cu_2ZnSnS_4 (CZTS) absorber layer has recently been put under extensive research as a potential replacement of CIGS absorber layer because of its excellent electrical and optical properties. In this work, CdS, ZnS, ZnSe, In_2S_3 and TiO_2 have been used as buffer layers in a CZTS/Buffer/i-ZnO structure. The use of i-ZnO as a Transparent Conducting Oxide (TCO) layer has been seen to enhance the performance of an ideal CZTS absorber layer without deep level defects. The effects of deep level defects on the performance of the cells have been numerically analyzed in terms of the energetic distribution and capture cross-section parameters. CZTS/In_2S_3/i-ZnO structure showed the best efficiency of 11.68% (with V_{OC} = 0.77V, J_{SC} = 26.66 mA/cm^2 and Fill Factor = 56.96%). A variation of impurity concentrations have been used to offset the deterioration of efficiency and an optimum acceptor concentration of 2×10^{16} cm^{-3} was found for the enhancement of lower performance caused by electron and hole capture cross section parameters. The efficiency of the CZTS/In_2S_3/i-ZnO structure improved up to 14.56%. Furthermore, layer thickness has also been investigated as a potential way of compensating the effects of deep level defects. Finally, temperature dependence of various structures has been observed.**

Keywords-CZTS absorber layer, SCAPS 2802, buffer layers, deep level defects, TCO.

I. INTRODUCTION

The ever growing power demand in a world running out of conventional fossil fuels means that a call for the evaluation and development of alternative cost-effective resources are imperative now than ever before. Silicon-based photovoltaic solar cells have been dominating in the field of photovoltaics for the last few decades. But the high costs involved in these technologies have always been pulling back the prospects of solar cells. Polycrystalline thin film solar cells have been considered as prospective alternate to the solar cells in vogue. CIGS solar cells have been extensively researched on for the last 20 years and a conversion efficiency of 20.5±0.6% has been achieved [1]. The availability of copper, zinc, tin and sulfur on our earth's crust are 50 ppm, 75 ppm, 2.2 ppm and 260 ppm respectively [2]. The abundance of Zn & Sn in earth's crust are 1500 times and 45 times greater than that of Indium (In) respectively and the price of In is almost two orders of magnitude higher than of Zn and Sn [3]. The availability of Zn and Sn has led to extensive examination of a novel CZTS thin film solar cell which replaces In by Zn and Ga by Sn [4][5]. Copper-zinc-tin-sulfide is a semiconductor with excellent photovoltaic properties such as high absorption coefficient ($10^4 cm^{-1}$) and an optimal direct band gap energy of 1.4-1.5 eV which are highly desired in photovoltaic materials [6]. Cu_2ZnSnS_4 (CZTS) can be divided into two structures, stannite and kesterite, according to the different locations of Cu and Zn. Secondary impurity phases such as CuS, Cu_2S, ZnS, SnS, SnS_2 and Cu_2SnS_3 may also be generated during the process of depositing CZTS. The first-principle calculations prove that kesterite structures possess lower energy resulting in a more stable structure [7], while Olekseyuk et al. found that the monocrystal Cu_2ZnSnS_4 was of the stannite structure [8]. It has been widely accepted that the Cu-rich growth method aids a better grain size and performance. Tanaka et al. debated that although a higher Cu/(Zn+Sn) ratio gives an increased grain size, the Cu-rich condition has remarkably low resistivity, making it unfit for solar cell fabrication. Native defects can be formed by the deviation in composition from stoichiometry [9]. In 2011, E. Kask et al. reported two defect states in Cu_2ZnSnS_4 monograin cells attributing them to Cu_{Zn} deep acceptor defect and interface states [10]. Wan-Ching Hsu et al. adopted that both Cu-rich and Zn-rich growth has equal potential in the making of a good operating cell [11].

In this paper, the effect of deep defect states within the absorber layer on the performance of the solar cell has been studied, considering the case for models including and excluding Transparent Conducting Oxide (TCO) layer. The contributions of acceptor doping concentration and CZTS layer thickness to the enhancement of the performance have also been evaluated. At last, the effect of temperature on the performance of solar cells has been simulated.

II. METHODOLOGY

In this paper, the cell performances have been simulated using SCAPS 2802 simulator. The simulator allows a number of layers to be added in a single model. Various optical and electrical parameters can be set within each layer. A schematic diagram of the CZTS/buffer/TCO structured solar cell which is used in this study is given in fig. 1. A number of buffer layers on top of the CZTS absorber layer has been used, namely-CdS, ZnS, ZnSe, In_2S_3 and TiO_2. The TCO layer used is i-ZnO. The parameters used here are tabulated in table 1.

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TABLE I. MATERIAL PROPERTIES USED IN NUMERICAL ANALYSIS

Parameters	i-ZnO	n-CdS	n-ZnS	n-ZnSe	n-In_2S_3	n-TiO_2	p-CZTS
Layer thickness (μm)	0.040	0.050	0.060	0.080	0.050	0.060	2.20
Band gap, E_g (eV)	3.40	2.41	3.50	2.90	2.80	3.20	1.50
Electron affinity, χ (eV)	4.55	4.50	4.50	4.09	4.70	4.33	4.50
Relative permittivity, $(\varepsilon/\varepsilon_0)$	10.00	9.00	10	10	13.5	55	10
CB effective DOS, N_c (#/cm^3)	4×10^{18}	1.8×10^{19}	1.5×10^{18}	1.5×10^{18}	1.8×10^{19}	2×10^{17}	2.2×10^{18}
VB effective DOS, N_v (#/cm^3)	9×10^{18}	2.4×10^{18}	1.8×10^{18}	1.8×10^{19}	4.0×10^{13}	6×10^{17}	1.8×10^{19}
Electron mobility, μ_n (cm²/Vs)	50	350	50	50	400	100	100
Hole mobility, μ_p (cm²/Vs)	20	50	20	20	210	25	50
Donor concentration, N_D (#/cm^3)	5×10^{17}	1×10^{17}	1×10^{17}	5.5×10^{17}	1×10^{18}	4×10^{14}	10
Acceptor concentration, N_A (#/cm^3)	0	0	0	0	10	10	2×10^{14}

The range of these material properties has been put together from a number of experimental results from previous studies [2]. SCAPS determines numerical solutions using basic semiconductor equations such as Poisson equation and Continuity equation for both holes and electrons. The transport mechanism at the semiconductor-semiconductor interfaces assume thermionic emission, interface recombination follows the Pauwels-Vanhoutte theory [12]. Up to three levels of deep defects can be added for each layer, recombinations in these levels are described by the Shockley-Read-Hall (SRH) formalism. The deep levels can be distributed energetically within the forbidden zone. The transport of majority carriers at the metal-semiconductor interfaces are described by thermionic emission (Bethe theory [13]) whereas transport of minority carriers is characterized by their surface recombination velocity [14]. The cell model not having a TCO layer on top has been simulated first for each buffer layer. Deep level defects were not associated with the absorber layer in these simulations. Then a cell model consisting of i-ZnO as a TCO material has been simulated for each buffer layer and compared to those not having a TCO material. A deep defect with a total density of 1×10^{17} cm^{-3} was installed in the CZTS layer having firstly uniform and secondly Gaussian distribution throughout. The results were then compared with the previous simulations.

In the next part of the study, electron and hole capture cross section of the deep defect levels have been taken into account and their effect on conversion efficiency was investigated. To counter the reduction in conversion efficiency, impurity concentrations of the CZTS absorber material have been varied to reach optimum conversion efficiency. Also the layer thickness of CZTS was taken into investigation to reduce the effect of the higher capture cross section values. And finally, temperature dependence of the performance of these solar cells have been analyzed.

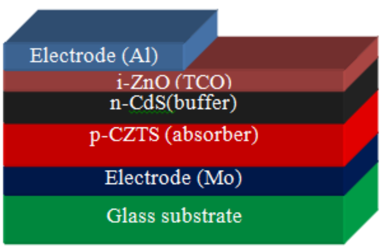

Figure 1. Schematic diagram of a CZTS solar cell

III. RESULTS AND DISCUSSIONS

A. *Effects of TCO layer*

TCO layers are used to provide both optical and electrical access. ZnO has been used as the transparent conducting oxide for transparency and conductivity. As a general requirement, TCO has to have a bandgap over 3eV to cover the visible wavelength range and also the resistivity (ρ) needs to be as low as possible [15]. A higher carrier concentration (n or p) reduces the resistivity according to (1).

$$\rho = 1/[e\,(\mu_n n + \mu_p p)]. \quad (1)$$

But mobility (μ) is a strong function of carrier concentration in high conductive semiconductor materials. So a very low resistivity may inherently reduce the mobility and narrow the transmission wavelength band. i-ZnO used along with buffer layers having very high bandgaps (close to or over 3eV) have resulted in a slight deterioration in performance parameters such as open circuit voltage (V_{OC}), short circuit current density (J_{SC}), fill factor (FF) and efficiency (⍰). The comparable bandgaps in TCO and buffer layers mean that, TCO layer contributes little in additional electron-hole pair (EHP) generation. And due to the low mobility the net collection of minority carriers across the junction is less, which may lead to the slight deterioration in performance from initial TCO-less model. A comparison between cell models with different buffer layers with and without TCO layer have been illustrated in table 2. CZTS/In_2S_3/i-ZnO gives the best result among the cell structures having a TCO layer above a buffer layer.

TABLE II. COMPARISON BETWEEN CZTS CELLS WITH AND WITHOUT A TCO (i-ZnO) LAYER

Buffer layers	**With TCO**				**Without TCO**			
	V_{oc} (V)	*J_{sc} (mA/cm²)*	*FF (%)*	*η (%)*	*V_{oc} (V)*	*J_{sc} (mA/cm²)*	*FF (%)*	*η (%)*
CdS	2.21	28.73	34.63	22.00	1.93	28.13	32.02	17.37
ZnS	1.92	28.31	32.18	17.48	1.92	28.40	32.12	17.53
ZnSe	1.58	28.39	38.31	17.20	1.84	28.24	33.31	17.39
In_2S_3	2.39	28.68	32.16	22.02	2.06	28.37	29.97	17.57
TiO_2	1.80	28.41	34.12	17.44	1.91	28.40	32.33	17.52

B. *Effect of deep level defects*

Deep defect level may lie closer to the midgap, so they can hold carriers more strongly than shallow levels. Smaller orbital of the electron or holes bound to a deep level defect means that the spread of the level in k-space is greater than those of the less tightly bound at shallow levels, aiding level to level transitions. Deep defect levels can reside throughout the energy bandgap [16]. In this work, both uniform and Gaussian distributions have been taken into account. Deep impurities may move through the lattice due to high diffusion co-efficient. The effect of defect levels depend on defect concentrations, position in the bandgap, electron and hole capture cross sections, shallow doping concentrations and temperature.

In this work, deep level defect has been assumed to be of neutral type, hole and electron capture section has been taken initially to be of a moderate value (1×10^{-15} cm^2). The defect level is 0.6eV below the conduction band corresponding to the assumption that deep levels stay closer to the midgap energy. The effects for both structures containing TCO and not containing TCO for different buffer layers have been investigated.

The Gaussian distribution of defect levels reduces the performance parameters to a significant amount. The mean level of the distribution may affect the performance the most, potentially becoming a recombination center.

The CZTS/In_2S_3/i-ZnO structure gives the best results for both uniform and Gaussian distribution. The results for both CZTS/In_2S_3 and CZTS/In_2S_3/i-ZnO are identical with respect to distribution of deep defect level. A comparison between simulated results for all the previously mentioned structures has been tabulated in table 3.

TABLE III. COMPARISON BETWEEN DIFFERENT CELLS WITH DEEP LEVEL DEFECTS IN THE CZTS LAYER.

Buffer layers		**Distribution type**							
		Uniform				***Gaussian***			
		V_{oc} (V)	*J_{sc} (mA/cm^2)*	*FF (%)*	*η (%)*	*V_{oc} (V)*	*J_{sc} (mA/cm^2)*	*FF (%)*	*η (%)*
CdS	With TCO	0.78	25.20	50.39	9.92	0.74	22.49	43.67	7.24
	Without TCO	0.78	24.97	50.40	9.82	0.73	22.30	43.69	7.18
ZnS	With TCO	0.78	24.89	50.10	9.72	0.73	22.01	43.32	7.01
	Without TCO	0.78	24.96	50.10	9.75	0.73	22.07	43.32	7.03
ZnSe	With TCO	0.78	24.74	49.36	9.51	0.73	21.71	42.82	6.81
	Without TCO	0.73	24.64	49.88	9.58	0.73	21.65	43.10	6.84
In_2S_3	With TCO	0.77	26.66	56.96	11.68	0.75	25.14	50.63	9.55
	Without TCO	0.76	26.68	56.95	11.69	0.75	25.16	50.62	9.56
TiO_2	With TCO	0.78	25.05	49.99	9.77	0.73	22.24	43.35	7.09
	Without TCO	0.78	24.84	50.00	9.68	0.73	21.87	43.19	6.93

C. *Effect of capture cross section of electrons and holes*

The capture cross sections of the excess carriers are directly related to the capture and emission rate in Shockley-Read-Hall (SRH) theory of recombination and are inversely related to the excess carrier lifetime. So, the increase in capture cross section may severely damage the performance of the solar cell.

In this work, the electron and hole capture cross sections have been varied to numerically analyze the effect of them on the performance of the solar cells. A variation of hole cross section (C_p) have been investigated keeping the electron capture cross section (C_n) constant and vice versa. The graphical representation of performance parameters (Voc, Jsc, FF, η) versus hole capture cross section has been illustrated in fig. 2.

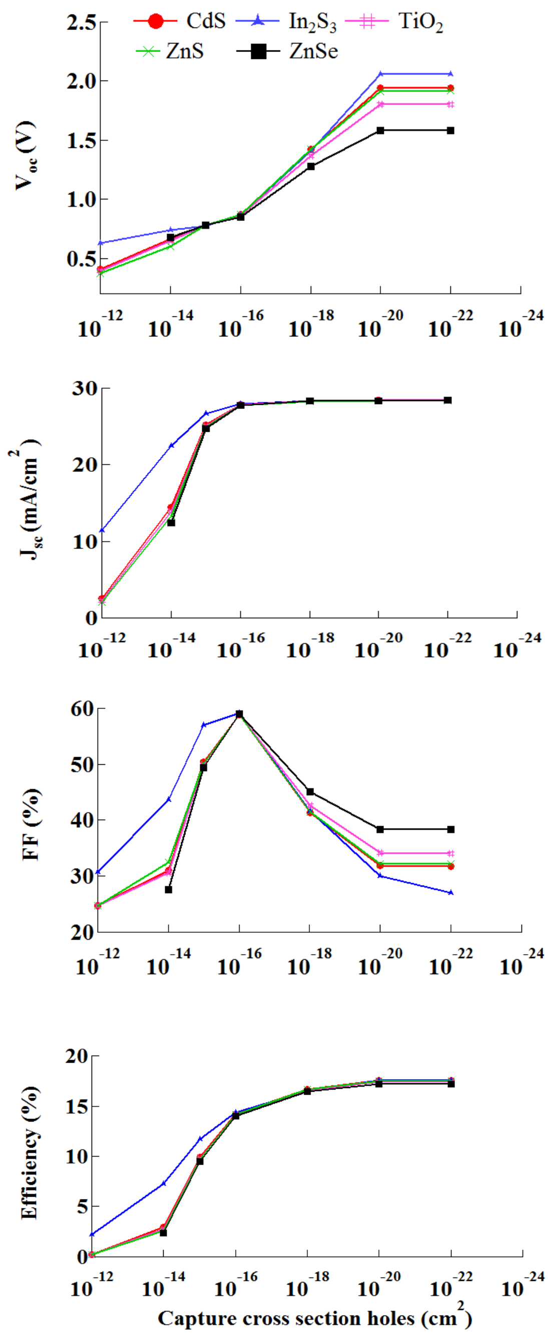

Figure 2. Performance with respect to hole capture cross section

The illustrations in fig. 2 show degradation in performance with the increase of C_p. A rapid deterioration has been observed for C_p above $1\times10^{-15}cm^2$. A higher C_p accelerates the process of hole capture from the valence band described in SRH theory. J_{SC} and □ reaches a steady-state value after C_p less than $1\times10^{-16}cm^2$ due to the reduced effect. CZTS/In_2S_3/i-ZnO offers the best performance in this case which can be attributed to high electron and hole mobility of In_2S_3.

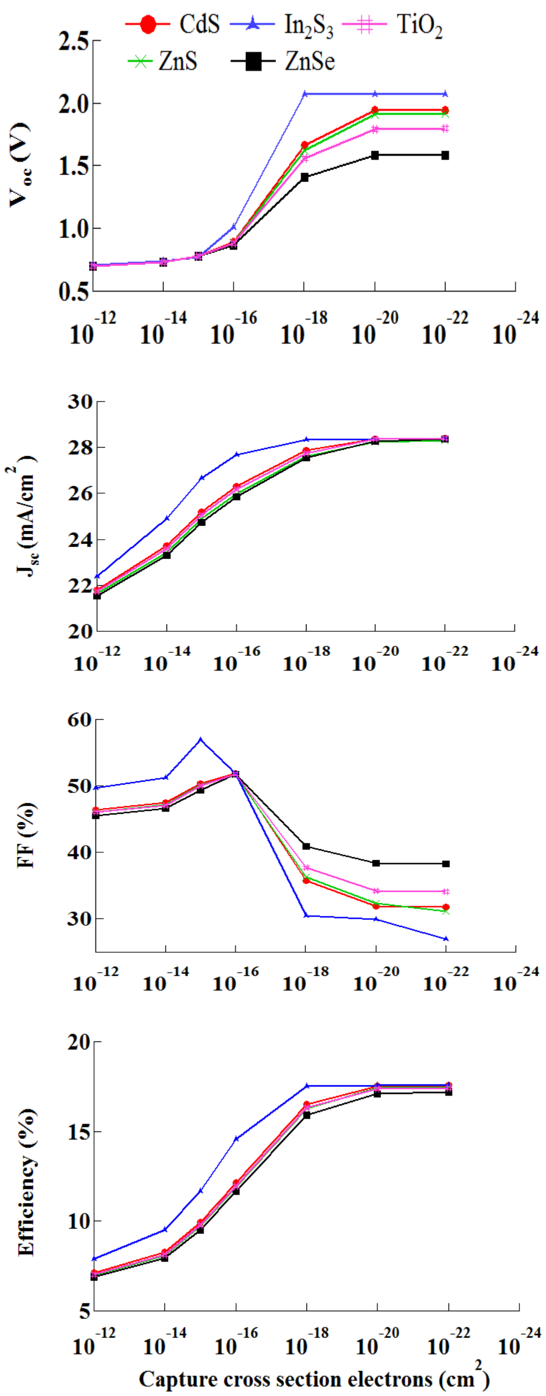

Figure 3. Performances with respect to electron capture cross section.

The illustrations in fig. 3 show a similar degradation in performance with the increase of C_n, although it is less rapid than with high C_p. The defect energy level being a little closer to the conduction band a high hole capture means more emission of electrons from trap level into the valence band.

D. *Effect of doping concentrations*

A higher acceptor doping concentration sends quasi Fermi levels for holes closer to the valence band and acts between the trap level and the valence band, thus reducing the number of electrons emitted from the trap level to the valence band. In this work, the less efficient cases from the previous study of capture cross sections have been considered for all the cells and shown in fig 4.

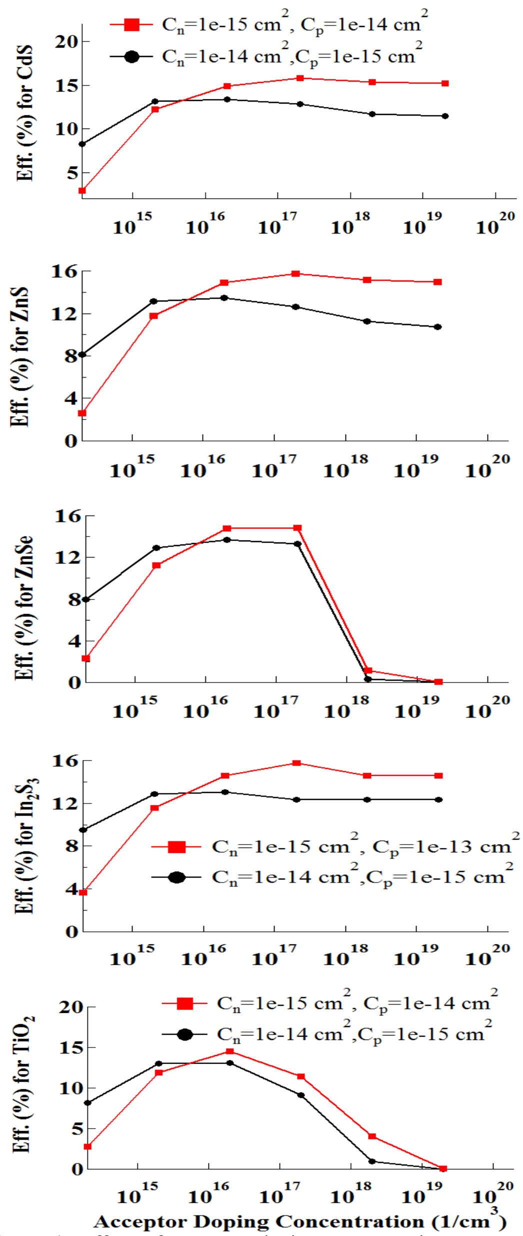

Figure 4. Effect of acceptor doping concentration on conversion efficiency.

From the illustrations of fig. 4 it has been observed that the optimum acceptor doping concentration for all the models is above 2×10^{16} cm^{-3}. But other parameters like FF, V_{OC}, J_{SC} show irregular and reduced numbers for these values of acceptor concentrations. So, 2×10^{16} cm^{-3} has been identified as the optimum value of acceptor doping concentration. Thus compensation can be done to counter the effects of high capture cross section of carriers due to deep level defects in this manner.

E. *Effect of layer thickness on CZTS absorber*

A thinner layer thickness can be adopted as another way of enhancing the performance which had deteriorated due to deep level defects. CZTS cells having deep level defects with higher hole capture cross sections which was investigated as more harmful in the previous sections, are simulated with thinner layers of CZTS absorber and the performance parameters have been plotted against the layer thickness in fig. 5.

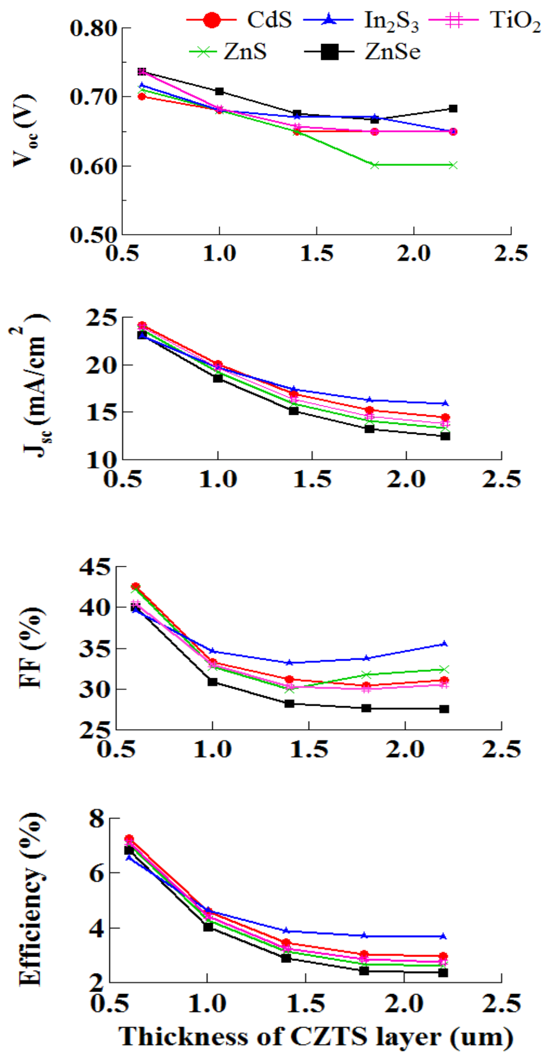

Figure 5. (V_{OC}, J_{SC}, FF, □) vs. layer thickness of CZTS absorber.

F. *Effect of temperature*

The operating temperature largely affects the parameters such as effective density of states (DOS), absorption coefficients, electron and hole mobility, band gaps and carrier concentration of the materials. The solar cells show almost same deviation of output parameters for CZTS/ZnS/i-ZnO and CZTS/TiO_2/i-ZnO structures. The effects of operating temperatures on the performance of CZTS/CdS/i-ZnO, CZTS/ZnSe/i-ZnO and CZTS/In_2S_3/i-ZnO structure have been investigated for the temperature ranging from 280K to 380K which is shown in fig. 6 and fig. 7. It is observed from these figures that Voc, Jsc, FF and efficiency decrease almost linearly with the rise of operating temperatures. The decrease rate of Voc ($-dVoc/dT(\%k^{-1})= 0.05$) and the decrease rate of Jsc ($-dJsc/dT(\%k^{-1})= 0.05$) are nearly constant for all three structures over the whole observed temperature range. For the operating temperature ranging from 300K to 320K, the temperature gradient of FF for CZTS/CdS/i-ZnO structure is positive ($0.017\%k^{-1}$) whereas it is negative for the structure of CZTS/ZnSe/i-ZnO and CZTS/In_2S_3/i-ZnO ($-0.04\%k^{-1}$ and $-0.09\%k^{-1}$ respectively). For higher degree operation (360-380K), the decrease rate of FF for CZTS/In_2S_3/i-ZnO ($-0.18\%k^{-1}$) is more negative than the rest of the structures ($-0.1\%k^{-1}$ for CZTS/CdS/i-ZnO and $-0.7\%k^{-1}$ for CZTS/ZnSe/i-ZnO). The temperature gradient of efficiency from 300K to 320K is $-0.07\%k^{-1}$ for CZTS/In_2S_3/i-ZnO structure whereas $-0.05\%k^{-1}$ for both CZTS/CdS/i-ZnO and CZTS/ZnSe/i-ZnO structures.

The solar cell shows optimum efficiency in the room temperature (300K). With the rise of temperatures above room temperature, the mobility of the carriers reduces which results in lower collection of minority carriers. From the performance analysis of CZTS solar cell at different operating temperatures, it is observed that cells with CdS and ZnSe buffer layer show better gradients than the one with In_2S_3 buffer layer for higher degree temperature operation.

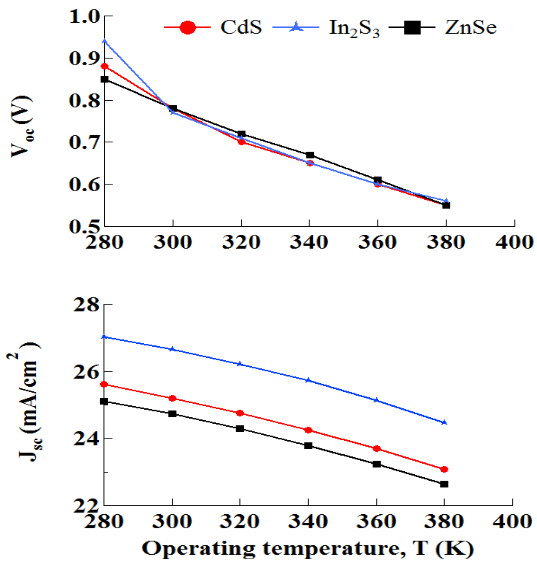

Figure 6. V_{OC} vs. Temp. and J_{SC} vs. Temp.

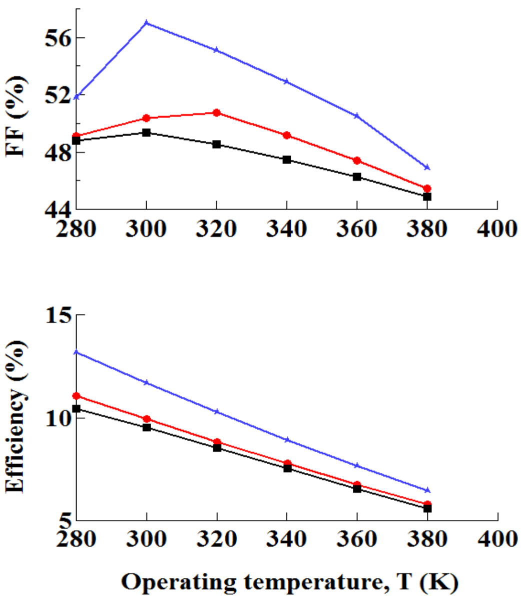

Figure 7. Fill factor vs. Temp. and Efficiency vs. Temp.

IV. Conclusion

CZTS solar cells with different buffer layers have been numerically analyzed using SCAPS 2802 simulator. The incorporation of TCO i-ZnO layer on top of buffer layers have resulted in a slight reduction in output parameters which could be attributed to low mobility effects. Deep defect levels within the CZTS absorber layer has been investigated which showed that the Gaussian distribution of deep defect energy lowers the performance more than the uniform distribution. Capture cross-section of carriers within the deep defect level have been pondered on and it has been concluded that the high hole capture cross section leads to a worse performance of the solar cells than high electron capture cross section. Two ways to offset the damage done by deep defect levels has been proposed and investigated upon. Increased concentration of shallow acceptor impurity has been observed to be able to compensate the effect of deep defect levels. And a reduction of absorber layer thickness also improved the performance of the solar cells.

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Application of Short Term Energy Consumption Forecasting for Household Energy Management System

K.M.U. Ahmed[1],
Dept. of Electrical and Electronic Engineering (EEE)
University of Asia Pacific (UAP)
Dhaka, Bangladesh
kmu.ahmed@uap-bd.edu

M.A. Al Amin[2]
Dept. of Electrical and Electronic Engineering (EEE)
University of Asia Pacific (UAP)
Dhaka, Bangladesh
masumeee@uap-bd.edu

M.T. Rahman[3]
Dept. of Electrical and Electronic Engineering (EEE)
University of Asia Pacific (UAP)
Dhaka, Bangladesh
towhid@uap-bd.edu[3]

***Abstract*— In the context of the smart grid, energy management systems at household level has a vital impact on distribution grid. PV based energy systems at household level become more popular day-by-day. Thus scheduling residential energy storage device is necessary to optimize technical and market integration of distributed energy resources (DERs), especially the ones based on renewable energy. The first step of electricity consumption forecasting at individual household level is used to achieve proper scheduling of the storage devices. Then an intelligent agent based controlling technique is proposed to make sure the financial benefits of end-user as a part of energy management system. In this paper the forecasting ability of Artificial Neural Network (ANN) is evaluated to capture the daily electricity consumption profile of an individual household.**

***Index Terms*-- Artificial Neural Network (ANN), machine learning, short-term load forecasting (STLF), storage device scheduling**

I. Introduction

Household energy management systems are facilitated efficiently by using advanced micro-grid and DERs. However, the implementation of small energy storage devices at the household level facilitates the participation of end users in a liberalized electricity market. The storage devices provide flexibility for satisfying self-consumption and realize energy trading in a local market. Thus, it is important to schedule the storage devices to maximize the economic benefit of the consumer through an efficient energy management system [1]. This paper is focused on day-ahead load forecasting at the household level for proper scheduling of residential energy storage devices focused on intelligent agent-based control of the residential energy storage. Part of the agent intelligence is the ability to learn specific electricity consumption profiles and adapt to the conditions that change those profiles. For realizing the scheduling of storage device, the forecasted load profile needs to be as accurate as possible for the benefit of the owner of the storage device. Reducing the forecasting errors can have a positive impact on the electricity bill of the consumer [2].

Various fundamental short term load forecasting (STLF) techniques such as dynamic linear and non-linear models [2], Kalman filtering [3] and some optimization methods for load forecasting [4] are found in literature. Machine learning techniques have also seized the attention of researchers, such as fuzzy-neural model, support vector machines (SVMs) [5], artificial neural network (ANN) [6] and genetic algorithms to optimize ANN structure [7]. Apart from machine learning techniques, some researchers focused on time series forecasting models such as auto regressive integrated moving average (ARIMA) [8, 9] or auto regressive moving average (ARMA) [9]. The ANN model evaluated in this paper are based on feed-forward ANN (FNN), very popular choices for STLF [10, 11]. The forecasted consumption profile is used for scheduling storage devices.

For aforementioned forecasting technique historical data is very important depending on the characteristics of input variables. Depending on the model input could be of the same type (only electrical energy or heat production) or combination of different types of data (energy consumption with temperature or seasonality etc.). In this work, electricity consumption along with the day identification is used as input of the models. Using the forecasted electricity consumption, it is possible to have an idea about the amount of stored energy. After mitigating self-consumption from PV generation, surplus energy is used to charge the storage devices. The consumption and PV generation profile used for testing is real data of twenty eight Bangladeshi household consumers.

II. Forecasting Models

ANN is a machine learning technique inspired by the biological learning system, particularly the functioning of the human brain. The electricity consumption profile of a day of a consumer, captured in 15 minute sample is shown in Fig. 1.

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Due to the variation or non-linearity in the input data ANN is a typical solution as forecaster [12, 13]. The factors behind the high accuracy rate are the parallel processing of the input data and model building process which is not dependent on any prior assumptions. However, FNN is the most common ANN used as a forecasting model because of its simplest and fast propagation algorithm [12]. In FNN, it transmits information from input layer to output layer using some simply structured hidden layers. However, forecasting accuracy of the model differs depending on the proper training algorithm and structure of input - hidden - output layers [6, 10]. The single hidden-layer FNN network is most widely used for time series forecasting [14].

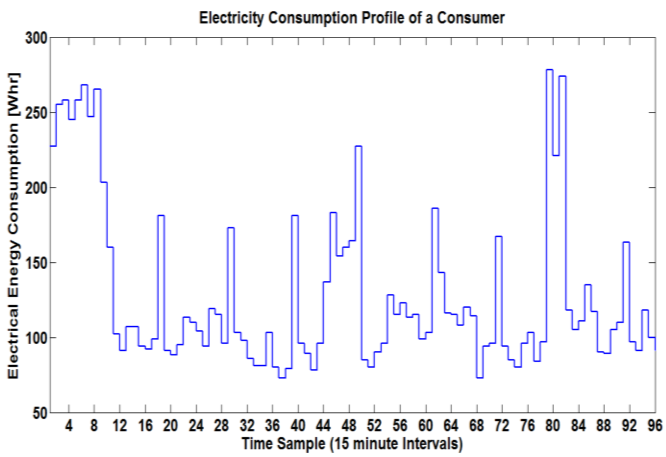


Fig. 1: Two Days Electricity Consumption of Consumer 26

Depending on time period and type of input data improve the accuracy rate of the FNN forecasting model is objective of this work. Moreover, better scheduling of the storage devices depend on the accuracy of the forecasted result. Different errors can be used to evaluate the performance of the models. In this paper, mean square error (MSE) and mean absolute percentage error (MAPE) are used to evaluate the level of accuracy of the models [15, 16]. The regression factor is another criterion to evaluate the modes, which tries to find a linear relation between the outputs of the network and the targets. In section IV it is discussed in detail.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(\hat{Y}_i - Y_i)^2$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Y_i - \hat{Y}_i}{Y_i}\right|$$

where $\hat{Y}$ is a vector of n predictions, and Y is the vector of the real values.

III. Methodology

The experiment is done in two phases: model evaluation and demonstration of the forecasting performance via a use-case. The models are implemented in MATLAB® 2012a. The accuracy criteria is the regression factor, MAPE and MSE. For the FNN, the previous 92 days (from March'13 to May'13) consumption data is used. The consumption data is in Whr. The assumption of the authors is that 92 days is enough as an adaptive period for the agent to capture changes in electricity consumption, while the 15 minutes resolution is a common practice from a data acquisition point of view.

The single hidden layer FNN is the most commonly used forecasting model. In this paper, FNN with 10 neurons is used to map the relationship between inputs and outputs through a unidirectional information flow, shown in Fig. 2. The performance of FNN depends on the number of hidden neurons and total number of inputs. Electricity consumption and logical day is used as inputs. Logical day is the Boolean value for weekdays and weekends (Monday to Friday represented by 1; Saturday, Sunday represented by 2). Fig. *2* illustrates the structure of the FNN model used in this work. The input data is divided in three data sets, for training, testing and validation respectively. It is a common practice to divide 70% data for training, 15% for testing and 15% for validation [16].

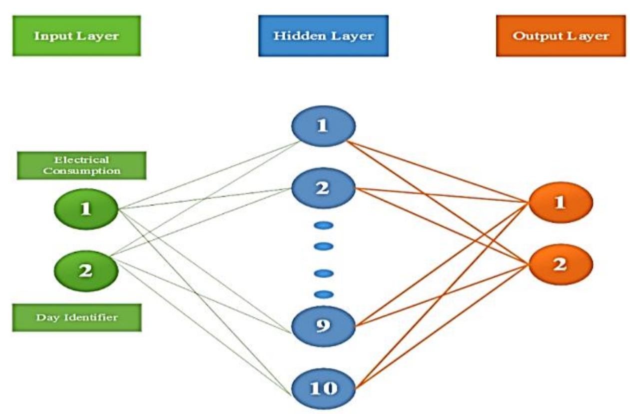


Fig. 2: Architecture of ANN

The scheduling of the storage device refers to the control of its charging profile. The forecasted electricity consumption profiles are used to schedule the storage devices day-ahead. In our use case, priority is given to self-consumption, while the surplus energy stored in the battery can be traded/ shared in neighboring area. We explore FNN as forecasting model can be accurate enough to allow for profitable participation in this market. It is assumed that every consumer has two storage devices of rating 2.5KWhr, connected with PV panels.

IV. Results

A. *Model development of FNN:*

As it is mentioned Section II, for forecasting FNN is the best suited model. There are various type of FNN depending on number of hidden layers [17] and single hidden layer FNN is mostly used for forecasting. Designing a single hidden FNN model for STLF involves several major steps:

- Determine the number of target variable(s) (here only electricity consumption)
- Determine the input variable(s) (here day identification number of the week)
- Determine the number of hidden neurons

This is the most important step to build an optimal model. There is no predefined rule for this. Thus, depending on some parameters a trial and error method is followed and the outcome is shown in Fig. 3. The number of neurons are varied from 5 to 20 and it is observed that 10 hidden neuron takes less time with highest number of epoch (iteration) to map the characteristics of inputs and target towards output. However, highest number of epoch ensures better convergence, thus FNN model has less error (MAPE) with 10 hidden neuron Fig. 3.

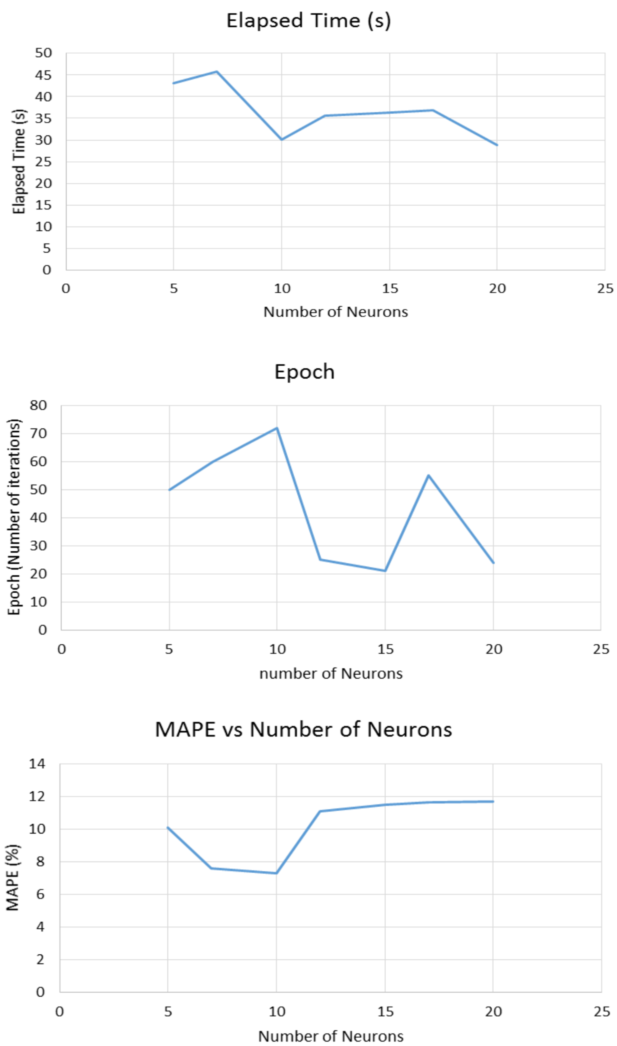


Fig. 3: Optimal Number of hidden neurons

B. Demonstration of day-ahead consumption forecasting:

The forecasting performance of a selected day in mid-summer is performed with different consumer with varying consumption pattern and behavior, demonstrated in this following section.

i. Consumption forecasting on mid-summer (June 01, 2013):

As it is mentioned in Section II, historical electricity consumption of previous three months is used as training data, whether day identification number and hour information are used at FNN as external input.

Forecasting with FNN:

As it is mentioned earlier, electricity consumption data from March to May is chosen as the training data. The noticeable aspect here, the starting of the training data is the end of winter (March) and the target day is mid-summer. But here no seasonal identification number or variable is used. Thus, the hour information is used to identify the change in consumption due to seasonal change based on hour.

From MAPE point of view, consumer 25 has one of the best forecasting result compared to other because it has lowest error margin (MAPE=11.13) shown in Fig. *4*. However, anther error indication parameter shows consumer 25 has quite high level of error (MSE=2131.90) and also the regression factor, R shows that it has a large number of mismatching point (among 96 point), thus it deflects a lot form 1 (R = 0.82822). The forecasting value mismatch shown in Fig. 4 is small up-to sample 50, but from 52 there is no match between the forecasted values and the actual values. That indicates a change of the behavior of the consumer in the evening of that particular day, where he did not have his usual evening peak. The regression function and MAPE of the forecasting result is shown Fig. 5.

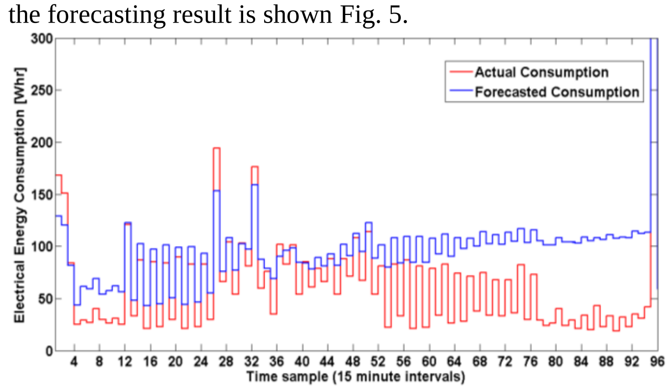
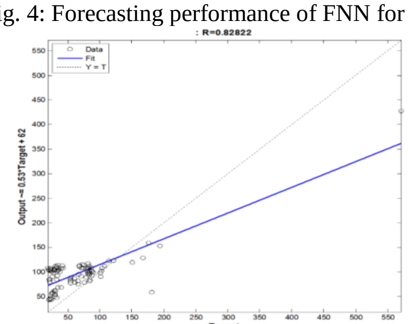
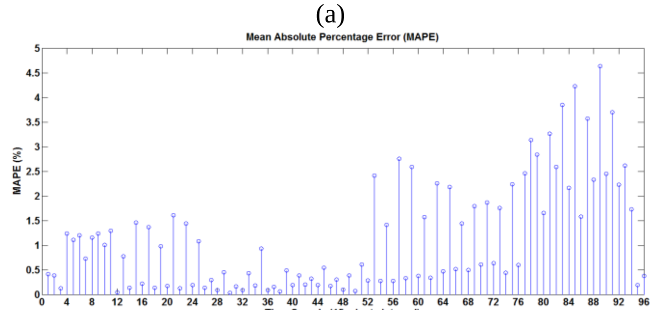


Fig. 4: Forecasting performance of FNN for consumer 25



(a)



(b)

Fig. 5: R and MAPE of forecasted output of consumer 25 by FNN

The dashed line in Fig. 5(a) represents the exact result and the solid line (fit) represents the best fit linear regression line between outputs and targets. R (=0.828) is much lower than 1 indicating that this fail in forecasting is an exception rather than the rule. A significant amount of mismatched point is identified between the target ranges of 25Wh to 100Wh in Fig. 5(a). These dots lies above the dotted lines, which actually represent the ongoing predicting errors from sample 52 where FNN predict more than the actual consumption at Fig. 5. Moreover, the large spikes represent large errors compared to the actual value from sample 52 through MAPE in Fig. 5(b). The reason behind this deflection is shown in Fig. 6 illustrates the unusual consumption pattern on the target day (marked by red line). The consumer has change the consumption pattern in reality, compared to the previous weekend days. Thus, FNN cannot capture the changing pattern compared to the previous actual consumption, results a significant number of error at evening time of the target day.

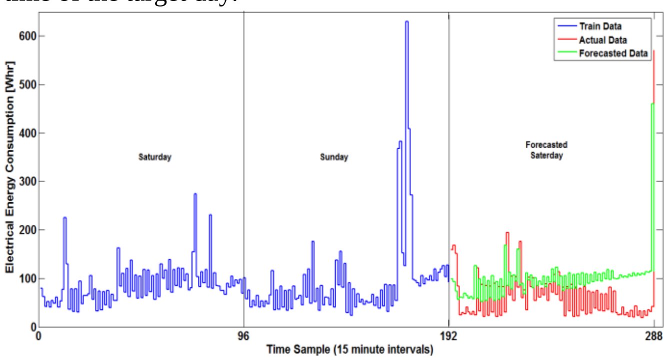


Fig. 6: Actual and Forecasted consumption compared with training data for consumer 25

For further investigation, FNN forecasting performance for consumer 9 has been demonstrated next by means of lowest MSE (=98.11) but with significant MAPE (=24.99%). The FNN response for consumer 9 is shown in Fig. 7. While the match is good during the low-consumption morning period, there is a significant under-estimation of the consumption during the evening and unusual late night peak hours. The patterns and positions of the peaks of the consumption profile is predicted, but size of the peaks are not. That was a general phenomenon in this simulations, as also shown in Fig. 7, indicating maybe small variations in the use of certain electrical devices during the evening, while the standard devices (the ones giving shape to the pattern) stay the same. Moreover, to realize the effect of this error the R and MAPE is shown in Fig. 8. In regression plot most of the lower valued predicted points are placed above the dashed means at these sampling points FNN predicts more than the actual consumption. However, the mainly scattered points are from the peaks as it is shown in Fig. 8(a). In Fig. 8(b) the MAPE plot is shown which has a very scattered pattern due to mismatch of prediction almost in every sample. Thus, a very few number of predictions are matched but most of the points are matched very close to the actual consumptions, shown in Fig. 7. So it gives comparatively very low value for MSE.

The focused aim of this research is to achieve an optimal scheduling for the storage devices rather than other demand response activities like valley feeling or peak shaving. So, the total error margin of a day is very important to have proper idea about consumption, where the location or value of the peaks are less prioritize. If the FNN gives large error, it may mislead the storage device controller and may results financial loss of the consumer. Thus, it is very important to improve the overall prediction capabilities of the forecasting model.

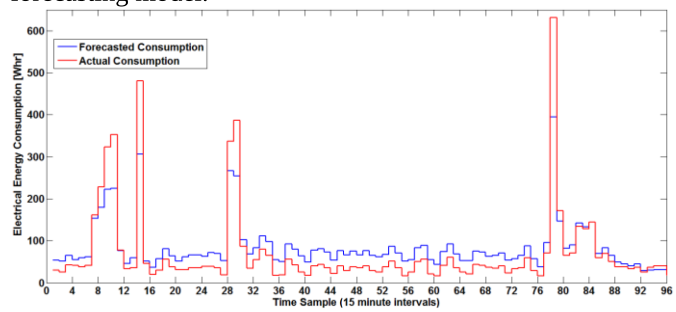
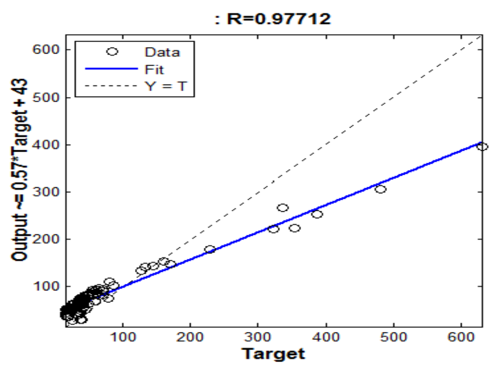
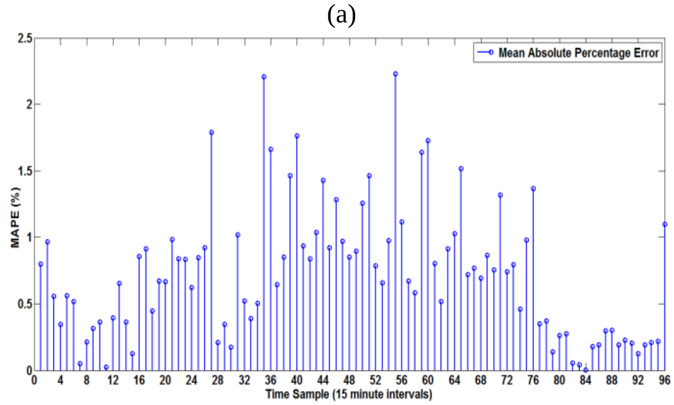


Fig. 7: Forecasting performance of FNN for consumer 9



(a)



(b)

Fig. 8: R and MAPE of forecasted output of consumer 9 by FNN

To analyze further the forecasting ability of the FNN, more results is shown Fig. 9 for consumer 16, where both of the error parameter and regression function lies within an acceptable range (R = 0.93749, MSE = 254.87 and MAPE = 21.21%). In this case, the consumption profile of a typical household has very low consumption at mid-night, whether at day time it has big peak at 2.30 PM along with some comparatively small peaks at evening. As like previous analysis, FNN is captured the patterns and positions of the peaks of the consumption profile precisely, but not the size of the peaks. For this case, there is a significant under-estimation of the consumption during the middle of the day. However, due to hour identification input FNN can located the expected time of the peak as it is observed in Fig. 9.

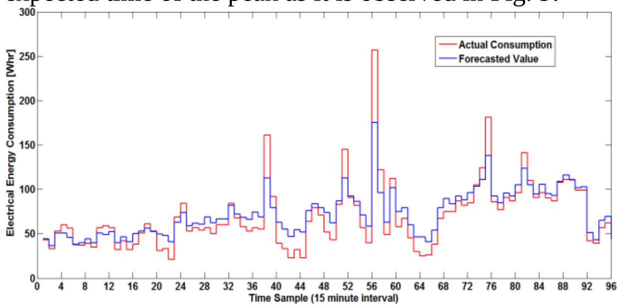


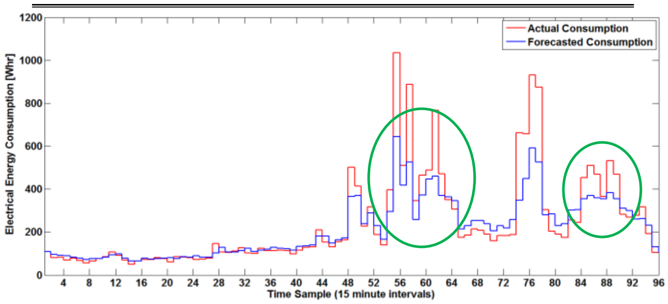
Fig. 9: Forecasting performance of FNN for consumer 16

ii. Forecasting with FNN with changed day identification variable:

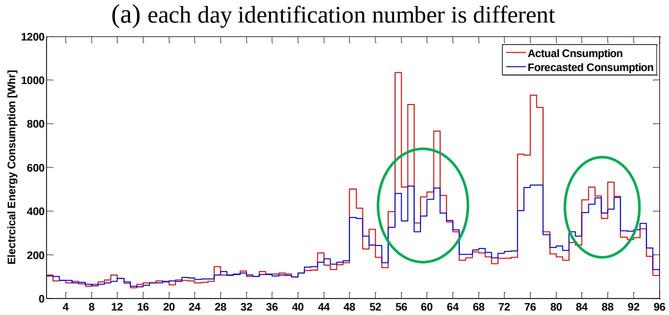
As it is discussed in [18], the household electricity consumption should vary with time during the days a week. For more justification of this, self-organizing mapping (SOM) which identify the different clustering of the training data of each day. Thus, a new approach is applied by representing each day of a week by seven integers shown in Table 1. To illustrate the effect of this change in day identification number, the forecasted performance of the FNN is shown in Fig. 10.

Table 1: New identification number of each day of week

Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	2	3	4	5	6	7



(a) each day identification number is different



(b) Only weekday and week end identification number

Fig. 10: Performance comparison of the FNN with changed day identification numbers (consume 24)

The FNN model can capture the change in consumption pattern on each day rather than only week or weekend days, due to introduce individual day identification numbers. Thus, the performance improves by means of each parameters shown in Table 2. So, based on the approach presented in this section, the performance of FNN is improved for forecasting individual household electricity consumption and results is shown in on going sections is followed by this new approach.

Table 2: Performance comparison of FNN for consumer 24

	R	MSE	MAPE
Each day identification	0.96725	85.40	13.90%
Only week-end or week day identification	0.95713	98.13	25.09%

V. USE-CASE

To analyze the performance of the scheduling of the storage device, we chose consumer 22. We assumed the presence of PV panels and electricity storage in his household. More specifically, the household is assumed to have two identical batteries of rating 2.5KWh with two PV panels. Thus, at a certain point both batteries will be fully charged. PV production and forested electricity consumption is shown in Fig. 11. The extra PV generated energy, after satisfying self-demand, charged the batteries up-to sample 53, after that it stops charging as shown in second plot of Fig. 11. In this case, consumer 22 can offer to trade/share extra PV generated energy in neighborhood for two hours (sample 54 to 70) which is 4.81KWhr as an application of Energy management from distribution side. However, the actual situation is shown in Fig. 12 where consumer has 4.92KWhr available to share. In this situation, consumer will lose a small amount of energy to trade in local day-ahead market. Thus, if we assume the opposite, if the owner cannot fulfill his proposed amount of energy in reality then it desire some smart control strategies to assure the stability of the distribution grid.

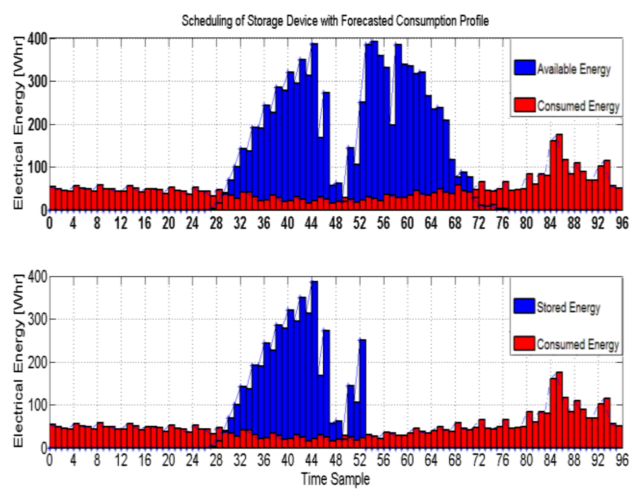


Fig. 11: Storage device scheduling using FNN Forecasted profile

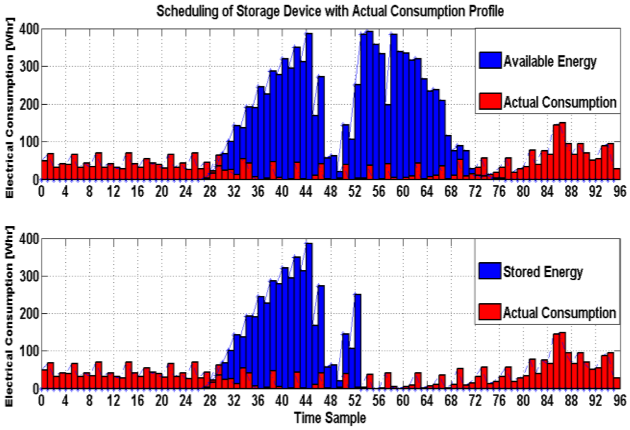


Fig. 12: Storage device scheduling using Actual consumption

VI. CONCLUSION

We evaluate the forecasting ability of the FNN to predict the electricity consumption profile of a single household. The FNN provided us with much better results for individual household consumption forecasting. It could predict the pattern of the electricity consumption profile, but it sometimes failed to predict the size of the peaks. We attributed this to the volatile changes in the behavior of the consumers, who, while using their basic devices in the same way every week, providing a predictable pattern, they use some smaller devices in different time intervals, altering the size of the peaks.

We examined the participation of the owner of PV panels coupled with an energy storage device in a day-ahead local market. While the FNN gave a good estimation of the available energy for trading/sharing, the mismatch between predictions and result may lead to reduced monetary benefit for the prosumer. Thus, we concluded that a prosumer with PV generation coupled with energy storage should only participate in future markets if the PV generation and the storage capacity are high enough to make the volatility of his electricity consumption profile negligible.

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Modelling of Solar Cell Characteristics Considering the Effect of Electrical and Environmental Parameters

Md Faysal Nayan
Department of Electrical and Electronic Engineering
Ahsanullah University of Science and Technology
Dhaka, Bangladesh
faysal.nayan@gmail.com

S.M.Safayet Ullah
Department of Computer Science and Engineering
Daffodil International University
Dhaka, Bangladesh
s.m.safayet.ullah@gmail.com

Abstract— **This paper focuses on a generalized model of eco friendly green power technologies like photovoltaic cell using MATLAB. Fundamental mathematical equations based on equivalent circuit of solar photovoltaic cell are used to set up the model. This model shows an overall performance of Photovoltaic cell characteristics by analyzing different types of electrical and environmental parameters. In this paper, MATLAB is used to investigate the I-V and P-V characteristics of solar photovoltaic cell considering the effect of temperature, solar radiation, ideality factor, series resistance and shunt resistance of solar cell, number of cells in PV array and reverse saturation current.**

Keywords- Solar cell; solar radiation; PV array; temperature; MATLAB; mathematical Model;maximum power point;

I. INTRODUCTION

Now a day's energy shortage is worldwide concern issue. Increased utilization of energy and global pollution awareness has made the renewable energy as a promising energy source. Due to increasing of energy demand in every year in the world, renewable energy can be an alternative option for improving this situation. Smart Grid technology can be a proper solution for overcome the power crisis problem. Renewable energy like solar energy is an added advantage to the Smart Grid ([1]-[2]) .

Renewable energy is a great solution to solve these phenomena. Among renewable energy, solar energy is emerging as one of the best energy solution. Solar Energy is a pollution free renewable energy sources which attributes high durability and reliability. Among the solar technology, the photovoltaic array (PV) has been making a positive attention due to its capability of energy conversion without intermediate thermal process ([2]-[4]).

PV system shows non-linear I-V and P-V characteristics which varies with different types of environmental and electrical parameters. This paper investigated a MATLAB model of PV cell that made possible the prediction of performance the PV cell under different varying parameters such as solar radiation, ambient temperature, ideality factor, series and shunt resistance, combination of series and parallel solar cells. In this paper, we have focused the equivalent circuit of single diode model and use basic fundamental equations to modeling the characteristics. Moreover, we will discuss the variation of maximum power point from the P-V characteristics of every curve by considering the change of solar radiation, temperature, ideality factor, series and shunt resistance, saturation current ([5]-[7]).

II. PHYSICS OF SOLAR CELL

Solar photovoltaic is a kind of technology which generates direct current (DC) using semiconductors when they are illuminated by photons [8]. Photovoltaic system made of different cells which convert sunlight into electricity [9].

Solar cells are generally made of semiconductor materials which contain weekly bonded electrons occupying a band of energy called valence band. When an energy is applied to a valence electron (greater then threshold energy), the bonds of valence electron are broken and electron is free to move to another energy band named conduction band. The band gap separates the free electrons from conduction band to valence band. Photons which are particle of lights supplied the energy to free the electrons ([8]-[9]).

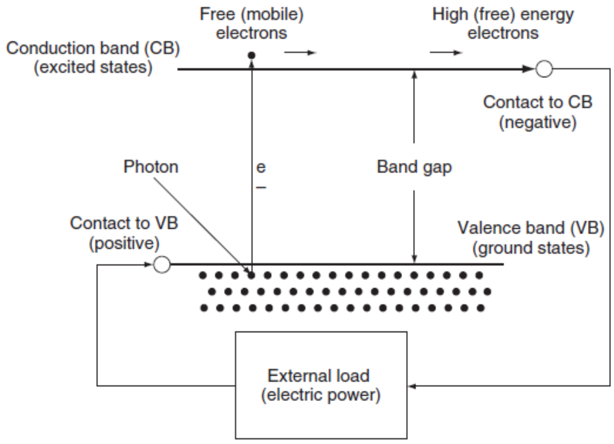

Figure 1. Concept of solar cell in terms of physics.

III. MODELING OF PHOTOVOLTAIC ARRAY

Solar cell is one kind of device that is fabricated in a thin layer of semiconductor. Solar cell is a p-n junction that is made by crystalline material like Si, GaAs, Ge etc. The main principle of solar cell is photoelectric effect. A typical solar cell device converts light energy into electrical energy ([5]-[6]).

Photovoltaic cells are generally connected in series configuration to form a PV module. The modules can be arranged to form large PV panel. Panels can be grouped to form large photovoltaic arrays. PV array is a complete arrangement of power generating unit, consisting of any number of PV modules and panels. Solar cell is basically building block of PV array [10].

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A. Equivalent circuit of solar cell

To analysis the characteristics of solar cell we need to implement a solar cell model. Modeling of solar cell involves investigating of I-V and P-V characteristics with the help of basic equations of solar cell model. The most popular approach of analyzing is to draw the equivalent circuit and derive the equations of output voltage and current in terms of various parameters ([7],[10]-[11]).

By observing the physical model of solar cell we can create an equivalent circuit for PV model. Since solar cell is basically a PN junction, so solar cell characteristics are equivalent to diode characteristics. ([5]-[7],[11])

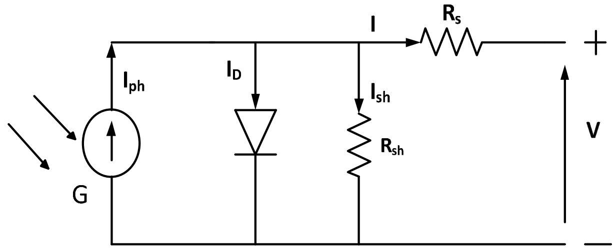

Figure 2. Equivalent circuit of solar cell

B. Fundamental Mathematical equations of Solar Cell

To develop the basic equations of solar cell, it is necessary to understand the physical configuration of the elements of solar cell and electrical equivalent circuit .The basic equation that represent the I-V characteristics of solar cell is based on the equivalent circuit are given below. ([5]-[6], [9], [13])

Using KCL we can write the equation of photocurrent which is given in equation (1).

$$I_{ph} = I_D + I_{sh} + I \quad (1)$$

In this equation, I_{ph} is Photo current generated in PV cell which depends on the solar radiation (G). I_D and I_{sh} are Diode current and Shunt current respectively. I represent the Load current of the solar cell ([6]-[7],[12]-[14]).

To analysis the effect of temperature and solar radiation we have to developed and implement some basic equations corresponding to solar PV cell which shows dependence of these parameters [5]-[7],[11]-[14]).

We know that from the solid state physics idea, semiconductor diode is a nonlinear device because its I-V characteristics always follow the nonlinear relationship. It can be demonstrated through the use of solid state physics that, the basic fundamental characteristics of semiconductor diode defined by the following exponential equation [15].

$$I_D = I_S\left[\exp\left(\frac{V_D}{V_T}\right) - 1\right] \quad (2)$$

Here, I_D and V_D represent the diode current and voltage across the semiconductor diode. I_S signifies Temperature dependent reverse saturation current and V_T is Thermal voltage which depends on temperature and ideality factor of diode.

$$V_T = \frac{nkT_C}{q} \quad (3)$$

Here , n= Diode ideality factor,
k = Boltzmann constant (1.3806503 × 10^{-23} J/K)
q = charge on electron (1.602× 10^{-19} C)

By analysing the figure 2, Using KVL we can say that,

$$V_D = V + IR_S \quad (4)$$

So from equation (2) and (4) we can write the following equation.

$$I_D = I_S[\exp(\frac{V + IR_S}{V_T}) - 1] \quad (5)$$

Where, R_s=series resistance of the cell that represents the internal losses of solar cell.
From figure 2, Shunt current, I_{sh} can be represented by

$$I_{sh} = \frac{V_{sh}}{R_{Sh}} \quad (6)$$

Here, R_{sh} is Shunt resistance of the cell which is parallel with the diode that takes the leakage current to the ground.
V_{sh} shows the value of voltage across the shunt resistance.

Since, voltage of parallel load is always same, so that V_D=V_{sh} . So we can write the equation V_{sh} using the equation (4) that,

$$V_{sh} = V + IR_S \quad (7)$$

So using the equation (6) and (7)

$$I_{sh} = \frac{V + IR_S}{R_{Sh}} \quad (8)$$

If we operate the semiconductor diode in reverse bias region then reverse saturation current will be I_{SO}. This current mainly depends on short circuit current, open circuit voltage and thermal voltage.

$$I_{SO} = \frac{I_{SC}}{[\exp(\frac{V_{OC}}{N_S V_T}) - 1]} \quad (9)$$

Where,

V_{oc} is Open circuit voltage per cell in Volt , I_{so} is Diode reverse saturation current, I_{sc} means Short circuit current per cell at reference temperature and solar radiation.
N_s and N_p represent the number of solar cell connected in series and number of solar cell connected in parallel respectively.

We know that, Diode reverse bias saturation current can be changed by the variation of temperature. The following equation represents temperature dependence of diode the saturation current ([6]-[7], [11]-[12]).

$$I_S = I_{SO}(\frac{T_O}{T_C})^3 * \exp[\frac{qE_g}{kn}(\frac{1}{T_O} - \frac{1}{T_C})] \quad (10)$$

Photo current generated in PV cell mainly depends on solar radiation and temperature. The value of Photo current is linearly proportional to the amount of solar radiation.

The equation of photo current based on temperature and solar radiation is represented by the equation (11) ([6]-[7], [11]-[12]).

$$I_{Ph} = [I_{SC} + K_{SC}(T_C - T_O)] * (\frac{G}{G_S}) \quad (11)$$

Using the equation of (1), (5) and (8) we can write the equation of load current as follows:

$$I = I_{Ph} - I_S[\exp(\frac{V + IR_S}{V_T}) - 1] - \frac{V + IR_S}{R_{Sh}} \quad (12)$$

$$I = N_P I_{Ph} - I_S(\exp[(\frac{q}{nkT_O})(\frac{V}{N_S})] - 1) - \frac{V}{R_{Sh}} \quad (13)$$

Where, K_{sc} is Short circuit current temperature coefficient and E_g represent the Band gap energy of crystalline material in eV.

G_S and G is solar radiation at standard test condition and operating Radiation condition respectively.

T_c is standard test condition temperature and T_0 is operating cell temperature.

IV. Analysis PV Model Using MATLAB

In this paper we used MATLAB software to investigate the maximum power point in different types of condition of electrical and environmental parameters. To perform this analysis we have used the data list of table 1. These data are based on 180 W ZED fabric mono-crystalline PV solar panel [16].

TABLE I
PARAMETERS OF ZED FABRIC PHOTOVOLTAIC SOLAR

Parameters	**Type/Value**
Cell Technology	Si crystalline
Number of cells in series	72
Open circuit voltage (Total)	45 Volt
Short circuit current (Total)	5.25 Ampere
Voltage at maximum power	36.31 volt
Current at maximum power	4.98 ampere
Maximum system voltage	1000 volt
Maximum power	180 watt
Temperature coefficient	.0023 V/^{0}Celsius
Saturation current	1.6595 nA
Temperature range	-40^{0}C to 80^{0}C
Cell efficiency	15.2%
Module efficiency	15%
Standard test temperature	25^{0}C
Standard test radiation	1000 W/m^2

A. *Effect of Variation of Temperature*

Changes of I-V and P-V characteristics are plotted for the variation of temperature shown in Fig. 3 and fig. 4.

1) *P-V characteristics*

For P-V analysis we have taken the value of radiation as fixed as G=1000 w/m^2 and varies the value of temperature from T= 0^{0}C to 40^{0}C. From the Figure 3 we have seen that, for 0^{0}C we have got the maximum output power, but at 40^{0}C maximum power point is minimum than other. So PV cell output power strongly dependent on temperature.

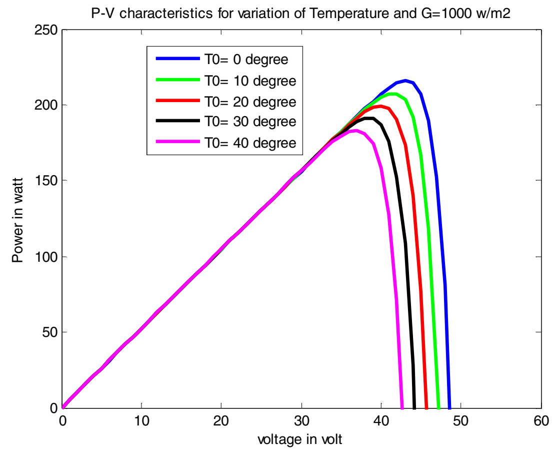

Figure 3. P-V Characteristics for temperature variation and G=1000 w/m^2

If we change the solar radiation condition to G=500 w/m^2, then value of maximum power is almost half than the first condition. The effect of solar radiation G=500 w/m^2 is shown in fig. 4.

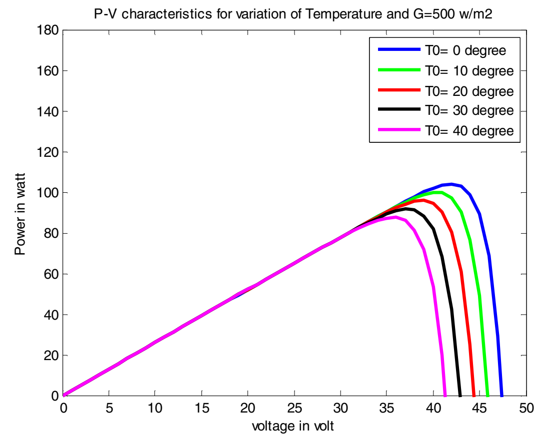

Figure 4. P-V Characteristics for temperature variation and G=500 w/m^2

2) *I-V Characteristics*

I-V characteristics are always important to verify the device characteristics. The change in I-V characteristics with the variation of temperature is shown in fig 5 and 6.

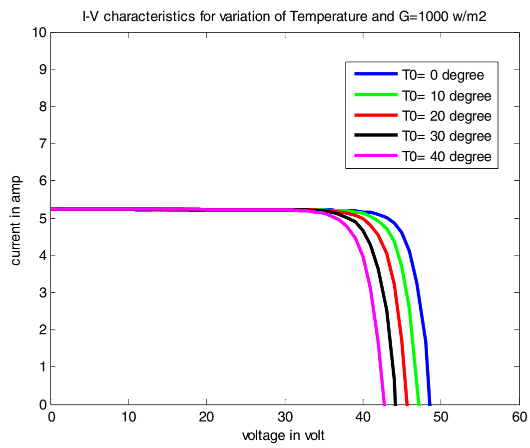

Figure 5. I-V Characteristics for temperature variation and G=1000 w/m^2

If we change the value of G from 1000 w/m^2 to 500 w/m^2, then value of maximum current is decreased from 5.5 to 2.75 ampere. Variation of I-V characteristics with temperature is shown in fig 6.

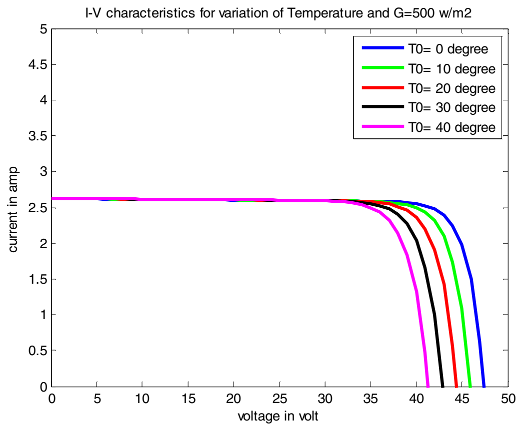

Figure 6. I-V Characteristics for temperature variation and G=500 w/m^2

B. Effect of Variation of Radiation

If we operate the solar cell with fixed radiation and cell temperature increases, then the value of V_{oc} decreases slightly but short circuit current increases. These conditions are shown in figure 7 and 8.

1) P-V characteristics

We have taken the operating temperature T=30 degree and 45 degree. Then we made a comparison between the two effects.

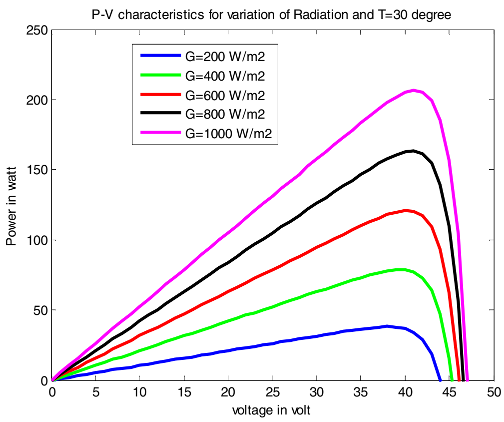

Figure 7. P-V Characteristics for radiation variation and T=30^0 C

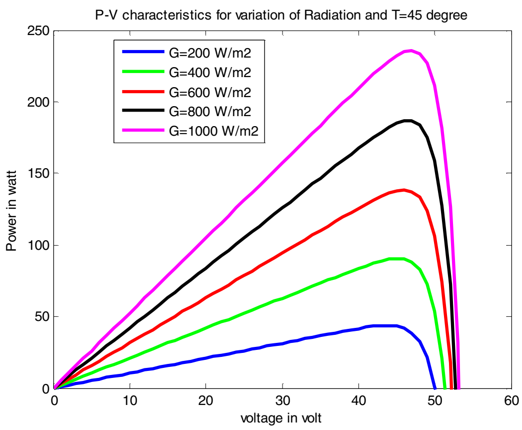

Figure 8. P-V Characteristics for radiation variation and T=45^0 C

By analyze the Fig 7 and 8, we can be predict, if we increase the temperature the maximum power point also increases at same solar radiation.

2) I-V Characteristics

PV cell current is strongly dependent on solar radiation. That effect can be understood from the figure of I-V characteristics with the variation of radiation.

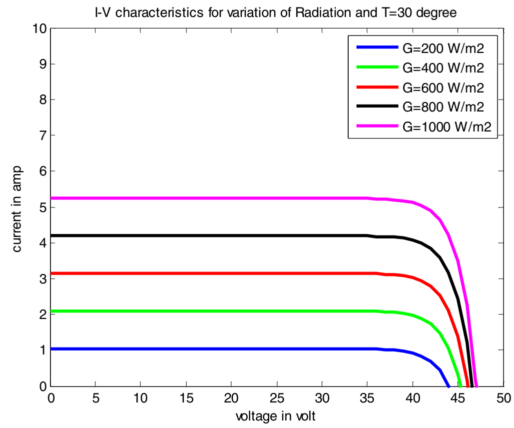

Figure 9. I-V Characteristics for radiation variation and T=30^0 C

C. Effect of Variation of Shunt Resistance of equivalent solar cell model

Shunt resistance is a significant property of solar cell. Without selecting proper value of shunt resistance we cannot find proper I-V and P-V characteristics.

1) P-V Characteristics of solar cell

After observing the figure, we can say that, shunt resistance should be high for proper power output. If the value of shunt resistance is too small as R_{sh}=5 ohm or 10 ohm then the value of maximum power is not perfect. But if we increase the value of shunt resistance higher than 100 ohm, then we can get proper maximum power point.

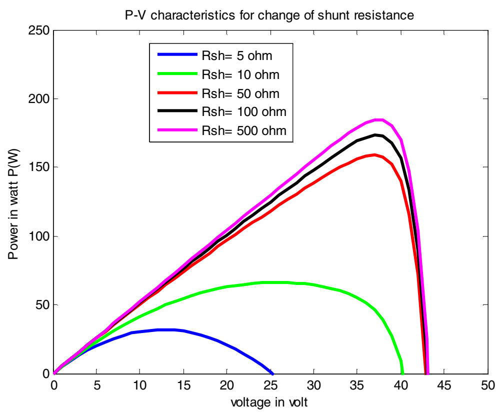

Figure 10. P-V Characteristics for variation of shunt resistance of equivalent circuit of solar cell and G=1000 w/m^2, T=30 degree

2) I-V Characteristics of solar cell

Figure 11 gives us an idea how shunt resistance is important to design a proper solar cell model. Without proper specification of shunt resistance I-V characteristics will not shown proper value.

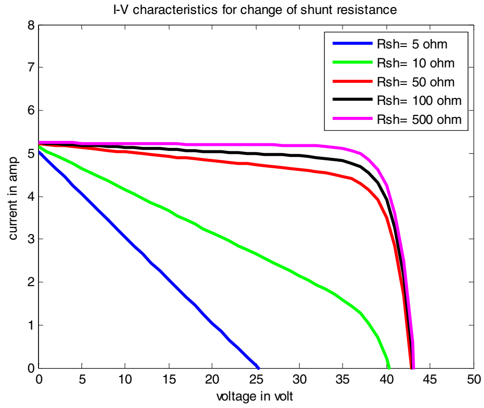

Figure 11. I-V Characteristics for variation of shunt resistance of equivalent circuit of solar cell and G=1000 w/m^2, T=30 degree

D. Effect of Variation of Ideality Factor of Diode

In this section, we have analysed the I-V and P-V characteristics of solar cell with the variation of ideality factor.

1) *P-V characteristics*

After illustrating the following figure, we can see that, unity ideality factor is expected for modelling the PV cell with higher output.

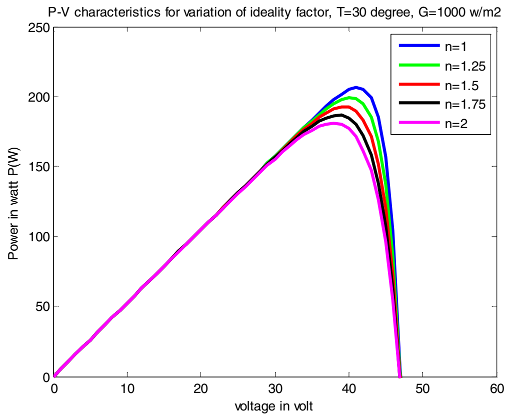

Figure 12. P-V Characteristics for variation of ideality factor and G=1000 w/m^2, T=30 degree

2) *I-V characteristics*

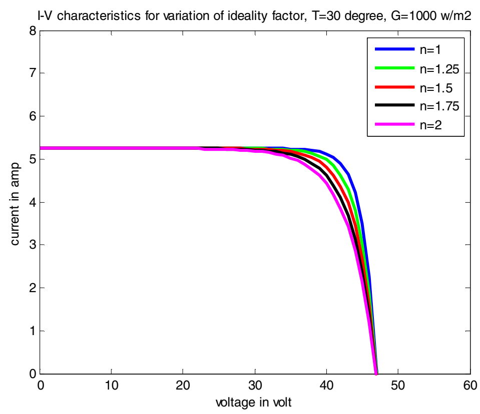

Figure 13. I-V Characteristics for variation of ideality factor

After observing the figure 12 and 13, it can be seen that ideality factor is also an important parameter for the design of solar cell.

E. Effect of Variation of Reverse Saturation current of equivalent solar cell model

In our paper we are considering the behaviour of saturation current to modelling the I-V and P-V characteristics. The curves of figure 14 and 15 were plotted for five different values.

1) *I-V characteristics of solar cell*

Figure 14 shows the I-V characteristics of solar cell model considering the effect of saturation current. It can be seen from this figure that, saturation current shows inverse relationship with the open circuit voltage.

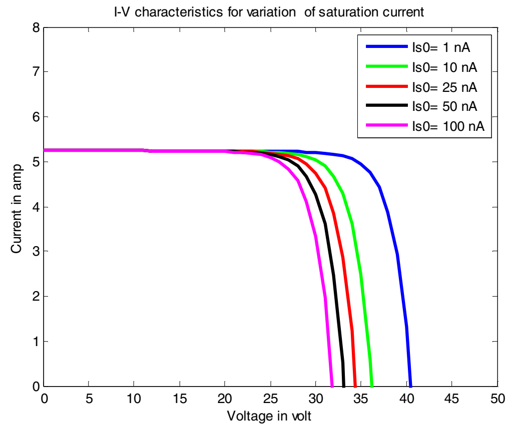

Figure 14. I-V Characteristics for variation of saturation current

2) *P-V characteristics of solar cell*

P-V characterises of the figure 15 demonstrates that, lower value of saturation current is better for maximum power output.

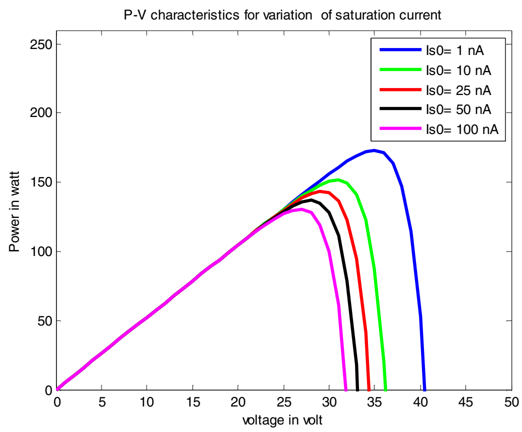

Figure 15. P-V Characteristics for variation of saturation current

F. Effect of Variation of Series Resistance of equivalent solar cell model

Series resistance signifies the internal losses of PV array. If we change the series resistance then we can predict the behaviour of PV solar model.

The simulation was performed with the value of series resistance 1mΩ, 5 mΩ, 10 mΩ, 20 mΩ and 50 mΩ.

1) I-V characteristics of solar cell

Figure 16 shows the influence of series resistance on open circuit voltage. So we need to apply negligible value of R_s for the PV cell design.

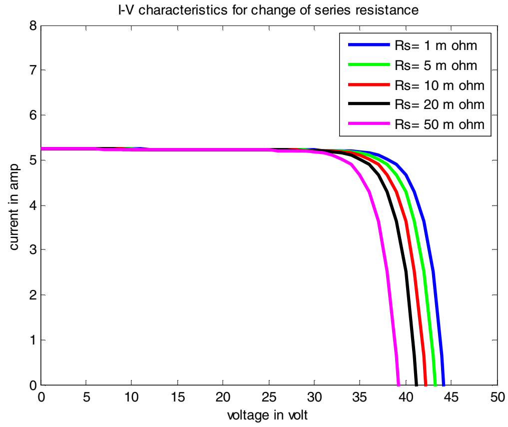

Figure 16. I-V Characteristics for variation of series resistance

2) P-V characteristics of solar cell

By observing the P-V characteristics shown in figure 17, it can be seen that lower value of R_s is suitable for design the PV model. Because we got maximum power output when R_s=1mΩ.

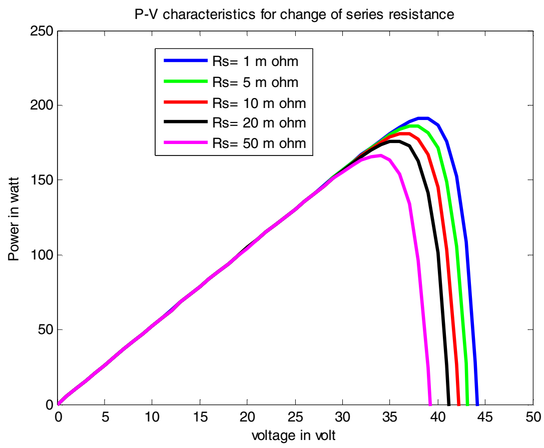

Figure 17. P-V Characteristics for variation of series resistance

V. CONCLUSIONS

A MATLAB model for the solar PV cell, modules and array was presented in this paper. This model used the fundamental circuit equations of a solar PV cell taking into account the effects of electrical and environmental parameters. In our paper, we refer the temperature and solar radiation as environmental parameters. Ideality factor, series and shunt resistance, reverse saturation current considered as electrical parameters. In our paper we considers the effect of temperature and solar radiation on n, R_s,R_{sh} and I_s. In this paper we select a set of data of a solar panel company for modeling the solar cell characteristics. We have seen from our paper that, solar radiation and temperature is two important factors for the design of PV cell. Maximum power output is strongly depends on solar radiation and temperature. For the maximum power output we have to maintain higher solar radiation and standard temperature condition. Ideality factors should be close to unity for better output power. Electrical parameters like series resistance should be low as possible for maximum power point. But others electrical parameters shunt resistance should be high for proper output. But reverse saturation current needs to maintain as low as possible. So this model can be used to predict the behavior of any solar PV cells under environmental and electrical parameters changes.

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The Prospect of Renewables of Bangladesh: A Study to Achieve the Policy Goal

Tanvir Ahmed

Department of Electrical & Electronic Engineering
Islamic University of Technology
Gazipur, Bangladesh
tnvrhmd2@gmail.com

***Abstract*— Sufficient energy supply capability is the key factor for the development of any country. Present world is mostly depended on natural resources for energy production. But as the amount of natural sources of energy are declining day by day, to meet the increasing power demand with the renewable energy sources are becoming important. This issue is important for country like Bangladesh as it faces high power demand for high population growth rate. The aim of this paper is to overview the present condition of renewable energy in Bangladesh and hence, different types of renewable energy are discussed from global perspective to achieve a transparent perception about solving power crisis issues with this sustainable approach.**

Keywords*— Renewable Energy, Energy Policy, Solar PV, Solar Thermal, Wind Energy, Hydro Power, Biomass, Tidal, Geothermal, Wave Energy.

I. Introduction

Electricity is one of the major breakthroughs in the history of mankind which has brought the human civilization at its pinnacle. It is the most preferred form of energy as it can be converted to other energy form easily and it is also clean and easy to use. But the primary energy sources that are available in nature like coal, oil, gases for the production of electricity are limited in nature. As the amount of these energy sources are declining with time [1], the alternative option to produce electricity like use of renewable energy technology is drawing more attention day by day. Moreover, issue like climate change is also compelling us to think more deeply over green technologies as the conventional fuels may have some negative impact on the environment. For example, use of fossil fuels like coal, oil and gas for power generation result in a significant amount of emission of carbon in the atmosphere [2]. If the nuclear fuel is considered, inadequate and sensitive waste management may have a severe effect on the environment [3].The global perceptions of renewable energy have shifted considerably since 2004 and over the last 10 years, continuing technology advances and rapid deployment of many renewable energy technologies have demonstrated that their potential can be achieved. But, still it has not become the one fourth portion of world total energy consumption. The lion's share of energy consumption is dominated by fossil fuels which are about 78.4% [Fig.1] while nuclear and all renewable contributions are 2.6% and 19% respectively [4]. In this paper, firstly the present power scenario of Bangladesh and the government policy towards renewable energy have been discussed. The prospects and possibilities of different types of renewable energy have been focused on the later sections.

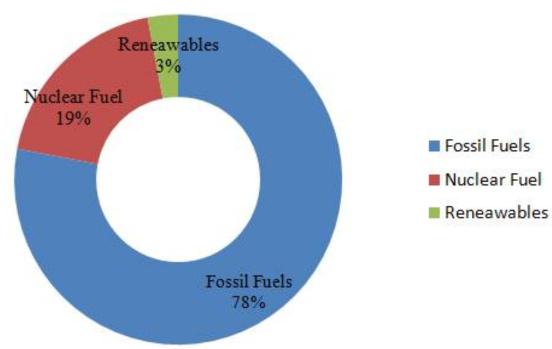

Figure 1: Global Energy Consumption [4]

At present, the total installed capacity and the derated capacity of Bangladesh are recorded as 11,532 MW and 10,937 MW respectively [5]. But, still it is not sufficient to meet the high power demand since only 68% of the total population has access to electricity and per capita generation is 372 kWh, which is very low compared to other developing countries [6]. The proportion of renewable energy sources as fuels is very less to the total generation contribution which is about 2% and it comprises mainly with hydro power [Fig.2].

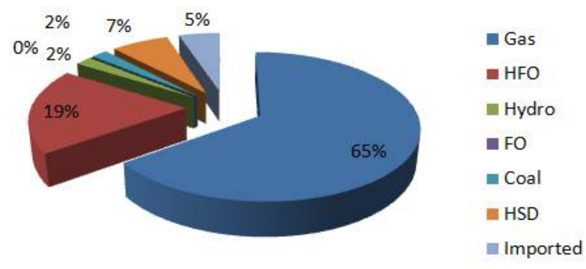

Figure 2: Various Fuels contribution in energy production [6]

Feeling the urge of diminishing of natural gas and other fuels, meet the growing power demand with sustainable energy and to achieve the goal of providing electricity to all by 2020, the government of Bangladesh (GOB) has adopted the renewable energy policy in 2008. The policy envisions that 5% of total energy production will have to be achieved by 2015 and 10% by 2020 [7]. In the next section of this paper, the contemporary conditions of different renewable energy like solar PV, solar thermal, wind, tidal, biomass, geothermal, wave, hydro and micro-hydro have been discussed and the specific features are highlighted with a view to achieving the goal of the policy.

II. SOLAR PV & SOLAR THERMAL

The energy from sunlight or solar energy has the capability of playing a salient role in electrical energy production. The worldwide solar energy utilization is quite flourishing and the total solar capacity has reached almost 143 GW which comprises solar PV mostly (139 GW) and also concentrating solar thermal energy (3.4 GW) [8]. Since the geographical position of Bangladesh lies in the Tropic of cancer region (From 20°34″ North Latitude to 26°38″ North Latitude and From 88°01″ East Longitude to 92°41″ East Longitude) which

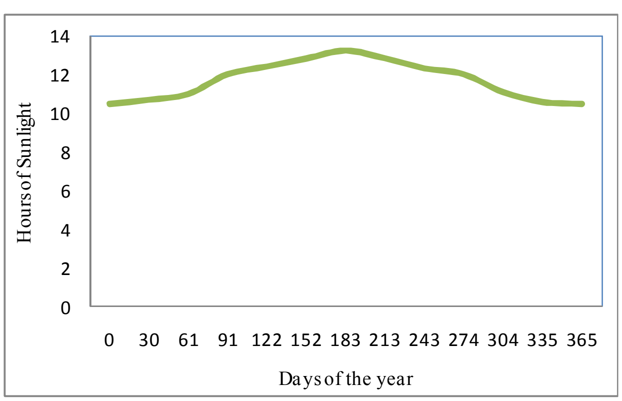

Figure 3: The amount of hours of sunlight in Bangladesh [9]

is adjacent to the equator, variation of the amount of sunlight per day is less significant here which makes it as a perfect place for solar energy utilization. This phenomenon is clearly illustrated in the curve of Fig.3.

Instead of being implemented as plant production to the grid, the solar power is more effectively used as distributed system in Bangladesh. Infrastructure Development Company Limited, IDCOL, as a government-owned financial institution and focused on renewable energy utilization, has been running three programs which are Solar Home System (SHS) Program, Solar mini-grid and Solar irrigation pump project. Under SHS program, IDCOL achieved its target to install 1 million SHSs by 2012 and over 2.9 million SHS have been installed all over Bangladesh till March 2014. The total number of beneficiaries under the program is about 13 million rural people which is more than 8.2% of the total population of the country [10]. IDCOL provides supports to install solar PV based mini grids to different organizations including non-government organizations (NGOs), micro-finance institutions (MFIs) and private sector companies. Solar irrigation pump program can contribute a lot to reduce the burden of subsidy and reliance on fossil fuel (diesel run pumps in this case) for irrigation purpose. Projection of installation of solar irrigation pumps till 2016-17 is given in TABLE I.

TABLE I

INSTALLATION OF SOLAR IRRIGATION PUMPS [10]

Year	No of Pumps	Cumulative installation
2012-13	17	17
2013-14	150	167
2014-15	300	467
2015-16	450	917
2016-17	633	1350

While Solar PV power systems are propagating with an increased rate throughout the country, the possibility of growing solar thermal energy plant is still remaining in pen and paper work. Although, BPDB had signed a deal with Solarium Power Limited to construct a 18 MW solar thermal power plant in Mymensingh, the unavailability of land, lack of mobility of fund and uncertainty in getting equipment and materials made this project work nipped in the bud [11]. Moreover, the installation of distributed solar thermal applications like solar cooking, water heating, distillation, drying, refrigeration has not established well yet. These factors should be given priority since successful implementation of them can be the solution of problems like declining of natural gas.

III. HYDRO POWER & GEOTHERMAL POWER

Hydro power is the generation of electrical energy by harnessing water's kinetic energy created by gravity. Hydro power is centered on the efficiency of the water 's kinetic energy converting to electrical energy. Global hydropower generation during the year was an estimated 3,750 TWh. About 40 GW of new hydropower capacity was commissioned in 2013, increasing total global capacity by around 4% to approximately 1,000 GW. By far the most capacity was installed in China (29 GW), with significant capacity also added in Turkey, Brazil, Vietnam, India, and Russia. Growth in the industry has been relatively steady in recent years, fuelled primarily by China's expansion. Modernization of ageing hydropower facilities is a growing global market. Some countries are seeing a trend towards smaller reservoirs and multi-turbine run-of-river projects. There also is increasing recognition of the potential for hydropower to complement other renewable technologies, such as variable wind and solar power. The Karnafuly Hydro Power Station is the only hydropower plant in the country (located at kaptai, about 50 km from the port city of Chittagong), having a capacity of 230 MW by 5 units. It is operated by BPDB (Bangladesh Power Development Board). Two sites have been chosen for another two Hydro power plants at the Sangu and Matamuhuri rivers, one named The Sangu project (140MW) and the other The Mata-muhuri Project (75MW). Being a riverine country and having a suitable geography condition, Bangladesh has an enormous prospect in micro-hydro power. BPDB has designed a 20kW micro-hydro power plant with the help of RETScreen, developed by CANMET Energy Diversification Research Laboratory of Canada (CEDRL) at Barkal (a sub-district in the Chittagong Hill tracts) waterfall [12]. In 1981, Bangladesh Water Development Board and Bangladesh Power Development Board explored potential sites which are suitable for micro-hydro power generation which are listed in Table 2 [13]. Sustainable Rural Energy (SRE) has explored some potential micro-hydro sites in Chittagong region in 2004 which is listed in Table 3.

TABLE II

PROMISING SITES FOR MICRO-HYDRO PLANTS [13]

District	River/Chara/Stream	Potential of Electrical energy in kW
Chittagong	Foy's Lake	4
	Choto Kumira	15
	Hinguli Chara	12
	Sealock	81
	LungiChara	10
	Budiachara	10
Sylhet	Nikhari Chara	26
	MadhabCha-ra1500ft. from fall	78
	Ranga pani gung	616
Jamalpur	Bhugai-Kongsa at 2 miles U/S. of Nalita-bari P.S.	69 kw for 10 months 48 kw for 2 months
	Marisi at Duka-bad near Jhinaigati Thana Head Quarter	35 kw for 10 months 20 kw for 2 months
Dinajpur	Dahuk at Burabari	24
	Chawai at U/S. of Chawai L.L.P	32
	Talam at U/S. of Talam L.L.P	24
	Pathraj at Fulbari	32
	Tangon at D/S of Nargun L.L.P	48
	Punarbhaba at Singraban	11
Rangpur	Buri Khora Chikli at Nizbari	32
	Fulkumar at Rai-ganj Bazar.	48

TABLE III

SITES EXPLORED BY SRE [13]

Site	**Expected Power Generation (KW)**	**Socio-economic Infrastructure within 1 Km**		
		House hold	***School / Mosque/ Bazaar/ Clinic***	***Small Industry***
Nunchari Tholipara, Khagrachari	3	100	3	1
Chang-ooPara, Bandarban	30	200	5	2
Bangchari, Bandarban	25	600	12	5
Liragaon, Bandarban	20	500	8	3
Kamalchar, Rangamati	20	150	8	9
ThangKhrue Rangamati	30	300	6	3
Monjaipara, Bandarban	7.5	50	3	-

Geothermal energy can be simply defined as the thermal energy which is stored inside the earth surface. The idea is to extract the heat from inside the surface and then process and convert it to electrical energy. At least, 530 MW of new geothermal power generating capacity came on line in 2013, bringing total global capacity to 12 GW, generating an estimated 76 TWh annually [8]. Recently, Bangladesh Government has approved planting a geothermal power station at Saland village in Thakurgaon district. A Dhaka based private company named Anglo MGH Energy is carrying out this project having the aim to add about 200 MW in the national grid. The northern part of Bangladesh can be a optimistic region for discovering suitable geothermal power sites as the geothermal map suggests that an acceptable high closed-surface temperature can be attained on those areas. But, before looking forward to mark more sites, the successful implantation and the initialization of generation of power from the Saland site which is now in pipeline development step, is to be ensured.

IV. TIDAL POWER & OCEAN WAVE POWER

The concept of tidal energy deals with using the tides of river or ocean as they flow with a varying altitude indicating remarkable potential energy and thus, this energy can be converted into electrical energy. Comparing with the other renewable energies like solar energy technologies, the growth of tidal energy is less flourishing. In fact, the worldwide energy production from tidal sources is still far behind from a remarkable benchmark. According to renewable 2014 global status report, ocean energy capacity, mostly tidal power generation, was about 530 MW by the end of 2013 [8]. The world's first and second large-scale tidal power plant, the Rance Tidal Power Station located at the estuary of the Rance River, operated in 1966 is 240 Megawatts, which is generated by its 24 turbines. It supplies 0.012% of the total power demand of France [14]. The world's biggest tidal power station operated by the Korean Water Resource Corporation in 2011 having total output capacity 254 MW with mean operating tidal range 5.6 m is situated at Sihwa lake tidal power station [15]. In Bangladesh, the most promising location for tidal power application is Sandwip Island which is located in the Bay of Bengal, about 15 km from the Chittagong mainland. A flood control barrier exists around the entire island, and this contains 28 sluice gates. These barrages and sluice gates can be used for electricity generation. Researches have been done to analyze the feasibility of establishing tidal power plant at Sandwip. One of the estimations is given in TABLE IV.

TABLE IV

SUMMARIZED OF SANDWIP PROJECT [14]

Parameter	Value
Tidal range	4.86m
No of sluice gates	28
No of turbine uses	05
Basin area	4×10^6m^2
Construction time	4 yrs
Cost	US $10.37 millions
Output Power	16.49 MW

Apart from Sandwip project, the government should also look forward the probable tidal sites of Mongla, Char changa, Hiron point, Teknaf, Cox'sbazar. As the mean tidal ranges vary from two meters to five meters in those sites[16], further researches and feasibility studies should be run on those cases. Ocean wave possesses both kinetic and potential energy and by means of ocean waves, tidal range (rise and fall), tidal currents, ocean (permanent) currents, temperature gradients, and salinity gradients, energy can be harnessed. Excluding tidal energy, very few wave energy generating stations are running at present. Organizations like Scotland's EMEC, the world's leading test facility for wave and tidal energy converters, continued to share its expertise globally during 2013. It announced an agreement to help set up a test facility in Singapore—the latest of several agreements with parties across North America and Asia [17]. In addition, neighboring Ireland recently launched its Offshore Renewable Energy Development Plan, committing funds for test facilities, R&D, and a feed-in tariff for ocean power [18]. Some analysis from research work shows us that it is possible to generate Power with full pace from April to October and considerable amount can be generated at rest of the months which is illustrated in Fig.4.

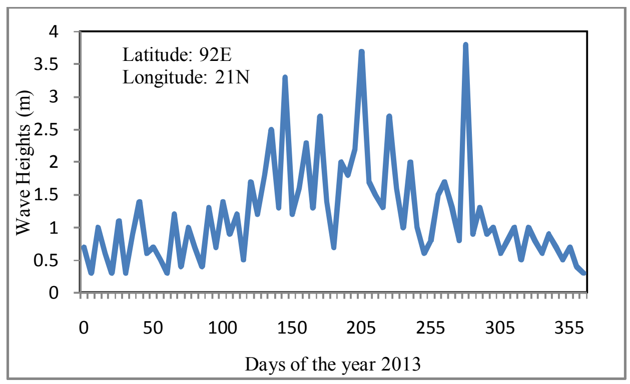

Figure 4: Wave heights of the year 2013[19]

V. BIOMASS & WIND ENERGY

Biomass energy refers to the inherited energy in the mass of biological material produced from the living processes. This includes the materials derived from plants as well as from animals. Being an agro-based country, Bangladesh has plenty of resources like cattle dung, agricultural residue, poultry dropping, water hyacinth, rice husk etc. for biomass power generation. Upto end of year 2013, biomass accounted for about 10% of global primary energy supply [8].

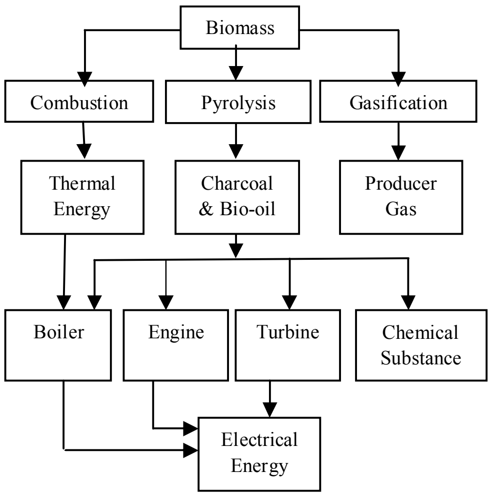

Figure 5: Biomass conversion into energy [20]

According to the latest census of the bureau of statistics of Bangladesh, Bangladesh has more than 97,000 poultry farms, 47,000 dairy farms for cattle fattening, 20,000 goat-farms registered ship-firms 394. The livestock industry of Bangladesh produces about 419,789ton wastes per day [21], polluting soil and water resources and creating environmental hazards. Besides, cow dung produced in many dairy firms can also be used for biogas based power generation. From this minimum 1,000 MW power can be produced. In addition, the slurry produced as a by-product, is a very good organic fertilizer and can be used for increasing agricultural productivity and maintaining soil stability. With support from SNV, Netherlands and KfW, Germany, the Biogas Program of IDCOL started as National Domestic Biogas and Manure Program in 2006. In 2012, the World Bank started providing supports as well. Till December 2013, more than 32,000 biogas plants have been installed all over Bangladesh [10]. Gas produced from these plants is used primarily for cooking purposes in rural households. IDCOL had so far financed 4 biogas based power plants with various capacities. The largest one with 140 cubic meter biogas plant can run a 50 kW generator for 6 hours daily. In developing countries like Bangladesh, where centralized grid systems fail to reach millions of people in rural and remote locations, distributed systems like biogas power plant can be crucial to providing access to electricity.

Wind energy technology is nothing but using the kinetic energy of wind to produce electricity. When the wind flows, it has a kinetic energy. A turbine rotates by the flow of this wind and then a generator coupled with it converts the mechanical energy to electrical energy.

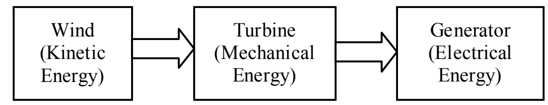

Figure 6: Conversion of Wind Energy to Electrical Energy

Bangladesh has approximately 710 km long coastline runs parallel to the Bay of Bengal [22] which comprises more than 200 km long hilly coast-line and more than 50 islands in the Bay of Bengal. The strong South and South-westerly monsoon wind coming from the Indian Ocean, after travelling a long distance over the water surfaces, enters into Asia over the coastal areas of Bangladesh. This trade-wind blows over our country from March to October. The wind is enhanced when it enters the V-shaped coastal regions of our country. Since this trade wind strikes the coastal belt of Bangladesh, after travelling a long distance over ocean water surfaces, it becomes energetic. Along the coastal area of Bangladesh, the annual average wind speed at 30m height is more than 5 m/s [23]. Wind speed in northeastern parts in Bangladesh is above 4.5 m/s while for the other parts of the country wind speed is around 3.5 m/s [23, 24]. Several organizations like Grameen Shakti, BRAC, IFDR have installed wind turbines in different places of the country [Table V].

TABLE V

INSTALLED TURBINE BY DIFFERENT ORGANIZATIONS [25]

Organization	**Location**	**Type of Application**	**Installed Capacity (KW)**
Grameen Shakti	Coastal Region	Hybrid	4.5
	Coastal Region	Hybrid	7.5
BRAC	Coastal Region	Stand-Alone	0.9
	Coastal Region	Hybrid	4.320
Bangladesh Army	Chittagong Hill Tracts	Stand-Alone	0.4
IFDR	Teknaf	Stand-Alone	1.1
	Meghnaghat	Stand-Alone	0.6
LGED	Kuakata	Hybrid	0.4
		Total	19.72

Apart from these distributed wind generated power systems, US-DK Green Energy (BD), a joint venture between Taylor Engineering Group of USA, ph-consulting group of Denmark and Multiplex Green Energy of Bangladesh, will set up a 60-megawatt wind turbine power plant at Kurushkul, southeast of Moheshkhali River in partnership in the coastal belt of Cox's Bazar to generate green electricity. The project that will be built at a cost of $120 million is expected to begin commercial operation by May 2015. It will boost the production of renewable energy, which now accounts for 2 percent of total electricity generated in the country.US-DK Green Energy will sell electricity at $0.12 a kilowatt-hour to state-run Bangladesh Power Development Board [26]. The future of wind energy depends largely on the success of this initiative.

VI. CONCLUSION

The overview and analysis of current status of power and renewables of Bangladesh clearly indicates that the undergoing renewable energy projects should be accelerated to achieve the policy goal. If the Ruppur nuclear power with 1000 MW of two units come into operation within 2018, then the present increment of renewables project will not be sufficient to reach the goal. Apart from policy accomplishment, enhancement of renewable energy is essential for fuel diversification program. Specific tasks should be given emphasis like the present subsidy towards SHS project should be increased from 10% to 25% as it was to ensure the fulfillment of demand of electricity to the rural people. Various rural-based solar projects like SHS run by different NGOs and the Government should also be extended to the cities. Mass implementation of it can reduce the pressure on the national grid effectively. Researches should be extended towards the utilization of tidal and wave energy of Bangladesh. A market should be developed so that local and foreign entrepreneurs would convince to invest in biomass gasification projects. Government of Bangladesh would need to amend energy policy so that the gasification plants can run to their full capacity and can sell the surplus electricity to the grid. The accomplishment of these steps can contribute significantly to solve the power crisis issues and have a positive impact on the environment.

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Performance Characterization of Photovoltaic Technology with Highly Efficient Multi-Junction Solar Cells for Space Solar Power Satellite System

Golap Kanti Dey, Kazi Tanvir Ahmmed

Department of Applied Physics, Electronics and Communication Engineering,

University of Chittagong, Chittagong-4331, Bangladesh

d.k.golap@gmail.com, tanvir@cu.ac.bd

Abstract- **In our research work electrical characterization with different generation of solar cells depending upon the emergence as- First Generation: Mono and Poly-crystalline Silicon, Second Generation: Thin-film Solar Cell, Third Generation: Full Spectrum Utilization with comparative efficiency study of different solar cells is investigated. Besides, major part of our research is Multi-Junction Solar Cells (MJSC), for Space Solar Power Satellite (SSPS) system, created from III-V semiconductor materials, exhibit high efficiencies comparing to other existing photovoltaic technology. Here we have shown MJSC's are composed of 3 layers of material that have different bandgaps. The upper layer has the largest bandgap while the lower layer has the smallest bandgap. This model allows less energetic photons to pass through the upper layers and be absorbed by the lower layer, which increases the overall efficiency. One significant estimation is that generated photocurrent in each layer must be the same since the layers are in series. Besides, for most effective absorption from the spectrum of incident radiation, the bandgaps of each layer should differ by approximately equal energies . Due to the high cost, multi-junction solar cells are usually used in the SSPS system, in Microwave Power Beaming from space to ground based receiving station and as collector cells where a large amount of sunlight is reflected onto the cell.**

Keywords: Solar Cells, electrical characterization, PV technologies, III-V Multi-Junction solar cell, efficiencies of solar cells etc.

I. INTRODUCTION

The Sun is a very powerful, clean and convenient source of energy, particularly for human being. Solar Power is totally free from any kinds of emissions, including carbon dioxide. According to an increasing world-wide energy demand in the 21st century and of a need for a clean energy source, humanity desperately needs assured, reliable, 24/7, economical energy sources and for that purpose Solar Power Satellite (SPS) [1] concept has been explored by scientists and engineers. Solar power satellite (SPS) is a renewable and infinite energy system in the Geostationary Earth Orbit (GEO), which works as an electric power plant in space. To collect solar power we need solar panel with efficient solar cell attached with satellite system.

A solar cell [2] is a semiconductor device designed and fabricated to efficiently absorb the light energy and convert it into electrical energy. Sunlight impinges through the top surface of the solar cell. Conventional Solar cell is made when an *n*-type and *p*-type semiconductor are brought together forming a metallurgical junction. This is achieved through diffusion or ion implantation of specific impurities or by deposition process. When the cell absorbs light, mobile electrons and holes are created. The electrons are holes move in opposite directions as shown in figure 1 and contribute in the generation of DC power from the illuminated cell.

Any electromagnetic radiation including solar radiation is composed of packets of energy or quanta which are made up of photons. Photons have wavelike properties having wavelength λ related to photon energy $E_p = hc/\lambda$ where h is Plank's constant and c is the velocity of light.

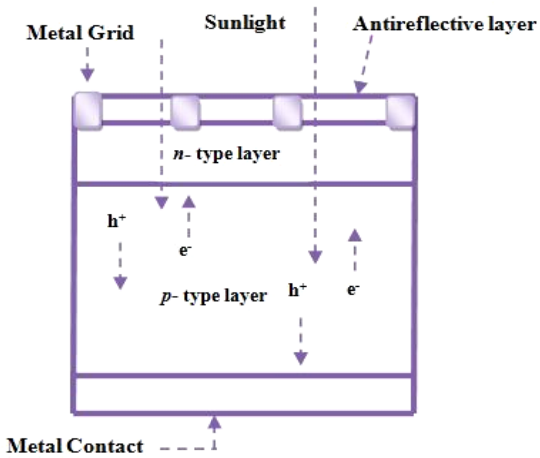

Fig. 1. Cross section of a simple conventional solar cell

The state-of-the-art in photovoltaic (PV) devices is multi-junction solar cell (MJSC). Space power generation has involved the continual improvement of device designs to achieve higher efficiencies from MJSC. Multi-junction solar cells [1] consist of some single-junction solar cells stacked upon each other, so that each layer going from the top to the bottom has a smaller bandgap than the previous, and so it absorbs and converts the photons that have energies greater than the bandgap of that layer and less than the bandgap of the higher layer.

The first multi-junction device was demonstrated in early 1980s, and it converted 16% of the solar energy into electricity [3]. In 1994, US National Renewable Energy Laboratory (NREL) broke the 30% barrier. An efficiency of 40.7% was achieved [4] in 2007 with GaInP/GaInAs/Ge triple-junction version of the solar cell. Besides, the maximum theoretical efficiency of multi- junction solar cell is 86.8% [5].

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However, recently in December 2014 Jointly Soitec and CEA-Leti, France, together with the Fraunhofer Institute for Solar Energy Systems ISE ,Germany announced that in the lab they have achieved an efficiency of 46% [6] for the conversion of sunlight into electricity using III-V multi-junction solar cell. Besides several investigation and research works are also conducting now-a-days by space agencies and laureate researchers. Though several researchers have been investigated on solar cells, however, further research regarding to the highly efficient solar cell for space solar panel is still needed.

In our research work we will deploy electrical characterization of solar cell with different generation such as- Mono and Poly-crystalline Silicon, Thin-film Solar Cell, and Full Spectrum Utilization. However, major part of this research work is Multi-Junction Solar Cell for the uses in SPS system. So the basic principle of our research effort is to give a brief idea about different kinds of solar cells available in market with their comparative efficiency study and every pros and cons with physics of Multi-Junction Solar Cell (MJSC) involved with space use. Present status of MJSC is also discussed here with efficiencies.

II. ELECTRICAL CHARACTERIZATION

A. Current-Voltage (I-V) Curves

Solar cells can be operated over a wide range of voltages and currents. I-V curves are used to measure the electrical characteristics of photovoltaic (PV) devices, and are normally presented as "current-voltage characteristic curves", or "I-V curves". These curves are realized by varying continually the load resistance from open-circuit to short-circuit states, registering the voltage and current values. Figure 2 displays a typical I-V curve plot. On an I-V plot, the ordinate refers to current, and the abscissa to voltage. The I-V curve passes through two significant points, the short-circuit current (I_{sc}) and the open-circuit voltage (V_{oc}).

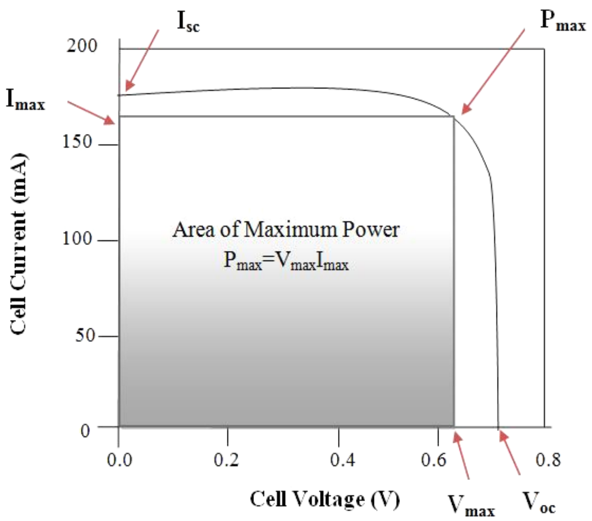

Fig. 2. Typical Characteristic I-V Curve of PV Cell

B. Maximum Power (P_{max})

The solar cell may be operated over a wide range of voltages and currents by varying the load resistance from zero to infinity. The Maximum Power (P_{max}) point occurs when the product of the current and voltage is maximum. The current and voltage at the maximum power point are denoted by I_{max} and V_{max}, respectively.

C. Fill Factor (FF)

The fill factor (FF) percentage measures the "squareness" of the I-V curve. It states the degree to which the voltage at the maximum power point (V_{max}) matches the open-circuit voltage (V_{oc}) and that the current at the maximum power point (I_{max}) matches the short-circuit current (I_{sc}). Therefore, a more "squared" I-V curve will have a higher fill factor. This relation is given by-

$$\text{Fill Factor (FF)} = \frac{I_{max}.V_{max}}{I_{sc}.V_{oc}}\ [\%] \ldots\ldots\ldots\ldots (1)$$

D. Conversion Efficiency

The conversion efficiency of a solar cell is the percentage of the total incident solar energy on a photovoltaic device that is converted into electrical energy. This relation is given by

$$\text{Conversion Efficiency} = \frac{P_{max}}{\text{Incident Solar Energy}} \ldots.\quad (2)$$

E. Quantum Efficiency (QE)

Quantum efficiency (QE) is the ratio of the number of charge carriers collected by the solar cell to the number of photons of a given energy incident on the PV device. QE therefore is related to the response of a solar cell to the various wavelengths in the spectrum of incident light on the cell. The QE is given as a function of either wavelength or energy.

III. DIFFERENT GENERATIONS OF SOLAR CELL (PHOTOVOLTAIC) TECHNOLOGY

Solar cell technologies are classified into three generations depending upon the emergence. Even though first generation of solar cells is mostly in production representing more than 85% of total solar cell production, from third generation solar cells we get maximum conversion efficiencies rather than other two generations.

A. First Generation: Mono and Poly-crystalline Silicon

Having a semiconductor *p-n* junction the first generation of solar cells is mostly consists of high quality mono-crystalline silicon wafers. This technology is already matured and slowly approaching the Shockley theoretical efficiency of 31% [7]. It is very difficult to grow large crystals of pure silicon, which is a major challenge in the reduction of production cost. Another Problem with mono-crystalline silicon solar cells is that the efficiency decreases with increasing temperature. Poly-crystalline silicon solar cells are the perfect replacement to mono-crystalline formation. They are made from multiple silicon crystals in mold reducing the cost along with a reduction in efficiency. The first generation devices attain cost parity with fossil fuel energy generation after a payback period of 5-7 years; however the cost of first generation technology is very unlikely to go down to $1/kWh [8].

B. Second Generation: Thin-film Solar Cell

The challenges of expense and energy requirements of first generation solar cells have been researched to meet by Second generation solar. Alleviating the amount of material needed will reduce the cost of first generation solar cells. Wafers of crystalline silicon are usually 150-300 µm thick. Advancement in technologies like metal organic chemical vapor deposition, chemical vapor deposition, molecular beam epitaxy etc. has helped in the development of thin film technology.

The second generation solar cells are formed on thin films of semiconductor made by any deposition techniques unlike the formation of first generation solar cells from the bulk crystalline silicon material, which is the prime difference between first and second generation devices. The deposited layers are quite thin in comparison to first generation solar cells reducing the fabrication cost. There are mainly three categories of thin film solar cells - amorphous silicon, cadmium telluride or cadmium sulfide (CdTe/CdS) and the chalcopyrite family alloys like copper indium gallium selenide (CIGS). First thin film solar cell is made up of CdTe material. Organic materials also fall in this category as the processing is relatively simple and less expensive; however very low efficiency (1% - 5%) is the major shortcoming of this technology [8-9]. Efficiency comparisons among different generation of solar cells [10] such as Si solar cell, III-V solar cell cells, Organic solar cell and Multi-junction solar cells are shown through pie chart in the figure-3.

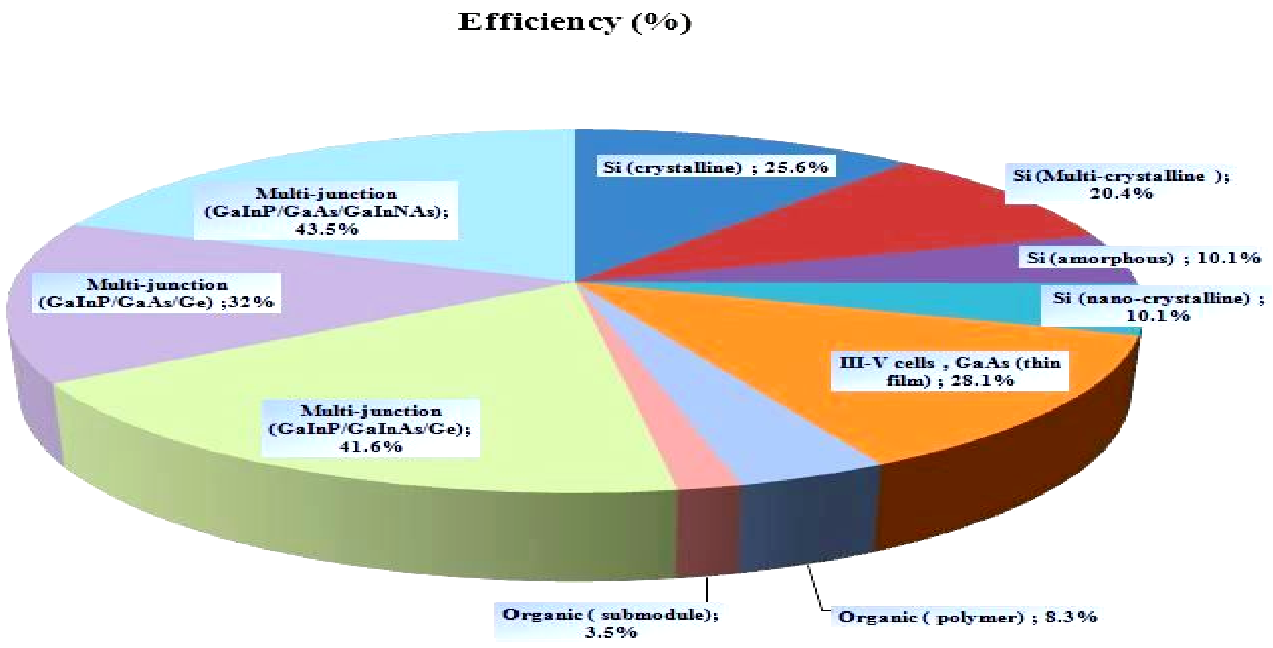

Fig. 3. Efficiency Comparisons among Different Solar Cells

C. Third Generation: Full Spectrum Utilization

There are two fundamental limitations in first and second generation solar cells .First of all, the photons of energy less than the bandgap of the semiconductor material are not absorbed by the solar cell and secondly even if a photon has energy greater than the bandgap, in fact the photons of equal energy of the bandgap are effective for conversion into electricity.For these limitations researchers are searching for designing and developing multi-junction PV [11] system or tandem solar cells to utilize the entire solar spectrum with different bandgap energy semiconductors. The multi-junction device [12] is basically a stack of cells each capturing a different portion of the solar spectrum. The materials of which the stack of cells are made have different bandgap energies with differing by nearly equal energies where the topmost cell having the highest bandgap and the bottom cell having the lowest bandgap energy. Higher energy photons are absorbed in the upper layers and lower energy photons are passed to the lower layers. The most efficient PV devices are made up of this multi-junction technology. Because of the high cost this technology is currently used for terrestrial purposes only but will be available for commercial applications soon. This technology will address the shortcomings of first and second generation PV technologies.

IV. HIGH EFFICIENCY III-V MULTI-JUNCTION SOLAR CELLS

III -V semiconductor materials show high efficiencies matched by no other existing photovoltaic technology. Multi-Junction Solar Cell (MJSC) uses multiple materials with bandgaps that span the solar spectrum.

Multi-junction solar cells consist of some single-junction solar cells stacked upon each other, so that each layer going from the top to the bottom has a smaller bandgap than the previous, and so it absorbs and converts the photons that have energies greater than the bandgap of that layer and less than the band gap of the higher layer. Schematic of a multi-junction solar cell is shown in figure-4.

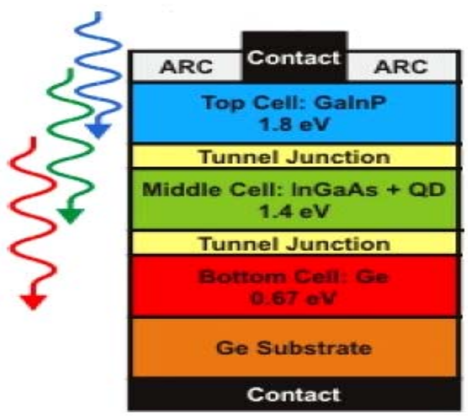

Fig. 4. Schematic of typical multi-junction third generation Solar Cell (Source- Sunlab, Ottawa, Canada)

Alloys of groups III and V of the periodic table are good candidates for fabricating such multi-junction cells: their band gaps span a wide spectral range, and most of the bandgaps have direct electronic structure, implying a high absorption coefficient, and their complex structures can be grown with extremely high crystalline and optoelectronic quality by high-volume growth techniques [12,13]. Figure 5 shows the solar energy that can be theoretically used by single- and III-V triple - junction cells.

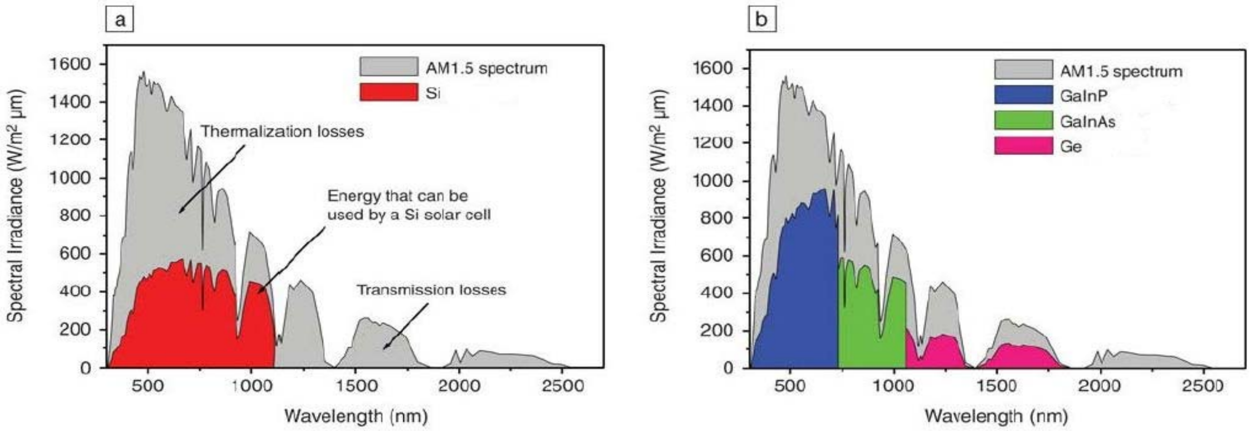

Fig. 5. The AM1.5 solar spectrum1 and the parts of the spectrum that can, in theory, are used by: (a) Si solar cells; (b) $Ga_{0.35}In_{0.65}P/Ga_{0.83}In_{0.17}As/Ge$ solar cells [14]

A. Wavelength Dependence of Photon Conversion Efficiency

Since the solar spectrum is broad, containing photons with energies in the range of about 0 to 4 eV, single-junction solar cell efficiencies are thus inherently limited to significantly less than the efficiency with which monochromatic light can be converted. The solution to this problem is simple: rather than trying to convert all the photon energies with one cell with one band gap, divide the spectrum into several spectral regions and convert each with a cell whose band gap is tuned for that region. The greater the number of spectral regions allowed, the higher the potential overall efficiency.

B. Spectrum Splitting

The multi-junction approach requires that incident photons be directed onto the junction that is tuned to the photon's energy. Perhaps the conceptually simplest approach would be to use an optically dispersive element such as a prism to spatially distribute photons with different energies to different locations, where the appropriate cells would be placed to collect these photons. This approach is illustrated in Figure 6 (a). Although conceptually simple, in practice the mechanical and optical complexities of this scheme make it undesirable in most circumstances. A generally preferable approach is to arrange the cells in a stacked configuration, as illustrated in Figure 6 (b), arranged so that the sunlight strikes the highest band gap first, and then goes to the progressively lower band gap junctions. This arrangement makes use of the fact that junctions act as low-pass photon energy filters, transmitting only the sub–band gap light. Thus, in Figure 6 (b), photons with $h\nu > E_{g3}$ get absorbed by that junction, photons with $E_{g2} < h\nu < E_{g3}$ get absorbed by the E_{g2} junction, and so on; in other words, the junctions themselves act as optical elements to distribute the spectrum to the appropriate junctions for multi-junction photo conversion.

C. Bandgaps

For the maximization of conversion efficiency the solar cell should be designed in the way so that it can absorb as long of the spectrum as possible, and so bandgaps [15, 16] be able to cover a wide range. In addition, band gaps of adjoining layers should differ by as small amount as possible, because the amount of excess energy from light converted to heat is equal to the difference between the photon energy and the bandgap of the absorbing material.

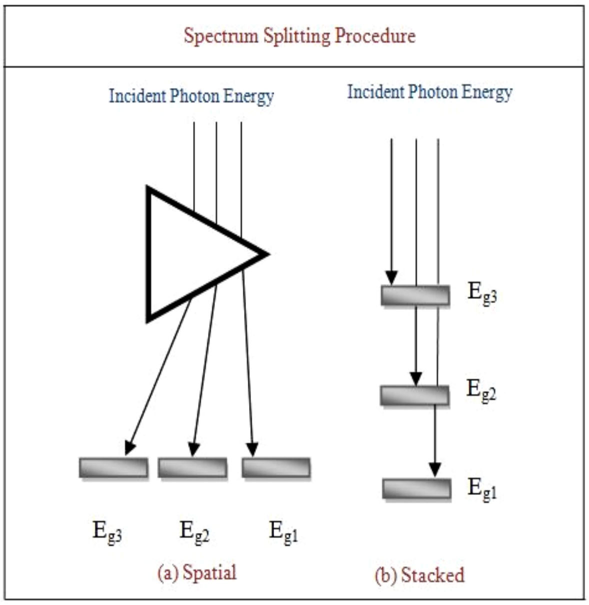

Fig. 6. Schematic comparison of (a) spatial-configuration approaches and (b) stacked- configuration approaches to distributing light to sub cells of different band gaps.

D. Lattice Constants

To generate optical transparency and maximum current conductivity in monolithic multi junction solar cells, all layers must have similar crystal structure. The spacing of the atom locations in a crystal structure is commonly known as lattice constant. Any kinds of mismatch in the crystal lattice constants of different layers create deviation in the lattice of the cell layers and significantly decline the efficiency of the solar cell. NREL showed [17] that a lattice mismatch as small as 0.01% significantly decreases the current produced by the solar cell. In the figure-6 lines between different materials represent semiconductors that can be created by combining different amounts of the two materials. GaAs, AlAs and Ge have same lattice constant with different bandgaps, and compositions of these materials are currently used to create high-efficiency triple-junction cells [18].

E. Current matching

The fabrication of monolithically-grown multi-junction solar cells makes matching of currents a desirable characteristic [19]. As the layers are in the series the currents through each of the subcells are imposed to have the same value. The current is directly proportion al to the number of incident photons exceeding the semiconductor's bandgap, and the absorption constant of the material.

A layer must be made thinner if the photons that exceed the bandgap are in abundance. At the same time, a layer with a low absorption constant must be fabricated thicker, as on average a photon need to pass through more of the material before being absorbed.

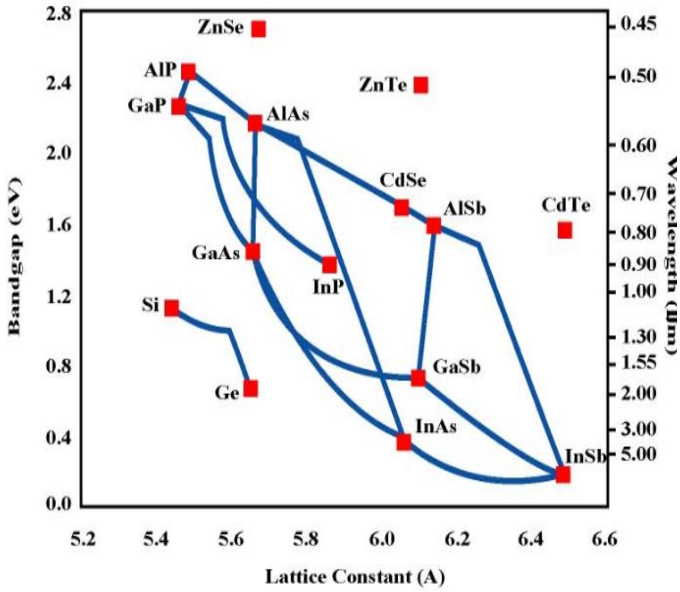

Fig. 7. Ternary and quaternary III-V compounds relation between lattice constant and band gap [20].

F. Present Status of Multi-junction Solar Cell

The most efficient present-day multi-junction photovoltaic cells are made of GaInP, GaInAs, and Ge layers on Ge substrate. Quantum Efficiencies (QE) of each layer of this cell are demonstrated on Figure 8 [21]. Besides, Triple-junction solar cells currently in production are made of GaInP (1.9 eV), GaAs (1.4 eV), and Ge (0.7 eV); advanced multi-junction solar cell concepts foresee use of AlGaInP (2.2 eV), AlGaAs (1.6 eV), GaInP (1.7 eV), GaInAs (1.2 eV), GaInNAs (1.0-1.1 eV) [10]. For example, Spectrolab's record-breaking cell used $Ga_{0.5}In_{0.5}P$ with band gap energy of 1.85 eV and the lattice constant of 5.65 A^{o}. Less gallium and more indium would be used in the compound, if a lower bandgap material were desired, up to the resulting InP with band gap energy of 1.3 eV and the lattice constant of 5.88 A^{o}. However, such an adjustment in bandgaps should be made in conjunction with lattice-constant constraints [22].

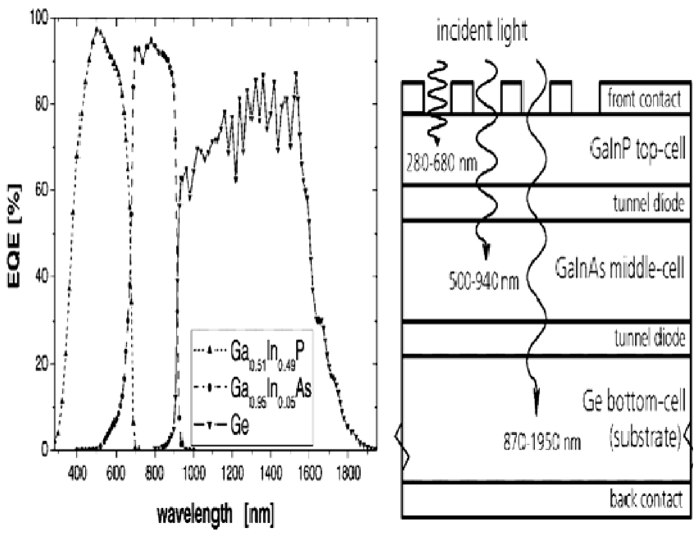

Fig. 8. Quantum Efficiency of Triple Junction System and Corresponding Cell Design [21]

The configuration of the record-efficient triple-junction Spectrolab's device is $Ga_{0.44}In_{0.56}P/Ga_{0.92}In_{0.08}As/Ge$. Its behavior is represented by current versus voltage curve on Figure 9.

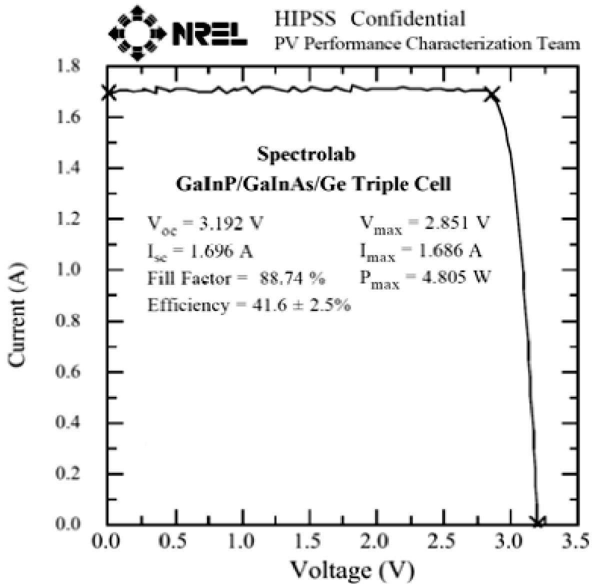

Fig. 9. Performance characteristics of Spectrolab's GaInP/GaInAs/Ge solar cell [23]

However, the current multi-junction cell architectures with reported efficiencies in the 40% range are shown in figure 10.

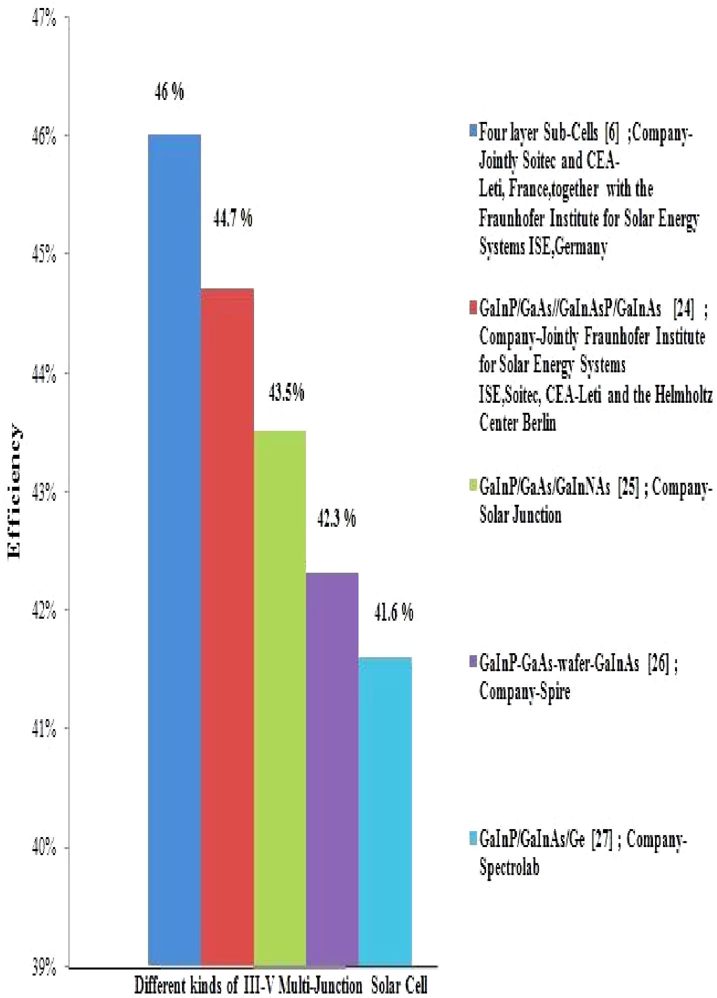

Fig. 10. Summary of Efficiencies for III-V Multi-Junction Solar Cells

V. CONCLUSION

Due to the world's economical growth over the past thirty years, there is increasing demand in finding new, highly efficient renewable alternatives to fossil fuel-based energy supplies. One of the most promising and easily available non-fossil fuel alternatives is solar power. To collect solar energy we need PV technology i.e. Mono and Poly-crystalline Silicon solar cells or Thin film solar cells or III-V Multi-junction solar cells (MJSC). The efficiency of space solar cells has achieved dramatic improvements as the focus diverted from Si toward multi-junction semiconductor solar cell such as $Ga_{0.35}In_{0.65}P/Ga_{0.83}In_{0.17}As/Ge$ etc. We have depicted in our research work that III-V MJSC's are the suitable candidate for the Space Solar Power Satellite (SSPS) system to collect solar power through utilizing the entire solar spectrum. The higher efficiencies rather than other available solar cells and radiation resistance of III-V MJSC's have made them perfect replacement for silicon cells on many space vehicles and satellites. So, it can be said that the state-of-the-art in photovoltaic (PV) devices is III-V Multi-junction solar cell which consists of some single-junction solar cells pile up upon each other, so that each layer going from the top to the bottom has a smaller bandgap than the previous with differing by nearly equal energies. Higher energy photons are absorbed in the upper layers and lower energy photons are passed to the lower layers. Although III-V multi-junction cells are costly to produce rather than the other solar cells, Concentrated Photovoltaics (CPV) can be used to counter this issue. The application of concentrators allow multi-junction solar cells to be manufactured at a much lower cost as the relative value of a lens or mirror is much lower than semiconductor material.

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Solid State Lighting can Resolve the Present Power Crisis in Bangladesh

Md. Meganur Rhaman
Dept. of EEE
Ahsanullah University of Science & Technology
Dhaka, Bangladesh,
mizan.eee@aust.edu

M A Matin
Dept. of GCE
Bangladesh University of Engineering and Technology
Dhaka, Bangladesh
matin.gce@buet.edu

Tanvir Ahmed Toshon
Dept. of EEE
Ahsanullah University of Science & Technology
Dhaka, Bangladesh
toshon.ndc@gmail.com

Abstract—**Power crisis is the most concerning problem in Bangladesh for the past few decades. Despite a lot of attempts by the Bangladesh Government, due to increasing population & rapid industrial growth, this problem seems to be augmenting day by day. Energy preservation is the result of financial capital increase of the country and also increases the environmental values. Being a developing country, Bangladesh lacks the utilization of renewable energy sources, so almost majority of the power generation techniques are based on Fossil Fuel, Gas and Coal, which is created air and water pollution, also negative impact on global calamity. So, to solve the power crisis, alternative means are needed to be taken account of. If power consumption can be reduced somehow, then with the present generation capacity, it would be possible to generate power in coherence with the demand of the consumers. In this paper, we have discussed about how Solid State Lighting (SSL) like Light Emitting Diode (LED) can reduce the daily power consumption in Bangladesh. SSL offers many benefits such as long life, energy saving, better quality light and so on, only one drawback is initially high cost which is not accountable for long terms use. By utilizing the features of SSL the power consumption in Bangladesh can be reduced significantly. We have represented the features of solid state lighting compared to other means of lighting sources. We have shown LEDs prospective contribution in reducing the power consumption with necessary calculations and statistics.**

Keywords— Bangladesh; SSL; LED; CFL; Incandescent lamp.

I. Introduction

A light-emitting diode is a two-lead semiconductor light source. It is a basic p-n junction diode, which emits light when it is activated. Anode side indicates positive sign (+) which is fabricated by P-type materials and Cathode side indicates negative sign (-) which is fabricated by N-type materials.

The present improvements in high power white light emitting diodes (LED) technology with 100 thousand hour's life time per LED chip and efficacy exceeding that of Incandescent lamps and Compact fluorescent lamp (CFL), brings the solid-state lighting (SSL) close to a reality. Long life is one of the key features of LEDs that has attracted the lighting community to this technology. The luminous efficiency of LEDs is soon expected to reach over 300 lumens/W. LEDs light source made of Red, Green and Blue (RGB). LEDs can provide a compact white light source with unique features. However, the white light generation using many compact, discrete RGB light sources. Specifically, the white color point maintenance is a stringent requirement in many applications. For maintaining this requirements, severe challenges due to the variation in the optical characteristics of the RGB-LEDs with temperature, time and forward current and the spread in the LED performance.

II. Solid State Lighting

Solid State Lighting (SSL) based on LEDs is an emerging technology with potential to greatly exceed the efficiency of traditional lamp-based lighting systems like incandescent lamp, CFL lamp. LEDs have already replaced traditional lamps in a number of lighting systems, including traffic lights, signs, and displays.

TABLE I. LED COMPARE TO TRADITIONAL LIGHT SOURCE BASE ON LIFE TIME

Light Source	Typical Range (hours)
Incandescent	750-2000
Halogen Incandescent	3000-4000
Compact Fluorescent(CFL)	8000-10000
Linear Fluorescent	20000-30000
Hugh power white LED	50000-100000

TABLE II. LUMINOUS EFFICIENCE TABLE OF LED WITH OTHERS LAMP

Light Source	Typical luminous efficacy (lumens/watt)
Incandescent light	12.5-17.5 lm/W
Halogen lamp	16-24 lm/W
Compact Fluorescent lamp	45-75 lm/W
LED lamp	Up to 300 lm/W

TABLE III. EQUIVALENT WATTAGE AND LIGHT OUTPUT OF INCANDESCENT, CFL & LED BULBS

Light Output	**LEDs**	**CFLs**	**Incandescent**
Lumens	Watts	Watts	Watts
450	4-5	8-12	40
750-900	6-8	13-18	60
1100-1300	9-13	18-22	75-100
1600-1800	16-20	23-30	100
2600-2800	25-28	30-55	150

TABLE IV. COST COMPARISON BETWEEN INCANDESCENT, CFL & LED LAMPS

Parameter	**LED lamp**	**CFL**	**Incandescent lamp**
Light bulb Projected Lifespan	100,000 hours	10,000 hours	1000 hours
Watts per bulb (equiv. 60 watts)	7	14	60
Cost per bulb	$35.95	$3.95	$1.25
KWh of electricity used over 100,000 hours	700	1400	6000
Cost of electricity (@ 0.10per KWh)	$70	$140	$600
Bulbs needed for 100k hours of use	1	10	100
Equivalent 100k hours bulb expense	$35.95	$39.5	$125
Total cost for 100k hours	$105.95	$179.5	$725.0

TABLE V. COMPARING DIFFERENT FEATURES OF LED WITH OTHER LAMPS

Features	**LEDs**	**CFLs**	**Incandescent**
Durability	Durable	Fragile	Fragile
Emission of heat	Low	Medium	High
Hazardous materials	None	5mg mercury/ bulb	None
Sensitivity to humidity	No	Yes	Some
Sensitivity to temperature	No	Yes	Some
Turning on	Yes	Slight delay	Yes
Frequency on/off cycling	Negligible effect	Shortens lifespan	Some effect

The greatest impact of SSL will likely be in general illumination applications that demand a high-quality white-light source. A major challenge for LEDs can be considered as the delivery of highest efficacy performance at the current densities and temperatures relevant to high-power operation. LED-based illumination systems must also provide efficient and flexible approaches to extract and distribute light. Table I. shows the legibility of LEDs light compare with other conventional light. Table II. mentions the luminous efficacy of LEDs with compare others Lamps. Table III. compares the wattages and light output of Incandescent, CFL and LEDs bulbs. Table IV. indicates the cost comparison between LEDs, CFLs and Incandescent light. Table V. Vindicates the features of LEDs compared to the other lamps.

III. Efficiency & Technical parameters

Typical indicator LEDs are designed to operate with no more than 30–60 milliwatts (mW) of electrical power. Around 1999, Philips Lumileds introduced power LEDs capable of continuous use at one watt. These LEDs used much larger semiconductor die sizes to handle the large power inputs. Also, the semiconductor dies were mounted onto metal slugs to allow for heat removal from the LED die.

One of the key advantages of LED-based lighting sources is high luminous efficacy. White LEDs quickly matched and overtook the efficacy of standard incandescent lighting systems. In 2002, Lumileds made five-watt LEDs available with aluminous efficacy of 18–22 lumens per watt (lm/W). For comparison, a conventional incandescent light bulb of 60–100 watts emits approximately15 lm/W, and standard fluorescent lights emit up to 100 lm/W.

As of 2012, the Lumiled catalog gives the following as the best efficacy for each color [1]. The watt-per-watt value is derived using the luminosity function. In September 2003, a new type of blue LED was demonstrated by the company Cree Inc. to provide 24 mW at 20 milliamperes (mA). This produced a commercially packaged white light giving 65 lm/W at 20 mA, becoming the brightest white LED commercially available at the time, and more than four times as efficient as standard incandescent. In 2006, they demonstrated a prototype with a record white LED luminous efficacy of 131 lm/W at 20 mA current. Nichia Corporation has developed a white LED with luminous efficacy of 150 lm/W of a forward current at 20 mA [2]. Cree's XLamp XM-L LEDs, commercially available in 2011, produce 100 lm/W at their full power of 10 W, and up to 160 lm/W at their input powers of 2W. In 2012, Cree announced a white LED giving 254 lm/W [3] and 303 lm/W in March 2014 [4]. Practical general lighting needs high-power LEDs, of one watt or more. Typical operating currents for such devices begin at 350 mA. Figure 1. shows the Efficiency (lm/W) of Incandescent, Fluorescent and LED light in the chronological order of years. LED performance largely depends on the ambient temperature of the operating environment – or "Thermal management" properties in Figure 2. Over-driving an LED in high ambient temperatures may result in overheating the LED package, eventually leading to device failure. An adequate heat sink is needed to maintain long life. This is especially important in automotive, medical, and military uses where devices must operate over a wide range of temperatures, which require low failure rates. Toshiba has produced LEDs with an operating temperature range of -40 to 100 °C, which suits the LEDs for both indoor and outdoor use in applications such as lamps, ceiling lighting, street lights, and floodlights [5].

The efficacy of LED light sources has already surpassed that of incandescent, halogen, high intensity discharge, and linear fluorescent lamps, and will continue to improve. By 2020, LED luminaires will be capable of luminaire efficacies approaching 170 lm/W, more than twice that of a typical fluorescent fixture.

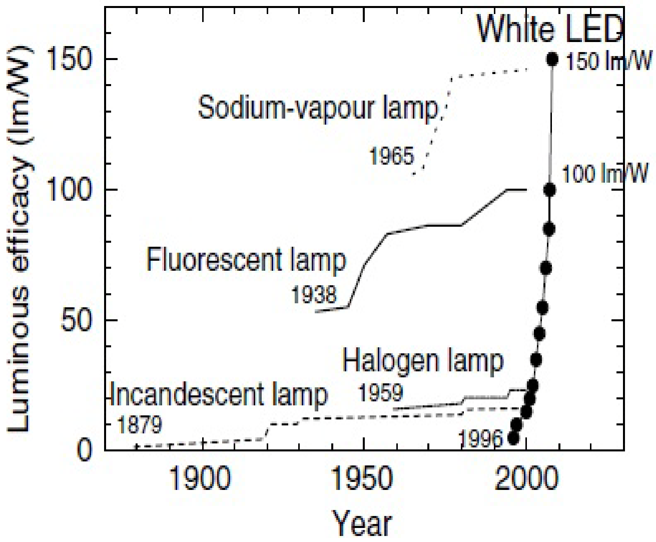

Figure 1. Efficiency (lm/W) of LEDs compared to others

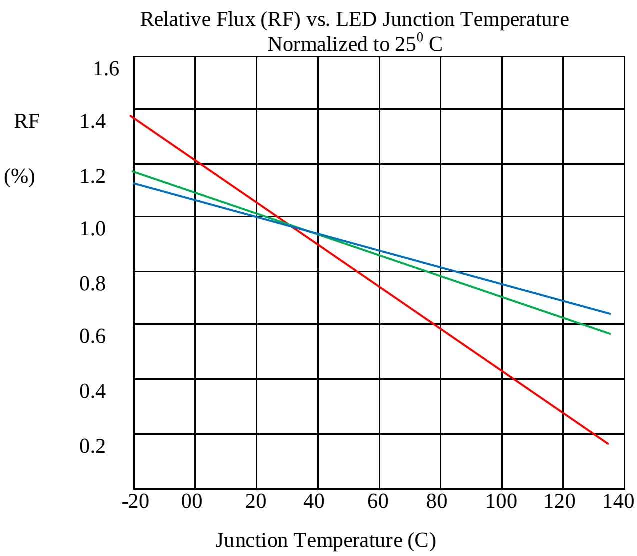

Figure 2. Variation of the light output with the junction temperature

Figure 3. Solid state lighting luminous performance curve

The sampling of high-efficiency LED products shown in the blue bar on the graph achieves an average of 85 lm/W, with a range of 70–120 lm/W [6]. In Figure 3 shows the performance curve of Solid state lighting luminous.

IV. Power generation & consumption Statistics in Bangladesh

Bangladesh Government is facing the tremendous social, economic and political pressure to solve power crisis now a days. Maximum Generation as of 7/18/2014 is 7418MW [7]; however, daily peak demand is 9268 MW [8]. In general, rapid industrialization and urbanization has propelled the increase in demand for energy by 10% per year. The Government has taken up a number of programs to bring the whole population under electricity coverage by 2025. Indigenous natural gas, coal, nuclear, cross-border trade and hydro resources are mainly considered for generation planning as fuel. In case of generation plant sitting regional balance in generation is being given due importance. Other factors such as availability of fuel, cooling water, transportation of heavy equipment, proximately to grid network & load center etc. are also considered for plant sitting. By implementing various development programs 49 percent of the total population has been brought under electricity Coverage by April 2011, it was 47 percent in April 2010 [9]. Table VI. show the last ten years analysis of power generation, demand and load shedding for Bangladesh [10], [11]. From the table it is clear that the generation capacity is definitely augmenting in every passing year, but because of the increasing population and the rapid growth of industries, the demand of power is outreaching the maximum generation, which in turns leads to load shedding. Despite the attempts of Bangladesh Government, this crisis seems to be getting worse day by day. Now, the only way to cover up the ongoing crisis is to reduce the power consumption, which will compensate for the load shedding.

TABLE VI. LAST 10 YEARS POWER STATICTIC IN BANGLADESH

Year	Maximum Generation Capacity (MW)	Maximum Generation of Power (MW)	Power Demand (MW)	Load Shedding (MW)
2014	10709	7418	9268	1850
2013	8525	6675	8349	1674
2012	8100	6350	7518	1168
2011	6639	5174	6500	1326
2010	5271	4698	5800	1102
2009	5166	4296	5250	954
2008	5262	4415	4800	385
2007	4693	3449	4550	701
2006	4690	3810	4490	680
2005	4685	3782	4375	593

V. SOLID STATE LIGHTING IN TERMS OF POWER CRISIS REDUCTION

Solid state lighting has the potential to reduce lighting energy used in Bangladesh by nearly one third. SSL offers more than ten times as efficient as incandescent lighting and twice as efficient as fluorescent lighting [12]. Energy efficient solid state lighting is a smart strategy for reducing the carbon emission. It is also economically feasible and will deliver superior performance while reducing consumption of fossil fuels. In terms of Bangladesh, the use of solid state lighting is negligible. The main reason behind this can be the unawareness of the feasible features that SSL offers. In home or industries incandescent lighting is mostly used, around two thirds of the total lighting. Another one third is Fluorescent lighting. However, because of lack of use of SSL the power consumption that occurs from these lightings is huge. Rapid industrialization and increasing population lead to more power consumption every year. Bangladesh Government has taken several attempts to balance the situation. In the Power System Master Plan (PSMP) -2010 demand forecast was made based on 7 % GDP growth rate. The electricity development is required to be accelerated to increase access and attain economic development. The desirable economic growth rate would be about 7% p.a. Based upon this study the peak demand would be about 10,283 MW in FY2015, 17,304 MW in FY2020 and 25,199 MW in 2025 [13].

VI. CALCULATION

Nearly thirty percent of total energy consumption is used for lighting purposes in Bangladesh [14] shown in Figure 4. So, forecasting the demand for the year 2020 from Table VI, we can calculate the saving that can be done if the conventional lighting techniques are replaced by solid state lighting. Here we shown the amount of saving power is enough to solve the present power crisis of Bangladesh.

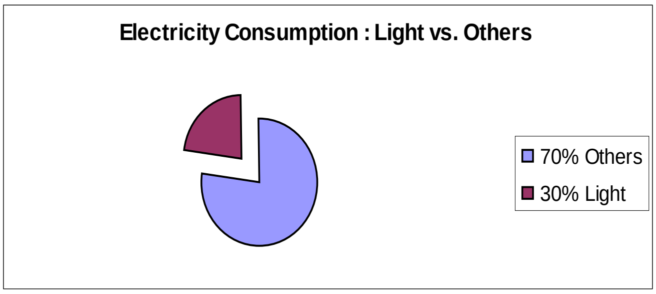

Figure 4. Energy consumption is used for lighting purposes in Bangladesh

Peak demand in 2014 = 9268 MW
Power consumption in lighting purposes 30% = 2780 MW

If one third of the lighting source is CFL [14], then the consumption from these types would be = 917 MW

Another two third incandescent lighting, this type will consume = 1863 MW

Solid state lighting is near about ten times more efficient than incandescent lighting. So, if incandescent lighting is replaced by SSL, than the consumption= 186.3 MW

SSL is two times more efficient than CFLs. So, If CFLs are replaced by SSL, then the consumption= 458 MW

After being replaced by SSL the total lighting sector consumption will be = 186.3 MW + 458.5 MW = 644.8 MW

So, Total Saving = 2780 MW – 644.8 MW = 2135 MW

It can be seen from the above calculation that, the saving 2135 MW is much greater then load shedding 1850MW.

VII. CONCLUSION

The main drawback of LED is high initial cost but comparing with life time absolutely it is not expensive. LED light offers flexibility, reliability, economically efficient and it can contribute significantly to diminish the power crisis that currently Bangladesh is suffering. The peak demand outreach the maximum generation in Bangladesh, it has been shown by calculation that the inauguration of LED in lighting sector can compensate for the shortage that remains between the peak demand and maximum generation. If the Government of Bangladesh initiates the project of replacing conventional lighting sources by LED light, then it is definitely possible to diminish the present power crisis in Bangladesh. Sustained advances of LEDs are essential for wide-scale adoption of SSL and realizing the potential for tremendous energy saving and environmental benefits. A building's carbon footprint from lighting can therefore be reduced by 85% by exchanging all incandescent bulbs for new LEDs [15].

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Study of Power Quality with changing customer loads in an urban distribution network

Tareq Aziz
Department of Electrical & Electronic Engineering
Ahsanullah University of Science & Technology,
Dhaka, Bangladesh.
Email: aziz.tareq@gmail.com, taziz@ieee.org

Sanjib Kumar Nandi, Md. Siddikur Rahman, Ridown Rashid Riadh
American International University-Bangladesh,
Dhaka, Bangladesh.
Email: sanjib.eee.aiub@gmail.com,
rahman.siddikur286@gmail.com,
rashidridown@gmail.com.

Abstract— **Power quality is one of the most significant current discussions in electric energy distribution systems. The issue of harmonics has been a controversial and much disputed subject within the field of power quality. Harmonic current originates from all types of nonlinear loads. This paper attempts to show the impacts of rapidly increasing share of nonlinear loads on harmonic distortion of urban distribution feeders. The recommendations of IEEE Std. 519-1992 and Bangladesh Grid Code are considered carefully. Simulations have been carried out to find out how far the existing distribution system can accommodate non-linear loads. Results show that though the connected load is not hampering power quality of test distribution at present, an increase of nonlinear load share above 30% would cause Total Harmonic Distortion (THD) go beyond tolerable limit and result in poor power quality.**

Keywords-Power Quality, Distribution System, Harmonic Sources, Nonlinear Load, Total Harmonic Distortion (THD)

I. INTRODUCTION

The term power quality is the assurance of proper power in power distribution system [1, 2]. The purpose of the electric utility is to provide sinusoidal voltage at properly sustained scale all over their system. In real scenario, it is quite impractical to attain this kind of state. When a sinusoidal voltage is applied to a certain type of load, the current drawn by the load is determined by the voltage and impedance. Loads that cause the current to vary disproportionately with the voltage during each cyclic period are classified as nonlinear loads. Nonlinear loads create harmonics by drawing current in abrupt short pulses rather than in a smooth sinusoidal manner. Since harmonic distortion is caused by nonlinear elements connected to power system, any appliance/ equipment that has non-linear characteristics will cause harmonic distortion. The influence of harmonic currents on power system is a fairly-investigated topic at present. High harmonic currents cause fuse blowing in capacitor banks resulting in a loss of reactive power supply to the system. Harmonic voltage distortion may cause equipment insulation stress particularly in capacitors. Keeping low THD values on a system ensures proper operation and longer life span of equipments. However, in recent years, a substantial increase of non-linear loads has been noticed across all types of feeders in recent years. Along with residential and commercial feeders, industrial feeders having metal factories are also facing similar situations [3, 4, 5].

Research work has been conducted on load behavior and harmonic contribution in various sectors of power system. The influence of load model on behavior of electrical power system is examined in [6]. Experimental determination of nonlinear loads in power systems have been carried out in [7]. The sources of harmonic distortion and the propagation of the distortion in the power system and their effects are observed in [8, 9, 10]. However, very few papers have investigated the detail impact of nonlinear load along with the ultimate limit of its inclusion in test feeders.

The goal of this paper is to investigate harmonic distortion in an urban distribution network due to changing load pattern. A practical urban system has been taken as test system where the ultimate inclusion limit of non-linear load has been sorted out. This paper is organized as follows: Section II presents a brief overview of sources of harmonics and their measurement index in distribution feeders. A detail account of recent changes in customer load pattern has been presented in section III. Simulation results along with analysis have been discussed in section IV. Finally section V concludes the work highlighting the major contributions.

II. HARMONIC SOURCES AND MEASUREMENT

In an ideal power system voltage and current waveforms are purely sinusoidal. In a simple circuit containing only linear circuit elements (resistance, inductance and capacitance), the current which flows is proportional to the applied voltage. So that it results in a sinusoidal current flow. In practice, non-sinusoidal currents result when the current flowing through the load is nonlinearly related to the applied voltage [5]. This section identifies the common sources of harmonic along with the measurement index of harmonic contents.

A. Harmonic Sources

Industrial, commercial, and residential facilities are exposed to various sources of harmonics. In general, sources of harmonics are divided into: (a) Domestic loads (b) Industrial loads (c) Control devices [11]. Figure 1 depicts this classification.

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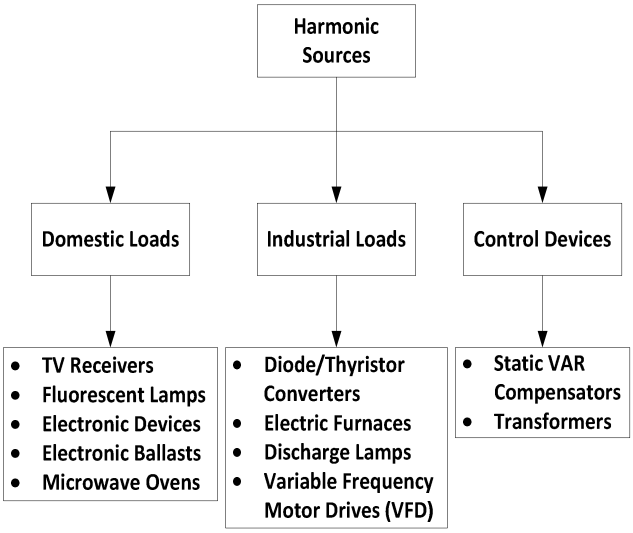

Figure 1. Classification of source of harmonic [11].

Examples of common sources of power system harmonics include transformer saturation and inrush currents, magneto motive force (MMF) distribution in AC rotating machines, electric arc furnaces, fluorescent lighting, switch mode power supplies in computer, battery chargers, electronic ballasts, imperfect AC sources, variable frequency motor drives (VFD) in motors, inverters, and television power supplies [5, 11, 12].

Prior to the development of power electronic switching devices, harmonic current propagation and the main source of harmonics have involved substation and customer transformers operating in the saturation region. Rotating machine is another example of equipment that may behave as a harmonic distortion source under overloading conditions. Arc devices (specifically: electric furnaces, soldering equipment, fluorescent and mercury-vapor or high-pressure sodium lamps) can become very special sources of harmonics in that they can involve frequencies below the fundamental power frequency and fractional harmonics. The expanding presence of distributed generators (DGs) in distribution networks also contributes to an overall rise in harmonic distortion [13].

B. *Total Harmonic Distortion*

In standards and literature, the most common index used for measuring harmonics is Total Harmonic Distortion (THD) [14]. THD includes the contribution of the magnitude of each harmonic component as given by

$$THD_V = \frac{\sqrt{\sum_{h=2}^{\infty} V_{h^2}}}{V_1} \quad (1)$$

$$THD_I = \frac{\sqrt{\sum_{h=2}^{\infty} I_{h^2}}}{I_1} \quad (2)$$

Where, THD_I and THD_V are THD values for current and voltage, respectively. I_1 and V_1 are the current and voltage r.m.s values for the fundamental frequency, respectively.

IEEE Standard 519-1992, suggested harmonic values for power systems can be described as follows [15]:

"Computers and allied equipment, such as programmable controllers, frequently require ac sources that have no more than 5% harmonic voltage distortion factor [THD], with the largest single harmonic being no more than 3% of the fundamental voltage. Higher levels of harmonics result in erratic, sometimes subtle, malfunctions of the equipment that can, in some cases, have serious consequences."

The limits on voltage harmonics are thus set at 5% for THD and 3% for any single harmonic. According to Electricity Grid Code 2012 - Bangladesh, Power quality should be elucidated as the constitution of the voltage, incorporating its frequency as well as the effecting current measured in the normal conditions. It states that the affordable range of harmonic voltage distortion is 3% at a voltage level of 66 KV or below [16].

As explained in section II.A, load characteristics influence THD of any distribution system to a large extent. A detail description of recent changes in load pattern is explained in next section.

III. RECENT CHANGES IN CUSTOMER LOAD PATTERN

The most common classification of customer loads follows the billing categories used by the utility companies. This classification includes residential, commercial, industrial, and others. Residential customers include domestic users, whereas commercial and industrial customers are obviously business and industrial users respectively [14]. Other customer classifications include municipalities, state and federal government agencies, electric cooperatives, educational institutions, etc. Although these load classes are commonly used, they are often inadequately defined for certain types of power system studies. For example, some utilities count apartments as individual residential customers, while others count the entire apartment complex as a single commercial customer. Thus, the common classifications overlap in the sense that characteristics of customers in one class are not unique to that class.

Moreover, number and pattern of loads vary continuously through time as non-identical load elements have been switched on or off in response to industrial, commercial as well as residential activities [17]. Variable factors such as change in weather may also cause highly incalculable and asymmetrical variations in the nature and amount of load. Majority of these connected loads were used to be of linear type that included Power Factor improvement capacitors, incandescent lamps, heaters, conventional air conditioners, AC motors etc. However, in recent time, rapid advancements of power electronic devices and increased awareness for saving energy have led to the usage of large number of nonlinear loads by all types of customers. Computers, office automation, inverter air-conditioning systems, adjustable speed heating ventilation, uninterruptible power supplies (UPSs), personal computers (PCs), and entertaining devices can cause drastic amount of harmonic current flow throughout the distribution network [18].

For example, inverter air-conditioning system is one of the newest types of non-linear load among customer appliances. Traditional air conditioners contain a compressor driven by a single-speed induction motor and exhibit cooling capacity whereas compressor speed of inverter air conditioner is controlled by an inverter driven variable-speed motor. The drive circuit draws a non-sinusoidal, harmonic-rich current when supplied with sinusoidal voltage from the service power network. Such harmonic currents are known to produce undesirable effects in power systems. It is unlikely that one inverter air conditioner would draw enough harmonic current to have a perceptible effect on the power distribution system. However, if many such inverter air-conditioner loads are connected to a given distribution feeder then large amount of harmonic current drawn by these air conditioners would cause significant power quality disturbances [19]. Next section represents the simulation results carried out on a practical distribution system having both residential and commercial customers.

IV. Test System & Simulation results

In this study, a 33/11 kV primary distribution substation (S/S) of Dhaka Electric Supply Company (DESCO) at Nikunja with a total load of 17 MW and 5.1 MVAr as shown in Figure 2 has been used as test system [20]. The maximum load demand of this S/S has been found 26MW in summer season. The quality of supply voltage is fully dependent on the supply from the grid of Power Grid Company of Bangladesh (PGCB) Limited. Overall power factor of the system has been recorded as 0.96. Power is distributed among feeders through two buses. There are 9 active feeders- Nikunja 1 (Residential), Nikunja 2 (Residential & Commercial), Nikunja 3 (Commercial), Uttara O/H 1 (Residential), Uttara O/H 2 (Residential), CMH (Commercial), Lake City (Residential), Best Holdings (Residential), Biman O/H (Residential & Commercial)along with 3 spares. The percentage of linear and nonlinear load in each feeder is set according to collected data.

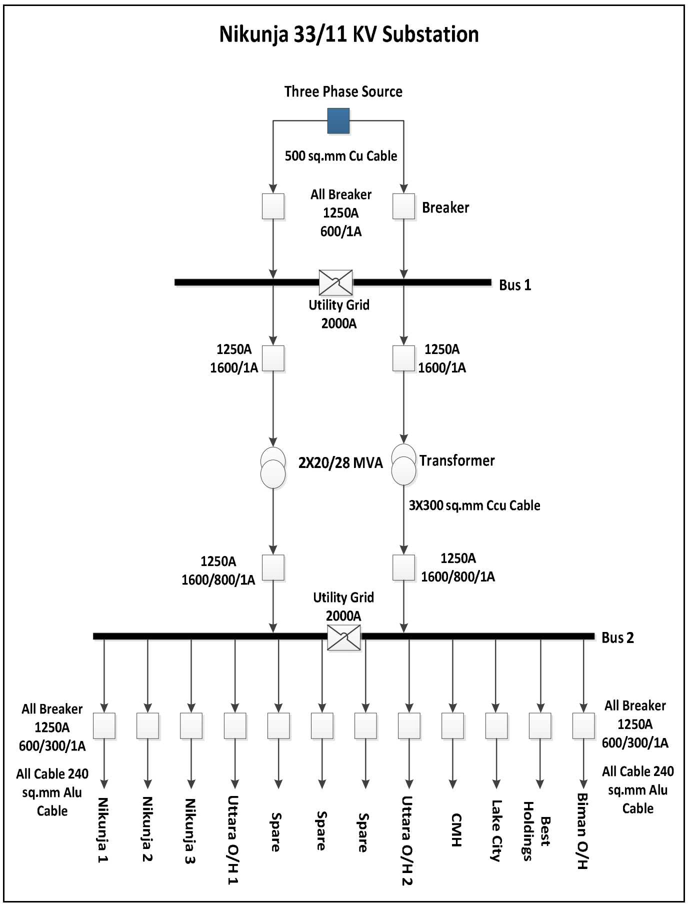

Figure 2. Single Line diagram of Nikunja 33/11 KV Distribution Substation [20].

All the results presented in this paper were simulated with research analytical tool SimPower System based on Matlab. With the help of SimPower System under SimScape division in Matlab, results of THD have been measured for changing load patterns. Simulations have been carried out with two case studies. Case study 1 calculates the existing THD of test feeder under present load scenario. Case study 2 considers the trend of changing load pattern (i.e. increasing share of nonlinear load) and shows the resulting impact on THD of test feeder in future.

As shown in Figure 2, Nikunja Substation has a number of feeders which are mostly of residential/commercial type. This study has considered Nikunja 1, Nikunja 3 and Nikunja 2 as commercial, residential and combination of residential & commercial feeder respectively based on collected data [18].

Case Study 1:

The amount of load supplied by each feeder with share of linear and nonlinear load is shown in Table I.

TABLE I. LOAD CONNECTED TO TEST FEEDERS

Name of feeder	Type of feeder	Total load (KW)	% of linear load	% of nonlinear load
Nikunja 1	Commercial	2090.88	90%	10%
Nikunja 2	Residential & Commercial	2100.52	92%	8%
Nikunja 3	Residential	1298.88	98%	2%

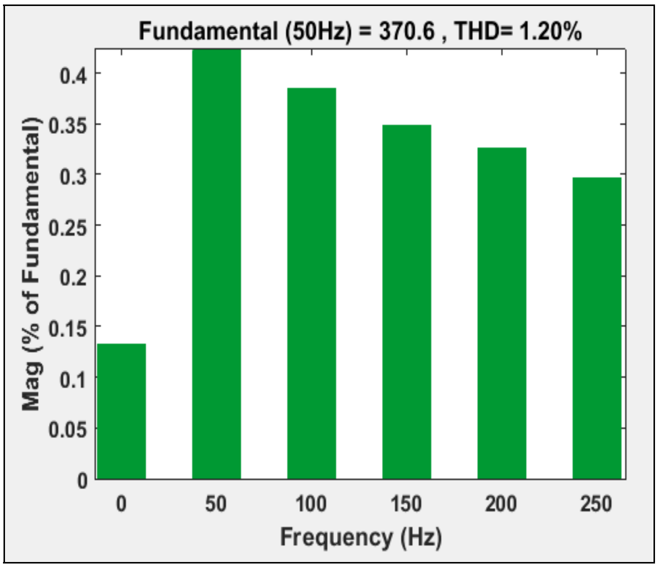

Figure 3. THD_V at phase-B (Nikunja 1)

From the Fast Fourier transform (FFT) Analysis, Figure 3 represents percentage of voltage harmonic distortion (THDv) at phase B of Nikunja 1 feeder as 1.20% resulting in a distorted voltage of 370.6 V with fundamental frequency is 50 Hz, 100 Hz being second harmonic, 150 Hz being third harmonic and so on. It has been seen from Fig. 3 that fundamental frequency has the highest magnitude. Rests of the magnitudes against harmonic frequencies are expressed as percentage of highest magnitude and they are gradually decreasing. Similar to Figure 3, Figure 4 and 5 represent percentage of voltage harmonic distortion (THDv) at phase B of Nikunja 3 and Nikunja2 as 0.79% and 1.08% respectively. They are resulting in distorted voltages of 371.1 V and 370.6 V respectively.

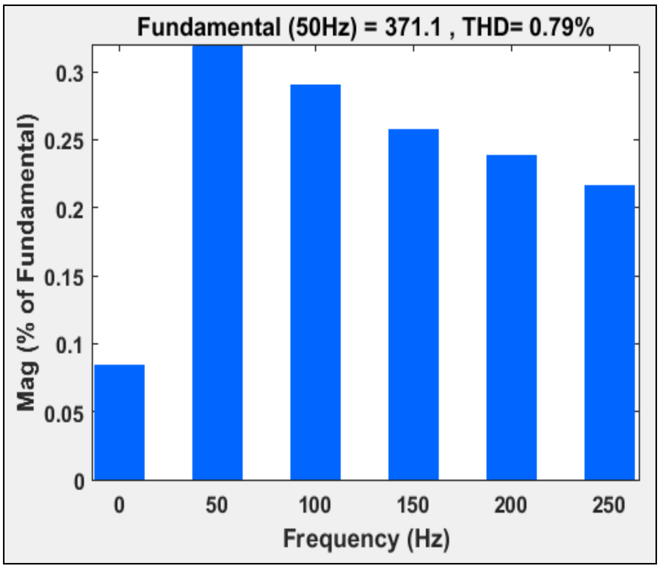

Figure 4. THD_V at phase-B (Nikunja 3)

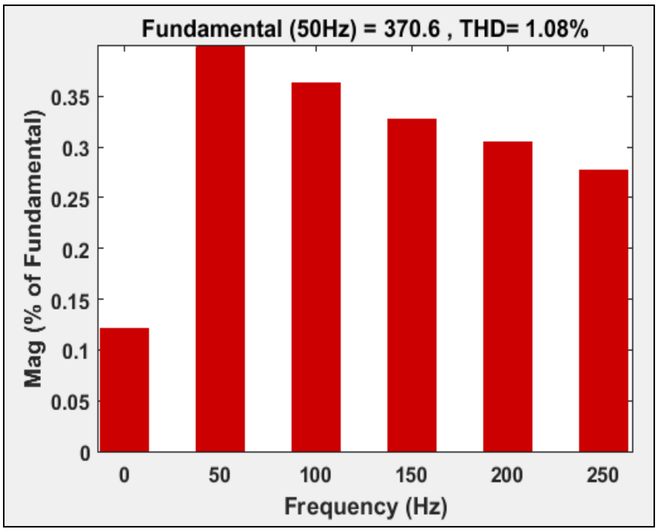

Figure 5. THD_V at phase-B (Nikunja 2)

THD findings at different types of distribution feeders based on the present data are summarized in Table II. It can be noticed that the THD findings at present do not violate the 3% limit defined by Bangladesh grid code.

TABLE II. VALUES OF THD AT DIFFERENT FEEDERS AT PRESENT

Phases	THD_V		
	Commercial feeder (Nikunja 1)	*Residential feeder (Nikunja 3)*	*Residential & Commercial feeder (Nikunja 2)*
Phase B	1.20%	0.79%	1.08%

According to the discussions in section III; second case study is carried out to find the impact of increasing share of nonlinear load on THD in each test feeder.

Case Study 2:

Figure 6, 7, 8 shows the THD vs. Percentage of Nonlinear Load in phase B of all three feeders discussed earlier.

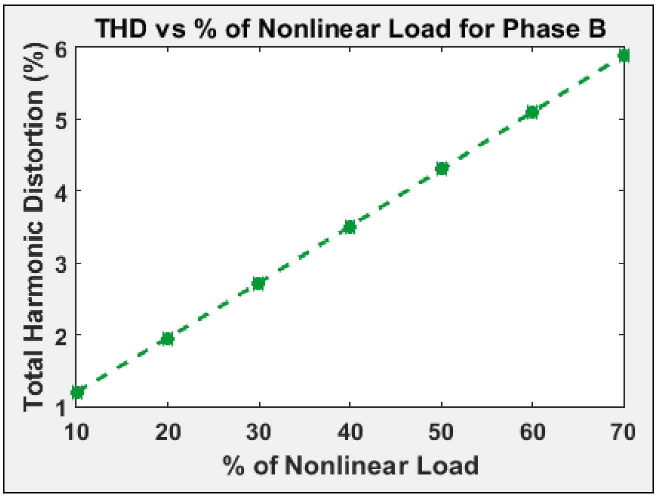

Figure 6. THD vs % Nonlinear Load (For Phase B at Nikunja 1)

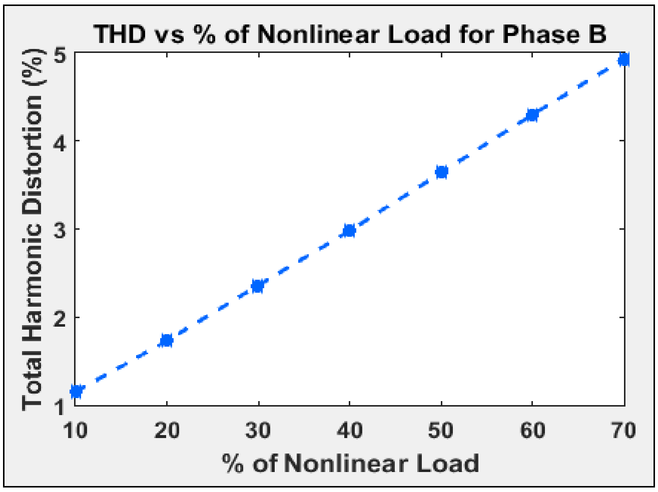

Figure 7. THD vs % Nonlinear Load (For Phase B at Nikunja 3)

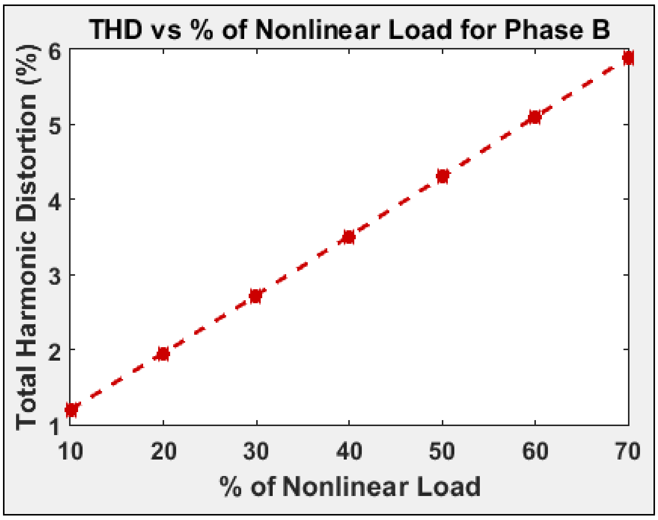

Figure 8. THD vs % Nonlinear Load (For Phase B at Nikunja 2)

The figures above show that THD changes with the change of linear to non-linear load ratio. The findings and measurement results of THD for the several sets of linear and nonlinear loads based on the above discussion are tabulated in Table III. Other phases follow similar pattern with increasing percentage of nonlinear load.

TABLE III. THE MEASURED RESULTS OF THD WITH LOAD VARIATION

Load (%)	**THD_V**		
Nonlinear	***Commercial feeder (Nikunja1)***	***Residential feeder (Nikunja 3)***	***Residential & Commercial feeder (Nikunja 2)***
	Phase B	***Phase B***	***Phase B***
10	1.20	1.15	1.18
20	1.95	1.73	1.85
30	2.72	2.36	2.66
40	3.51	2.98	3.41
50	4.30	3.64	4.16
60	5.10	4.30	5.02
70	5.89	4.93	5.78

As Bangladesh Grid Code 2012 does not allow THD above 3%, the amount of nonlinear load in Nikunja 1, Nikunja 2 and Nikunja 3 feeders should not cross 30%, 40% and 30% respectively. Hence, the findings in Table 3 define the capability of accommodating non-linear loads in each test feeder.

V. CONCLUSION

This paper has presented a study on the impact of widespread usage of nonlinear loads in customer utilities. Harmonic problems are now common not only in industrial applications but also in residential and commercial feeders. In this paper, harmonic distortions due to change in load pattern and the interactions of harmonic sources have been investigated. A detail model of a practical distribution network is employed in the analysis. The results obtained show that with present share of nonlinear load in test feeder, THD value is negligible and this would not cause any power quality issue. However, according to the changing customer load pattern, the share of nonlinear load would increase rapidly and THD value might go beyond tolerable range. The ultimate tolerable limit of percentage increase of nonlinear load has been examined through simulations. Data from these measurements will be useful for the utilities to understand the ability of accommodating harmonic producing load in existing power system and to prepare in advance for quality power supply in future.

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Electricity Generation by Using Amplitude of Ocean Wave

A.H.M. Zadidul Karim
Department of EEE, University of Asia Pacific (UAP), Dhaka, Bangladesh
E-mail: zadidkarim@gmail.com

Subrata Karmoker
Department of EEE, University of Asia Pacific (UAP), Dhaka, Bangladesh
E-mail: subrataa_2009@yahoo.com

MD.Mizanur Rahman
Department of EEE, Islamic University of Technology (IUT), Dhaka, Bangladesh
E-mail: mizan.eee32@yahoo.com

***Abstract*— Among available technologies for energy production from renewable sources, ocean wave energy and tidal power could give a significant contribution to develop a more sustainable energy system. Tidal power is one of the best renewable energy sources in coastal area and becoming popular around the world due to its own facilities. Ocean wave energy can play a vital role for producing electricity as new source of renewable energy to the off-grid power connection in isolated areas, namely Sandwip, in Bangladesh. Ocean wave energy having environmental friendly is the only sustainable solution of secure energy system in coastal area. Bangladesh has a huge potential of tidal power at different locations. It has a long costal area with 2-8 m tidal head/height rise and fall. This height is sufficient enough to produce power. So, tidal power has a bright future in Bangladesh. It can reduce the present energy crisis and improve the social, environmental and economic perspective of Bangladesh. But effective measures on this issue have not been considered sincerely. In this paper we propose a system which can be generated electricity by using amplitude of Ocean wave which may be an effective solution to overcome the recent power crisis in Bangladesh.**

***Index Terms*—Sustainable energy, tidal power, ocean wave energy, amplitude, power crisis.**

I. INTRODUCTION

Renewable energies technologies are becoming an increasing favorable alternative to tackle the climate change issue. Since renewable energy technologies are indigenous and non-polluting, they can cope with both security of supply concern and environmental issues [3]. There are several sources of renewable energy, such as wind, solar, wave and tidal, which exhibit a variable output, in other words, the output depends on weather conditions which cannot be controlled. Tidal energy offers an immense and reliable source of energy. The total energy flux of the tides is about 3 TW, however only a small fraction of this potential would be harnessed on the foreseeable future. This is due to the fact that the energy is spread over a wide area. Oceans which cover more than 70% of the earth have been appreciated as a vast renewable energy source. It is an emerging industry that has a potential to satisfy world-wide demand for electricity. Tidal power is knocking the future for electricity production. Nowadays, there are several techniques for extracting energy from the sea, among which are tidal energy conversion techniques. The use of tidal power originated in around 900 AD when early civilizations constructed tide mills. These mills used the force of the tide to turn a waterwheel, which in turn was used to grind grain into flour [5]. The first study of large scale tidal power plants was initiated by the US Federal Power Commission in 1924 which would have been located if built in the northern border area of the US state of Maine and the south eastern border area of the Canadian province of New Brunswick, with various dams, powerhouses and ship locks enclosing the Bay of Fundy and Passamaquoddy Bay. Nothing came of the study and it is unknown whether Canada had been approached about the study by the US Federal Power Commission. The world's first large scale tidal power plant (the Rance Tidal Power Station) became operational in 1966 [5]. The facility is located on the estuary of the Rance River, in Brittany. With a peak rating of 240 Megawatts, generated by its 24 turbines, it supplies 0.012% of the power demand of France [5]. Bangladesh has a long coastal zone, most of which is covered by embankments and sluice gates .In most cases, the coastal area of Bangladesh is remote from population centers and has no electricity . But this coastal environment is very resourceful in terms of agricultural production, shrimp aquaculture and other business and commercial activities . At present this area has expanded shrimp aquaculture haphazardly, which is unsustainable . This expansion has not been integrated with electricity supply. Some recent studies have suggested that coastal area of Bangladesh is ideal for harnessing tidal electricity from the existing embankments and sluice gates by utilizing small scale tidal energy technology [5]. Lack of electricity is the main barrier to coastal development in Bangladesh. Bangladesh can take tidal power generation opportunity as a challenge and can easily overcome at least some portion of the national power crisis.

II. RENEWABLE ENERGY SITUATION IN BANGLADESH

In our country renewable energy such as biomass, solar power and wind power are being used since time immemorial. Especially in areas which are outside gas coverage, usage of biomass for cooking and solar power and wind for drying of different grains as well as clothes are known to all. However, we are still lagging far behind in the scientific use of such energy. Moreover, the use of renewable energy has become popular worldwide in view of depleting reserve of non-renewable fossil fuel. Renewable energy is environment-friendly. At present, the different categories of renewable energy that are being used in limited ways in our country are as follows:

1. Solar power generation using solar rays
2. Wind-mill power generation using wind power
3. Hydro-electricity
4. Production of bio-gas using waste
5. Electricity produced by Biomass Gasification Method using wood, rice husk, etc. scenario

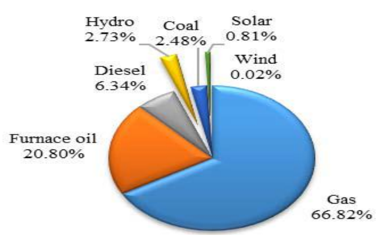

Fig. 1 The percentage of electricity generation in Bangladesh from different sources [3]

A. Solar Energy

Solar Energy is a great source for solving power crisis in Bangladesh. Bangladesh is situated between 20.30 and 26.38 degrees north latitude and 88.04 and 92.44 degrees east which is an ideal location for solar

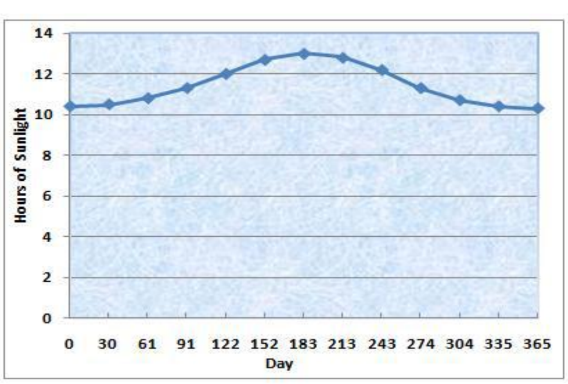

Fig. 2 The amount of hours of sunlight in Bangladesh

energy utilization [4]. At this position the amount of hours of sunlight each day throughout a year is shown in the following graph in the Figure-2. The highest and the lowest intensity of direct radiation in W/m² are also. Infrastructure development company limited (IDCOL) has supported NGOs in installation of solar home systems (SHSs) and a total of 1,320,965 SHSs having capacity of about more than 36.5 MW have been installed up to February 2012 [4].

B. Wind Energy

Bangladesh is in the midst of a severe energy and power supply crisis; one of the worst in South Asia. However, the government is now looking to explore the potential of wind energy, particularly along the country's 700 kilometer long coastline and many small islands in the Bay of Bengal, where strong south-westerly trade wind and sea-breeze blow in the summer months and there is gentle north-easterly trade wind and land breeze in winter months. . Along the coastal area of Bangladesh, the annual average wind speed at 30m height is more than 5 m/s. Wind speed in northeastern parts in Bangladesh is above 4.5 m/s while for the other parts of the country wind speed is around 3.5 m/s [4]. Recently, Bangladesh's first-ever generation of electricity from wind at a 900-kilowatt plant has ushered in new hopes for generation of power with minimum cost in the country. Grameen Shakti has already started providing electricity to fish and prawn farms in Cox Bazaar, an important fishing port. The Bangladesh Power Development Board has estimated that wind energy can contribute to 10% of the energy needs of the country. The Board has also calculated the cost to generate one kilowatt hour of power (kWh) from wind energy to be about half the cost of generating an equivalent unit of power from solar energy. The expansion of the potential of wind energy will be crucial in order for Bangladesh to achieve its national vision of providing electricity to all of its population by 2020.

C. Hydro-electricity

Hydro energy is a sustainable renewable energy. Bangladesh has good potential for the utilization of this energy in order to meet the demand. It can bring remarkable development in the energy sector in near future. The Jamuna-Padma-Meghna river system divides it into east and west and creates an average water flow of 1.3 trillion m3 in a year throughout in Bangladesh. Out of all the rivers about 57 rivers are Tran's boundaries originating from India and Myanmar [4]. During monsoon the flow rate of most of the rivers is high but it reduces substantially during winter. Hence the scope of hydropower generation is very limited in Bangladesh except in some hilly regions in the northeast and southeast parts of the country. Hydro power plants convert the Hydro power of the fluid into mechanical power which is further converted to electrical energy. The Karnafuly Hydro Power Station is the only hydropower plant in the country (located at kaptai, about 50 km from the port city of Chittagong), having a capacity of 230 MW by 5 units. It is operated by BPDB (Bangladesh Power Develop-ment Board). BPDB is considering the increase of production up to 330MW. Two sites have been chosen for another two Hydro power plants at the Sangu and Matamuhuri rivers, one named The Sangu project (140MW) and the other The Mata-muhuri Project (75MW). BPDB has designed a 20kW micro-hydro power plant with the help of RETScreen, developed by CANMET Energy Diversification Research Laboratory of Can-ada (CEDRL) at Barkal (a sub-district in the Chittagong Hill tracts) waterfall [4]. The Water Development Board (BWDB) and Power Development Board (BPDB) carried out a joint study on Micro-Hydro power potential in the country. BPDB has submitted a proposal to the government to install a 25kW power plant at the Teesta barrage.

D. Biogas

Bangladesh has a wonderful climate for biogas production. The ideal temperature for biogas is around 35ºC. The temperature in Bangladesh usually varies from 6ºC to 40ºC and also the raw materials for biogas are easily and cheaply available everywhere in this country [8]. The Government along with several NGOs is working together for development of power production from Biogas. Grameen Shakti is one of the most uttered NGO in field of biogas. They have completed 13,500 biogas plants [9]. Besides working in partnership with IDCOL (Government owned Investment Company), some organizations have constructed domestic biogas plants with their own funds. These are Grameen Shakti (about 3,664 plants of their own), BRAC (about 3,664 plants of their own), and some other private organizations which promote biogas plants independently [7]. Moreover, since May 2011, IDCOL along with its partner organizations; has installed 18,713 biogas plants in different parts of Bangladesh [10].

F. Ocean Wave Energy

Ocean wave energy is generated directly from the waves of the oceans. It is another special type of renewable energy which helps to decrease the harmful emissions of greenhouse gases associated with the generation of power. It can be potentially a significant source of electricity for Bangladesh. Though the main purpose of ocean wave energy is electricity generation, it can also be used for the pumping of water, water desalination etc. Bangladesh has potential for harnessing ocean wave energy from the BAY OF BENGAL.

G. Tidal Energy

Tidal power or tidal energy is a form of hydropower that converts the energy of tides into electrical power. As tides are more predictable than wind and sunlight, tidal energy can easily be generated from the changing sea levels. The coastal of Bangladesh has a tidal rise and fall of between 2 to 5 meters [12]. Among these coastal areas, with 5 meter tides experienced, Sandwip has the best prospect to generate tidal energy [12]. Moreover, according to Reference [11], Bangladesh can generate tidal power from these coastal tidal resources by applying Low head tidal movements and Medium head tidal movements, low head tidal movements which uses tides of height within 2m to 5m can be used in areas like Khulna, Barisal, Bagerhat, Satkhira and Cox's Bazar regions and the height tidal movements which use more than 5m of tides can be mainly used in Sandwip. So we can say that with suitable tidal height available, this can be a great source of energy for Bangladesh.

H. Geothermal Energy

The thermal energy which is generated and stored inside the earth surface is called geothermal energy. It is very much cost effective and environmentally friendly. With this technology, we can use the steam and hot water produced inside the earth surface to generate electricity. Geothermal energy is generated about 4,000 miles below the surface, in the earth’s core [12]. The process takes place due to the slow decay of radioactive particles, the high temperature produced inside the earth and it happens in all rocks [12]. About 10,715 megawatts (MW) of geothermal energy is generated in 24 countries worldwide [12]. The northern districts of Bangladesh show the prospect to explore the geothermal resources. The demand of electricity in urban as well as in the rural areas are increasing, but our production of electricity is not increasing. The rural demand for electricity can be covered by the production of electricity through geothermal energy. The electricity demand of urban areas can be met then by this saved electricity which is supposed to be provided in the rural area.

III. PHYSICAL PRINCIPLE OF TIDAL ENERGY

Tidal power, sometimes called tidal energy, is the energy dissipated by tidal movements which directly derives from the interaction of the gravitational forces between the seas and the primary astronomical bodies of our system . A tide is a regular rise and fall of the surface of the ocean due to the gravitational force of the sun and moon on the earth and the centrifugal force produced by the rotation of the earth and moon about each other. The effect of the gravitational force exerted by the moon on the earth is about 2.17 times larger than the exerted by the sun, due to the smaller distance between earth and moon.

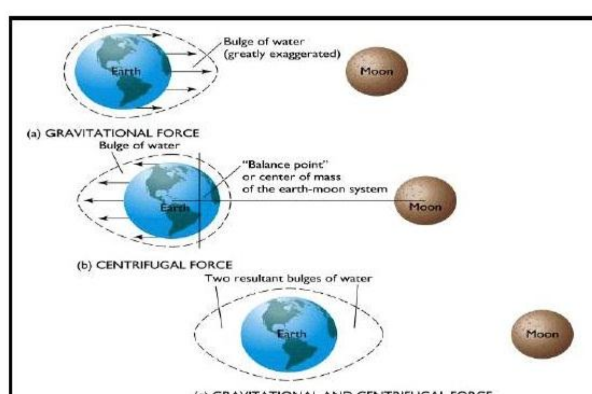

Fig. 3 Interaction between earth and moon

A bulge of water is created being greater on the earth side nearest to the moon due to the gravitational force. Simultaneously, another bulge of water is created due to the centrifugal pull due to the rotation of the earth-moon system, but in this case the water bulge is created on the side of the earth furthest away of the moon. As a result of the two forces, a resultant bulge is created around the earth as it is illustrated in Fig. 3 . When sun and moon are in line whether pulling on the same side or

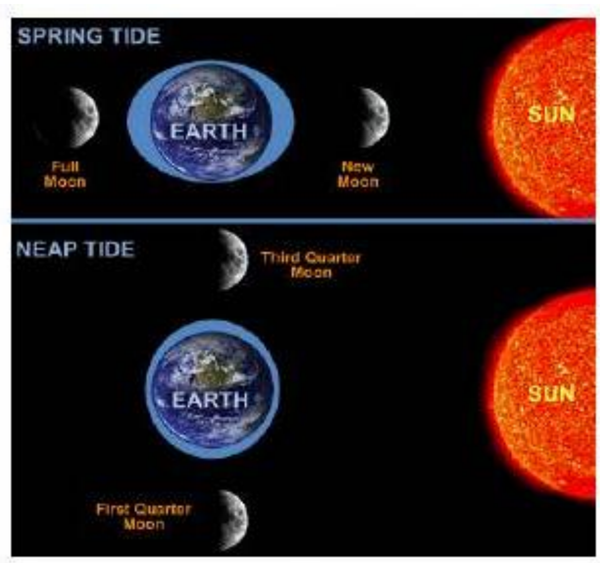

Fig 4. Sun and moon interaction with the earth

on the opposite side the gravitational attraction combine together causes high tides, known as spring tides. Conversely, when sun and moon are orthogonal, their gravitational forces pulls water in different directions causing the bulges to cancel each other, giving place to neap tides. The maximum power is produced during spring tide while the minimum is during the neap tide. Tidal phenomenon is periodic. The periodicity varies according to the lunar and solar gravitational effects, respective movements of the moon and sun, and other geographical peculiarities. The mean interval between conjunctions of the sun and moon (new moon to new moon) has a cycle of 29.53 days, which is known as Synodic month or lunation. There are three different types of tidal phenomena at different locations of the earth .

IV. PROPERTIES OF OCEEAN WAVE

Waves are the adulatory motion of a water surface. Two general wave categories: Progressive waves (Surface waves, internal waves, Tsunamis) and Standing waves Parts of a wave are wave crest and wave trough. Wave height (H), wave amplitude (1/2H), wave length (L), wave period (T) is the parameters of wave. Wave period provides a basis for classifying waves as capillary waves, chop, swell, tsunamis. Most of the waves present on the ocean's surface are wind-generated waves. Size and type of wind-generated waves are controlled by wind velocity, wind duration, Fetch, original state of the sea surface. As wind velocity increases wavelength, period and height increase, but only if wind duration and fetch are sufficient. As waves pass, wave form and wave energy move forward, but not the water. Water molecules move in an orbital motion as the wave passes. Diameter of orbit increases with increasing wave size and decreases with depth below the water surface.

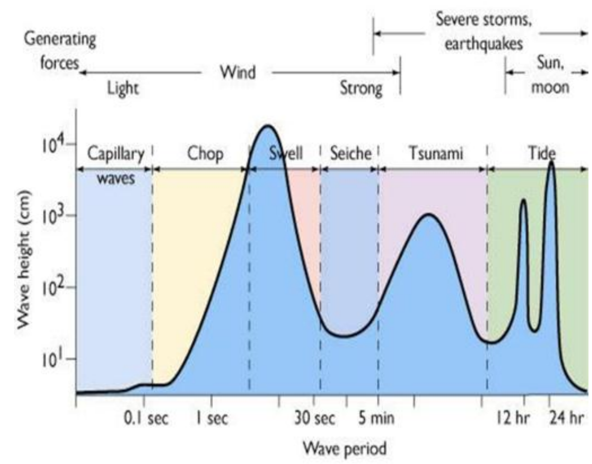

Fig 5. Idealized Wave Spectrum

V. OUR PROPOSED IDEA

Tidal power has great potential for future power generation because of the massive size of the oceans and if there is one thing we can safely predict and be sure of on this planet, it is the coming and going of the tide. To generate electricity by using tidal energy is very familiar. Tidal energy is produced through the use of tidal energy generators. The large underwater turbines are placed in areas with high tidal movements and designed to capture the kinetic motion of the ebbing and surging of ocean tides in order to produce electricity [ijsrp]. but our proposed idea is different from traditional electrical power generation from tidal power.at first we design a platform which can be floated on the ocean wave .this platform consist a generator, some gears and chain.

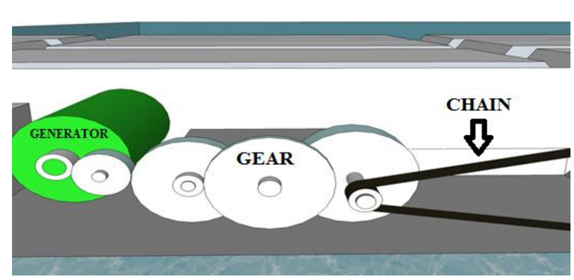

Fig 6. Inner side of each platform

Several numbers of platforms are connected with each other by chain. Then a group of platform floats on the ocean wave. Generator rotates according to motion of waves. Due to fluctuation of wave platform go upwards from the normal position and come downwards to return his normal position. Then gear which consist in the platform rotate due to inertia and gravitational attraction. This gear also helps to rotate generator because gear also works as a prime mover of generator. The output from generators also feed to the greed which meets up the demand of electricity in costal island.

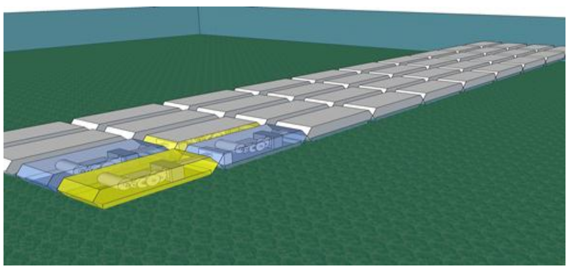

Fig 7. Groups of platform float on ocean wave

VI. EXPERIMENT SETUP

Our proposed platform consist generator, gear, chain, some metal plate, screw, bearing. Every platform is connected to other platform by a rounding bearing.

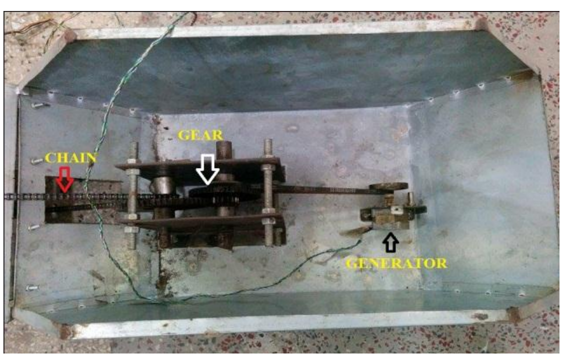

Fig 8. Inner side of platform

So it can get the tidal waves amplitude. On the other hand chain is connected to the gear of 1st platform named as 1. Two sides of chain also connect to the bottom and top of the left side platform named as 2.

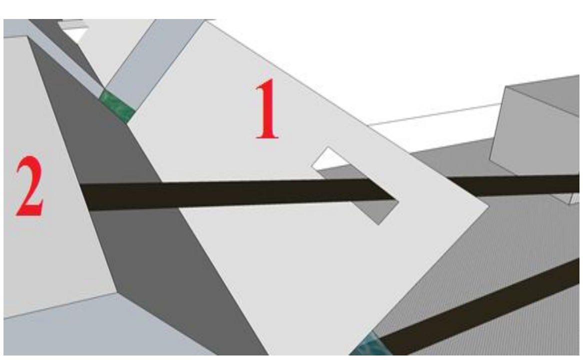

Fig 9. Interconnection between each platform by chain

There are some gears also. Gear is connected to the generator by belt for rotation. The total system set in a platform which is made by tin.

Fig 10. Our proposed platform

VII. WORKING PRINCIPLE

Tidal energy can be simply generated from the varying sea levels, and tides are more foreseeable than wind and sunlight. Changing tidal can be used to produce electricity across a coastal bay with huge differences between low and high tides. Due to amplitude of ocean wave our group of platform moves with the waves.

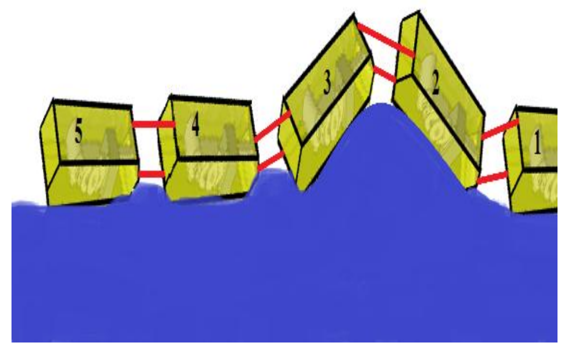

Fig 11. Movement of platform with wave's fluctuation

Let us we discuss about the working principle of a platform named as 3.platform 3 go downwards because wave moves forward with fluctuation. In this time a gear rotate freely due to gravitational force in the platform. This gear also coupled by a belt with generator. Then generator also rotate and electricity produced. Platform 3 connects with platform 2 by chain. When platform 3 goes downwards then chain pulls up the gear of platform 2.

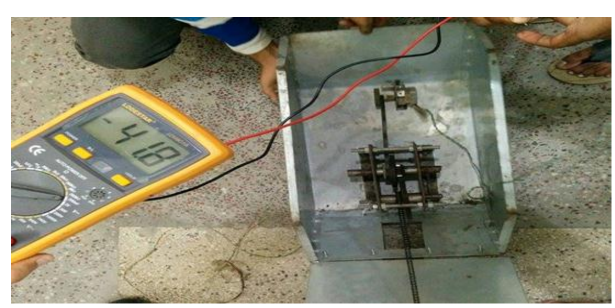

Fig 12. Electricity production from our proposed platform

Gear rotates another gear and every gear increases speed to the next gear. This gives us a comfortable speed. Finally generator rotates due the rotation of gear which is coupled with it by belt. Each platform gives us electricity as well as group of platform gives us a huge amount of electricity which is very helpful to meet up the demand of electricity.

VIII. ADVANTAGE OF OUR PROPOSED IDEA

1. Renewable resource, it needs no fuel to maintain, and free of charge
2. Totally no pollution, unlike fossil fuels, it produces no greenhouse gases or other waste.
3. Predictable source of energy (compared with wind and solar), it is independent of weather and climate change and follows the predictable relationship of the lunar orbit
4. More efficient than wind because of the density of water
5. It will protect a large stretch of coastline against damage from high storm tides

IX. DISADVANTAGE OF OUR PROPOSED IDEA

1. Presently costly
2. Holding back the tide allows silt to build up on the river bed.
3. You will need to find a way to connect the electricity to the grid.
4. Turbidity decreases as a result of smaller volume of water being exchanged between the basin and the sea.
5. The average salinity inside the basin decreases, also affecting the ecosystem
6. Only provides power for around 10 hours each day, when the tide is actually moving in or out.
7. Technology is not fully developed.

X. COMMENT

Bangladesh is lacking continuous supply of power from national grid connection especially in rural and remote areas. In case of Bangladesh the best form of renewable energy are Hydropower and Tidal Energy. Because Bangladesh is surrounded by a lot river and cannels and this gives practically zero fuel cost. There is long coastline in Bangladesh along the Bay of Bengal. In the coastlines and also in the big rivers of Bangladesh the tidal heights are suitable for power generation [5].A new model of an efficient, suitable and robust hybrid system has been presented in this paper to overcome this power problem in Bangladesh. We hope that our proposed idea fill up the demand of electricity in coastal area of Bangladesh.

XI. CONCLUTION

Bangladesh is a massively power-deficient country with peak power shortages of around 25%. The country only produces 7418 MW of electricity against a daily demand for 8349 MW on average [2], according to official estimates. With the increasing power demand in Bangladesh, there is no substantial plan to meet the upcoming power crisis by renewable energy. The country has a great challenge in the upcoming days due to unsustainable dependent energy sources [3]. Comparing with wind power energy and solar energy, tidal power seems not a big sustainable resource, but it is doing a fast-rate progress in recent decades. We can see a bright future of the tidal power and wave power (we can call them ocean energy) when we fix several problems. First we have to make the cost lower, so that it can be built in a large scale. Our proposed idea is unique and different from traditional tidal power energy. Production of power energy from amplitude of wave will be a new hope in energy sector of Bangladesh as well as world .We hope that our proposed idea meets the power demand in the coastal island in Bangladesh.

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A comprehensive study on green technologies used in the vehicle

Muhammad Sifatul Alam Chowdhury
Department of EEE
International Islamic University Chittagong
Chittagong, Bangladesh
m.sifatul.alam@gmail.com

Al Mahmudur Rahman
Institute of Engineering Mechanics
Karlsruhe Institute of Technology
Karlsruhe, Germany
al.rahman@partner.kit.edu

Nahidul Hoque Samrat
Department of Mechanical Engineering
University of Malaya
Kuala Lumpur, Malaysia
Sam_3e60@yahoo.com

Abstract—**To ensure the safety of environment a major challenge to the vehicle manufacturer is the emission rate of vehicle. Emission of environment polluting particles especially CO_2 from conventional vehicles is a direct threat to the environment. As global vehicle market are expanding day by day so this high rate of emission is already a nightmare to the environment specialist. That's why some of green technologies are introduced in the vehicle by which energy reuse can be happened in the vehicle. Which can impressively reduce the emission of polluting particles from the vehicle. The impressive add-ons among this technologies are fuel cell which can reduce the rate of environment pollution near zero level. Research are going on full swing on the other green technologies like the addition solar cell in the vehicle. Due to some limitations this awaited technology is yet to reach the remote people. Recovering exhaust heat and vibration energy can be a good source of energy in the vehicle. In this paper technologies invented in various time, used in the vehicle for a greener world like regenerative breaking system, fuel cell, energy harvesting from vibration, recovering exhaust heat and the use of photovoltaic panel in vehicle are briefly discussed. Beside this the business perspective of this technologies and cost of producing power from them are discussed.**

Keywords- Fuel Cell; Regenerative Braking System; Vibration Energy; Recovering Exhaust Energy; Photovoltaic Panel; Energy Feedback in vehicle.

I. INTRODUCTION

In recent age pollution from vehicle emission reached in a new dimension so that vehicle manufacturer are thinking about making a full green vehicle. Conventional vehicle with an internal combustion engine (ICE) which is powered by diesel, gasoline, petrol or similar fuel are responsible for environment pollution. The use of internal combustion engine made this system an environment pollutant system which is highly responsible for emitting polluting element. Average vehicle emission rate by vehicle type are briefly explained in [1].

To reduce the impact of vehicle in environment pollution, researchers are emphasized on green vehicle which containing green technologies. Green vehicle is powered by an alternative energy source with or without internal combustion. This alternative source can be battery, fuel cell etc. Improving fuel economy can play a vital to reduce the emission of CO_2 because the more fuel saved the less emission occur. By using modern technologies this can be done. Among the various types of green vehicle electric vehicle shows impressive performance compared to others. In electric vehicle a motor is used for propulsion along with an internal combustion engine. Electric vehicle already declared as the environment friendly transportation system. The usage of electric vehicle produces a little pollution and will leads to a decline of 290.44 ton toxic gases within the year of 2040 including 252.08 thousand ton CO, 21.92 thousand ton hydrocarbon with 16.44 thousand ton oxynitride [2].

I. METHODOLOGY

Supreme advancement are happened in the field of automobile after the invention of internal combustion engine. ICE powered vehicle are playing vital role to pollute the environment. Manufacturer are relentlessly trying to make the transportation system environment friendly. In this regard they are adding green technologies in vehicle to keep the environment safe. Organizations working on environment issue are always opposed the excessive use of internal combustion engine which is greatly responsible for environment pollution.

In this paper the key technologies which is used in the vehicle to make it environment friendly, economically efficient and a green vehicle are explained in detail. Emphasize given on their working principle, their integration with the vehicle, how this technologies are making less pollution than the conventional vehicle. With this the economic comparison between various technologies to produce power in the vehicle are shown. For doing this comparison tried to use most recent update. As there is a general goal that the cost of producing power from renewable technologies should be reduced in a significant level.

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A. Fuel Cell

The journey of fuel cell technology were started since 1838 but the commercial use was inaugurated by NASA for their space operations after almost a century. The name Fuel cell were given in 1889. General electric is the company which first invented the proton exchange membrane fuel cell. This was the revolutionary step to use fuel cell as an alternate source of power in the vehicle.

'Fuel cell', the word implies that this technology works within cells where hydrogen are generally used as fuel. More specifically the effective operation to produce power are done in cells which are placed in series. A large number of fuel cell connected in series are called fuel cell stack and this is done due to get required high voltage. In fuel cell technology the continuous supply of fuel and air results a chemical reaction which produce the required power to meet the application demand. But there is major difference between fuel cell and power sources like battery. In case of battery chemical are present there and chemical reaction takes place. On the other hand in fuel cell, fuel and air must be supplied continuously without continuous supply of fuel and air fuel cell system cannot sustain and it will supply uninterrupted supply power till the supply is going on.

The classification of fuel cell are done according to electrolyte used. Electrolyte is a particle through which electron cannot pass. But the proton can be passed through this which made electrolyte an integral part of fuel cell. Generally anode, cathode and electrolyte are the main components of fuel cell. There are various types of fuel cell like proton exchange membrane fuel cell, Phosphoric acid fuel cell, Solid oxide fuel cell, Hydrogen-oxygen fuel cell, molten carbonate fuel cell etc. Among this types of fuel cell proton exchange membrane fuel cell are the most convenient and most used fuel cell for vehicle.

All the fuel cell contains anode, cathode and electrolyte. Oxidation happened with the presence of catalyst which is responsible for producing electron and proton. Proton pass through the electrolyte but electron can't pass through the electrolyte. This electron carried out through wire which produce direct current. Each fuel cell can produce maximum of .7 V electricity that's why number of fuel cell are connected in series. Produced proton in the reaction turned into water by the help of catalyst. The total mechanism of fuel cell can be described as, two reaction is happen which results water and electricity. According to Figure 1 the detail mechanism of fuel cell are shown. Fuels are entered and oxidation reaction occur which results electron and proton to produce and proton passing through the electrolyte. The unused fuel are passed through the second way. On the other hand air is entering on the cathode side and unused gas passing out through the second way. Fuel cells are generally 40-60% efficient which is quite satisfactory compared to other energy sources. For example an internal combustion engine is 15-25% energy efficient and the efficiency solar sell is near 10-20% which is lower than that of fuel cell. The efficiency of the fuel cell can be increased by combined heat and power system where heat produced in the fuel are reused to generate power. It is known as the combined operation of fuel cell. There are some losses which reduces the performance of fuel cell.

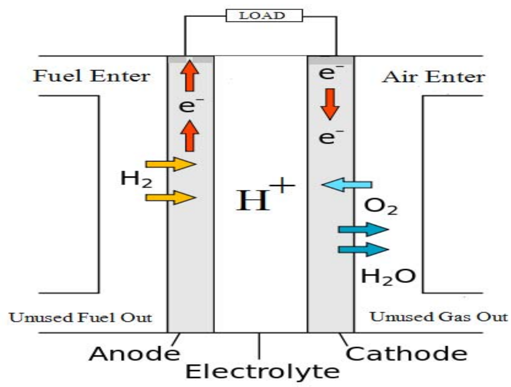

Figure 1. Internal operation of Fuel Cell [12]

Though fuel cell is the most convenient technology to overcome the never ending fuel demand of vehicle however the power production cost of fuel cell per kW is a great barrier. In case of hydrogen fuel, compressed hydrogen is used as fuel so the price of hydrogen is also a fact. According to Figure 2 in 2007 124$ was required to produce 1 kW power from fuel cell which was comparatively high. Then from 2008 to 2014 the cost of producing 1 kW power from fuel cell reduced to around 55$ which is pretty satisfactory. According to Figure 2 from 2010 the rate of cost reduction is pretty slow where in 2010 it was 59$ following year it was reduced to 57$ and in 2012 it was reduced to 55$. From 2012 the power production cost of fuel cell are staying at 55$. But at present producing power from fuel cell with this price is only possible at laboratory by using the most advanced technology and material. At present around 300$ is required to produce 1 kW power from fuel cell. Reducing the power production cost is depends on various things like material, technology, component cost. A goal is set to reduce the cost to 30$/kW within 2020.

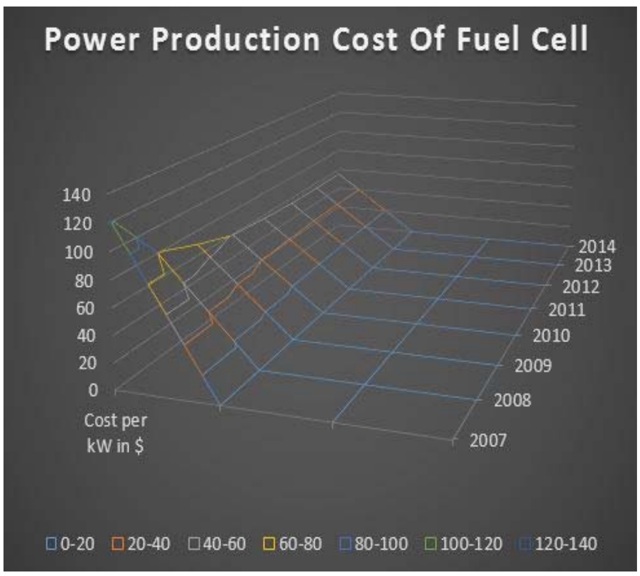

Figure 2. Cost of producing power from Fuel Cell

B. Recovering Exhaust Energy

Energy loss in vehicle is a big challenge to the manufacturer because it is directly related to the fuel economy. This losses are solely responsible for the fuel drainage of the vehicle. If some of this wasted energy can be reused than it will be a great advancement to improve fuel economy. That's why at present manufacturer of vehicles are very much interested to expand the reuse of energy in the vehicle. The losses occurred in the vehicle are listed below.

TABLE I. ENERGY LOSSES IN VEHICLE

Name of energy loss	Value
Exhaust heat	30-40%
Cooling	25-30%
Mechanical power	
Engine loss	11-12%
Transmission loss	5-7%
Resistance loss	11-12%
Brakes	5-7%
Air dragging	5-7%

This approximate measurement indicates that a big amount of loss is happening due to exhaust heat. Moreover only 20% of given energy are used to run the vehicle. So it is a very attractive option for the manufacturer to recover the exhaust energy for producing power.

In exhaust energy recovery system generally the heat energy are used to produce energy. There are two major benefit of using exhaust heat energy to produce power. One is the reuse of energy and second one is the reduced amount CO_2 emission. Emission of CO_2 from vehicle is largely responsible for environment pollution in current age.

Recovering exhaust heat, both the electrical or mechanical power can be produced. Electrical power can be stored at battery or mechanical power can be used to move the engine. Most importantly this technology can be used both in hybrid vehicle and conventional vehicle. There are two most popular technologies for utilizing exhaust heat one is Rankine cycle and another is thermoelectric generator. In case of Rankin cycle a fluid is used which is responsible for producing vapor. This fluid can be either water any other fluid depending on the temperature of the system. The pressure created due to the production of vapor will run a turbine which is directly connected to the crankshaft of the engine. On the other hand thermoelectric generator converts heat into energy through a method known seebeck effect. But the main demerits of using thermoelectric effect to recover the vehicle waste energy is its low efficiency which is only 5-8%. Besides the low efficiency of thermoelectric effect there high output resistance is a major drawback of this method. Different vehicle manufacturer uses different technology for their own brand for recovering exhaust heat energy such as German automobile giant BMW uses Turbo-steamer technology which is based on Rankine cycle.

C. Recovering Vibration Energy

Utilization of vehicle vibration energy can be a good option for saving energy. Vibration can be a good source of energy and now a day's manufacturer are pretty interested about this technology. It can ensure a good source of recyclable energy specifically for wireless sensor system. To use the vibration as energy source generally piezoelectric devices are used. Vibration is responsible for flexing the piezoelectric device. When piezoelectric device flex due to vibration it produces a voltage which although pretty small and directly related to amplitude of the deflection. According to Figure 3 performance of a piezoelectric device from measurement specialties are shown where the voltage are increasing simultaneously with the increase of deflection. There are various manufacturer whose are producing piezoelectric device however the performance of LTD0 from measurement specialties are quite impressive. According to Figure 3 LTD0 piezoelectric device produce 12 V AC voltage with only 4 mm of deflection and 25 V AC voltage with only 10 mm deflection.

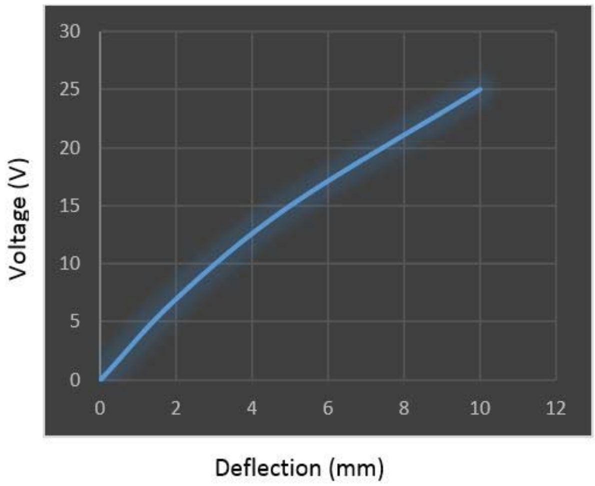

Figure 3. Performance of Measurement Specialties LTD0 (Courtesy to Measurement Specialties)

D. Regenerative Breaking System

Electric vehicle are continuously struggling with the battery efficiency. More specifically the major problem against the rapid growth of the electric vehicle market is the poor battery life. Regenerative breaking technology is comparatively an old technology but still playing a significant role for making the energy recyclable. It is a technique where kinetic energy of a vehicle can be utilized instantly or can be stored. This technology are mostly seen in the electric vehicle. In case of electric vehicle the energy is stored in the battery. Regenerative breaking technology impressively increase the energy efficiency of the electric vehicle. There are different type's regenerative braking system such as electric regenerative braking system, hydraulic regenerative braking system. Hydraulic regenerative breaking system is a joint invention of Ford motor company and Eaton Corporation.

The basic principle behind this technology is that slow down the wheel and the motor which running the vehicle starts to run reverse. So that the motor works as a generator and produce electricity. This electricity is used to empower the battery. Though this an impressive way to improve fuel economy however it has some limitation compared to the conventional braking system. This technology can only be implemented on the specific vehicle where exist an electric motor. That means without an electric motor this technology cant workout moreover this technology cannot work effectively in very high speed or very low speed. It requires a specific range of vehicle acceleration to recycle energy. Though electric motor ensure faster torque response then internal combustion engine. Regenerative braking system save up to 20-40% of energy which depends on the number how many the brake is used. Though the percentage is seems low but regenerative braking can be very effective in the countries having higher traffic like Bangladesh, Singapore where the rate of using brakes is high.

According to the Figure 4 the efficiency of the regenerative breaking system in parallel hybrid electric vehicle are shown for different types of battery. For NiMH battery the efficiency of regenerative braking system is around 65% which is completely an approximate value and for NaNiCl battery the efficiency is around 75%. Super capacitors are leading in this efficiency chart of regenerative braking system

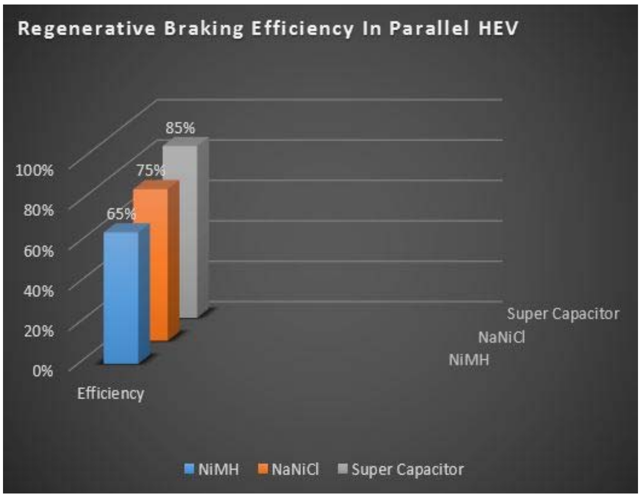

Figure 4. Efficiency of regenerative braking system for different battery in parallel hybrid electric vehicle

E. Photovoltaic Panel

Solar vehicle are the most awaited vehicle in market however due to some limitation it's not started to use widely but research is going on full swing to make this technology available to the remote people. In solar car solar cell are used to produce power to run the electric motor. Solar cell is a technology where light energy are converted into electricity but the production of electricity are directly proportional to the intensity of light. That means in rainy season or when the intensity of light is low the technology doesn't work with equal efficiency as it works when the intensity of light is high. The name solar vehicle implies that where this technology are used to produce electricity. Power produced by photovoltaic panel can be used to empower the full vehicle or a specific part of the vehicle. As mentioned before solar vehicle aren't available in practical life like the conventional vehicle, their use are limited to laboratory practice. There are existence of light sensor in photovoltaic device which detect the existence of light within a limit and produce electron hole pair. After separating the charge carrier they are extracted to an external circuit.

The major drawback behind the less use of photovoltaic panel in vehicle is its design criteria and cost. Most of the solar panel are designed only for stationary use however they are not suitable for moving vehicle. Cost is an important factor behind the less use Photovoltaic panel in vehicle because the making and installation of photovoltaic cell are costly which are responsible for increasing vehicle price. Also setting up photovoltaic panel is responsible for increasing vehicle weight which increase the use of fuel. Moreover the rate of power production of solar cell in vehicle are too low that its use in vehicle are not economically impressive. From Figure 5 it is clear that power production cost from solar cell are comparatively high from other energy sources [3].

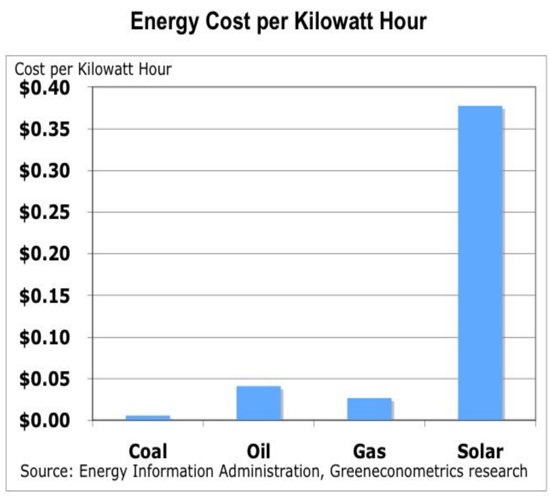

Figure 5. Cost of producing power from Solar cell and others

CONCLUSION

This paper included a comprehensive review on green technologies used in the vehicle. They are mentioned as green technologies because the emission from them are comparatively much lower than other similar technologies. The market of hybrid vehicle are increasing tremendously and manufacturer are positive about using this technologies because environment is a global issue. But all this technologies are not perfectly developed to implement in the vehicle right now. Though some of them like regenerative braking system is a pretty old technology and proved as a flexible technology to recover energy. On the other hand some of this technologies like photovoltaic panel are not available to use commercial vehicle till now. To make the transportation fully green researcher finds big hope on electric vehicle and this is not so far to get fully electric vehicle.

In this paper specific discussion are done on fuel cell, recovering exhaust energy, recovering vibration energy, photovoltaic panel or solar cell, regenerative braking which included detail mechanism, basic principle behind this technologies, how they works in vehicle along with cost statistics for producing energy from them.

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Design, Implementation and Performance Analysis of a Dual-Axis Autonomous Solar Tracker

Mohammed Saifuddin Munna
Dept. of Electrical and Electronic Engineering
Premier University
Chittagong, Bangladesh
Email: munna.puc@gmail.com

Mohammad Ariful Islam Bhuyan
Dept. of Electrical and Electronic Engineering
Premier University
Chittagong, Bangladesh
Email: arif.ajtfs@yahoo.com

Kazi Mustafizur Rahman
Dept. of Electrical and Electronic Engineering
Premier University
Chittagong, Bangladesh
Email: kazi.eee.puc@gmail.com

Md. Ashiqul Hoque
Dept. of Electrical and Electronic Engineering
Premier University
Chittagong, Bangladesh
Email: ahshawon222@gmail.com

Abstract— **This paper proposed a design, implementation & performance of an energy efficient solar tracking system based on closed loop technique. This solar tracking system is autonomous dual axis hybrid type. Solar efficiency depends on PV cell and its tracking system. In our works we concentrate on the panel tracking system. Our tracking system is a sensor based tracking system and it can track the sun continuously. A sensor placed on the surface of the panel and sensor compare light intensity continuously. Then our control unit sends signal to actuator unit to reposition the panel. This system is energy efficient because the actuator unit shut down in cloudy weather and turns on in sunny weather. Powerful microcontroller used to calculate and evaluate the light intensity form sensor unit, then send instruction to actuator unit. For graceful and accurate angular motion we used the servo actuator system. It's no need additional real time clock to track annual motion and daily motion because it's based on active closed loop system. Our implemented design is more efficient and convenient than other tracker**

Keywords-tracker; autonomous; active; microcontroller; sensor; motion; efficiency; PV; actuator; intensity; servo

I. Introduction

The last few years' renewable energy has gained much importance all over the world. There are different types of renewable energy like hydropower, wind power, biomass energy etc. Among them solar energy is an essential resource of sustainable energy [1]. Basically, solar cell converts the sun's ray into useful electric energy. Solar cell, also called photovoltaic cell or PV cell. The PV cell is like a classical p-n junction diode and its convert light energy into electrical energy. When semiconductor materials absorbs sunlight, which knocks electrons from their atoms then these electrons flow through the materials and produce electricity [2]. The solar system is not smoky and does not produce toxic gas, that's why it's very popular in the present condition of modernization [3].

Researchers estimate that covering 0.16% of the land on earth with 10% efficient solar conversion system would provide 20TW of power, nearly twice the world's consumption rate of fossil energy [4]. From this point we can conclude that solar tracking mechanism can make more power generation. Tracking mechanism helps to collect sunlight radiation on the solar surface perpendicularly which ensure more efficiency and more useful energy. Many researchers developed different types of solar tracker to ensure maximum solar efficiency. Fixed solar panel placed in a reasonable titled angle to face maximum daylight. After that there are two types of solar tracking system invented based on movement degree of freedoms. One is a single axis solar tracker and another is Dual axis solar tracker. Then these two systems further classified as active, passive and chronological trackers [5].

Different previous works have been done on a single axis solar tracker in which solar panel follows only the sun's daily motion. It is important that earth rotate in a complex motion [6]. In daily motion sun movement is from east to west. Annual motion cause tilt angle at a perpendicular axis while moving from east to west [7]. In other papers done based on Dual axis solar tracker. In that case real time clock used for timing purpose. Tracker moves based on time along with a daily motion from east to west and annual motion that is from north to south tracking done by position sensor.

In passive tracking system tracker determine the position of the sun in the sky, moves in response to an imbalance in pressure between two points at both ends of the track. The imbalance solar heat creates gas pressure, low boiling point compressed gas, fluid that is driven to one side or the other which then moves the structure. This method is not very accurate for tracking sunlight [8].

In chronological tracking system tracker tracks the sun with the help of real time clock. To perform this operation some calculation needed. To track the sun from east to west with the help of daily motion, the panel has to move 15° per hour. Also need to calculate tilt angle increment or decrement annually to track sunlight more accurately. Calculation performed by controller section and then sends to actuator unit to track the

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sun accurately. This is an efficient way to get maximum energy from solar panel [9]. But the active system (or concern) is more accurate and efficient than chronological system.

In an active tracking system, solar panel tracks the sun by using some light sensor. The light sensor continuously collects the light from the sun, and then sends corresponding analog output to the control unit. In that case the ordinary voltage divider rule helps. Then sensors output feed by ADC of microcontroller. Microcontroller all time compares the light intensity from sensors. If the sunlight is not perpendicular to the tracker, then there will be a difference in light intensity on one light sensor compared to another. This difference determines in which direction trackers have to move. This instruction sends to the motor driver as signal, and then driver drives the motor or actuator in desire angle. This operation is a continuous process in which tracker continuously tracks higher light intensity. As a result solar panel feed sunlight perpendicularly on a surface. This system is an energy efficient process because the control system is shut down on cloudy weather, then again activate during sunny weather. This process is accurate and efficient for tracking sunlight.

We used servo motor and accurate controller unit which helps to track maximum sunlight efficiently.

A. Why Autonomous Dual-Axis Solar Tracker

For the most part our common everyday solar cells run at an efficiency of 18-20%, meaning they convert 18-20% of the everyday they receive into electricity this is far better than the 3-6% efficiency that most green plants end up with, it doesn't quite meet our power needs. To bring in enough power we either need to improve the efficiency of our panels or find ways of getting more from our current solar panels.

Every panel you see in your day to day life is in a fixed position, most likely facing south at a 45 degree angle. While this approach is extremely simple and meets the needs of most small applications, it isn't producing as much energy as it could be. The single simplest way of getting more energy out of a solar panel is to have it track the sun. In fact solar panels that track the sun create around 30% more energy per day than a fixed panel.

B. Related Works

Many researchers already have done different research work on renewable energy. Solar energy based work, one of them. They work to enrich solar cell efficiency and many of them work on tracking system to get better output. One paper proposed fixed angle solar panel with a certain tilt angle to get sunlight. Another one proposed daily motion based single axis solar panel tracker with certain tilt angle. And one is done with chronological motion based Dual axis solar panel tracker [9]. Some works done based on passive panel tracking system [8].

II. METHODOLOGY

In Dual axis tracking system, solar panel can rotate in two directions, i.e. horizontal and vertical direction by taking azimuth and inclination angle as a reference. In that situation two techniques may be applied.

A. Open Loop Control Technique

Open loop control technique that depends on calculation the voltage corresponding to the output angles and feeding them into the DC motors.

B. Closed Loop Control Technique

Closed loop technique which mainly depends on the signal sent by the solar tracking sensors attached on the surface of the panel. The function of these sensors is to detect the position of the sun and feed the signal back to the electronic control circuit which in turn the signal to the motor to correct the real position of the panel perpendicular to the sun. (To which our work is concerned)

Each technique has its advantages and drawbacks where the open loop needs to keep motors operating all the time even when cloudy days. The closed loop technique saves power because it controls unit turn off when the weather is cloudy and turn on in shining weather. In this technique needs sensor, electronics control kits, a timer can be used to turn the whole system, pointing towards the east after sunset to put the panel in a ready position facing the sun in the next morning. So it is a little bit expensive. Let consider a solar panel to understand the axial movement in a yaw and vertical direction. To move in both directions, mechanical parts can be used in solar systems. Some electronics control kit used to control the mechanical system based on light intensity by using sensors.

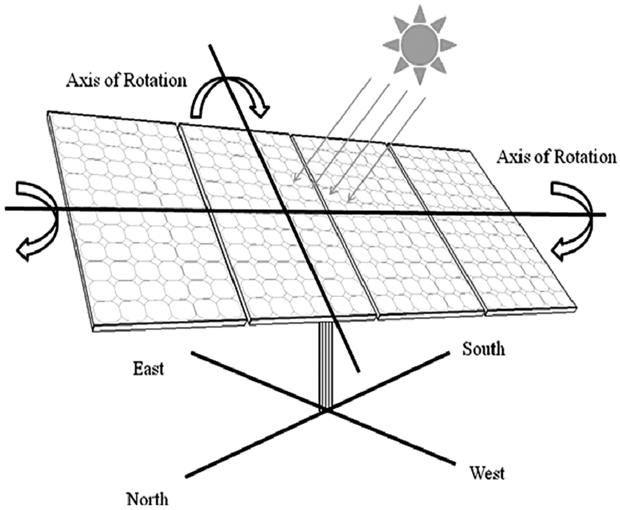

Figure 1. Dual-axis tracking system.

III. PROPOSED DESIGN

Our proposed design is based on closed loop control technique. It contains sensors, actuators, panel carrier, electronics and control kit. The total system is divided into two main sections. One is mechanical section and another is electronic control section. In brief, all these sections discussed below:

A. Mechanical Part

This part is challenging part in solar tracking system because of vertical movement and azimuth movement. Here motor plays a vital role. Panel systems have to rotate daily from east to west. Also have to rotate from north to south annually. In this case azimuthally movement helps to make annual movement. In that case light intensity captured by the sensor and angular movement done using control kit.

1) Servo Motor:

In our design we used servo motor for vertical and azimuth movement. Servo motor controlled by a PWM signal and it provide more accurate and smooth movement. There is a minimum pulse, a maximum pulse, and a repetition rate. From Fig.6 servo motors can usually only turn 90 degrees in either direction for a total of 180 degree movement [10]. The servo motor expects to see a pulse every 20 milliseconds (ms). Here a 1.5ms pulse will make the motor turn to the 90-degree position. Shorter than 1.5ms moves it to 0 degrees and any longer than 1.5ms will turn the servo to 180 degrees, as the diagram below:

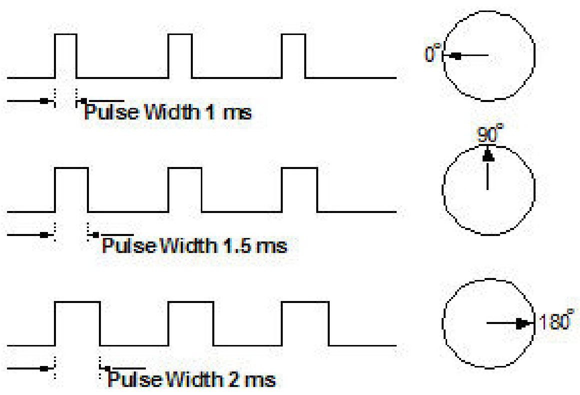

Figure 2. Servo Operation Strategy

2) Panel Carrier:

Panel carrier is basically a rectangular frame made of aluminum, which holds the solar panel with the help of a circular rod. One end of the horizontal base of the panel carrier is attached to the single rod hook of servo motors and other is a vertical axis shaft with another servo motor. Both motors shaft perpendicular to each other. So panel can move along with a vertical axis and horizontal axis.

B. Electrical Circuit Part

In a close loop system, electrical circuit part is another important section. This part helps to sense light intensity, then compares it and moves panel to the higher intense position. This part contains several circuit sections:

1) Light Sensor:

In this system light sensor is used to measure light intensity. Then generate corresponding analog output value and feed by microcontroller's analog port. Then analog value converted to digital voltage. Our system does not need a real time clock (RTC) to move annual direction i.e. north to south. This operation is done by light sensor, by comparing the light intensity it can move yaw axis and vertical axis. So always get maximum sum light. Basically voltage divider rule used to perform this operation. The divider circuit shown below:

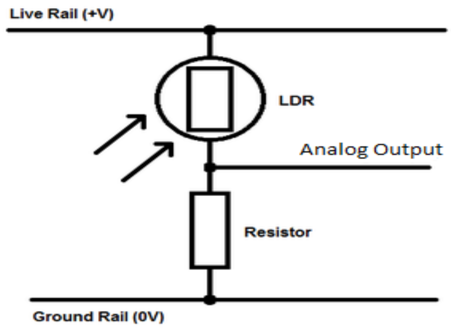

Figure 3. Light Sensor Circuit

Here we used a light dependent resistor (LDR) is a resistor whose resistance decreases with increasing incident light intensity. The relationship between the resistance (resistance of the LDR) and light intensity (Lux) for a typical LDR is given in the following equation:

$$R_{LDR} = \left(\frac{500}{LUX}\right) k\Omega$$

Where R_{LDR} = Resistance of LDR

2) Micro controller:

This is the brain of our control system. Here we used ATmega328P controller. Sensors analog output feed by ADC of this microcontroller. Then it's comparing the light intensity and sends the signal to servo motor to move from desire angular position. This microcontroller is cheap and has robust design. It has Analog Input Pins 6, DC Current per I/O Pin 40mA, DC Current for 3.3V Pin50 MA, Flash Memory 32KB of which 0.5KB used by the boot loader, SRAM 2 KB, EEPROM 1KB. Pin diagram shown below:

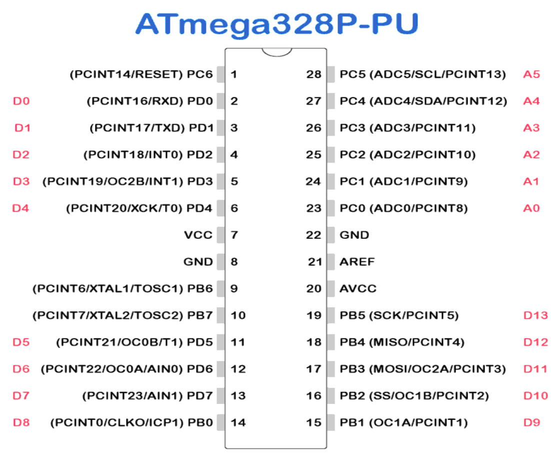

Figure 4. Pin Diagram of ATmega328P Microcontroller

IV. SYSTEM ALGORITHM

A. System Block Diagram

In this system we used sensor, microcontroller and servo motors. A sensor placed on the frame surface of the solar panel.

So sunlight falls on the sensors. After that sensors output feed by ADC port of microcontroller. Then controller find out the average value between two sensors then compared all of the tensors output voltage. Then the microcontroller sends the signal to the servo controller and servo start rotate as per instruction of intensity. This process is shown as block diagram below:

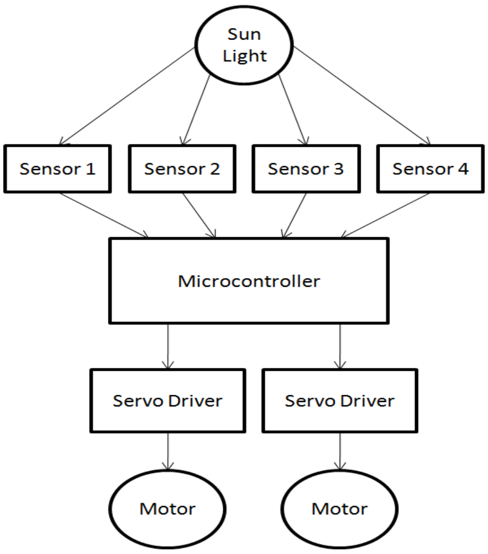

Figure 5. Block Diagram of Dual Axis Solar Tracker System

B. *System Program Algorithm*

Our system is totally autonomous. So it is coding algorithm to perform mathematical calculations and comparing them. Motor deflection or impulse is based on an artificial coding algorithm which is given below:

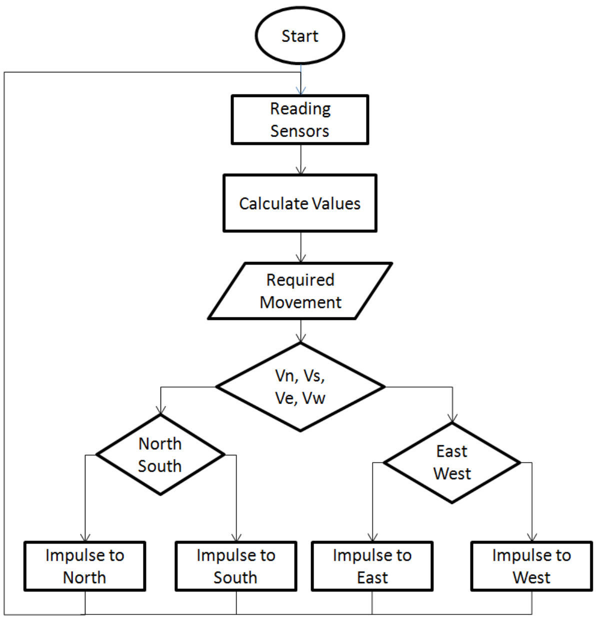

Figure 6. Algorithm of Dual Axis Solar Tracker System

C. *Overall Circuit Diagram*

Our electronic part consists of sensors, microcontroller, motor and motor driver. Sensors output work as voltage divider. Than controller sends signal to the motor. The total connection diagram given below:

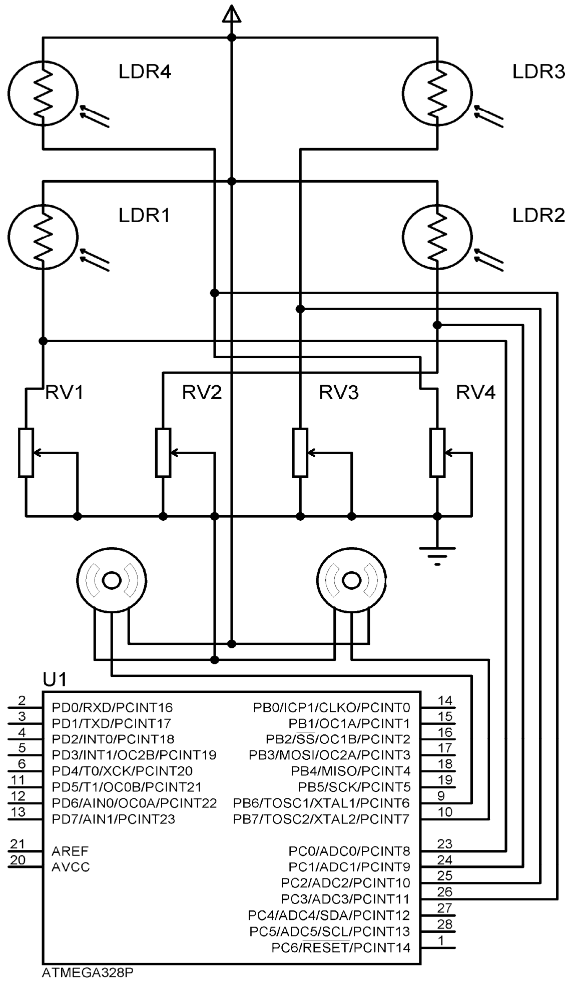

Figure 7. Circuit Diagram of Proposed System

V. RESULTS AND DATA ANALYSIS

A. *Experimental Data Tables*

We take several data tables in case of our system and other systems. Then we compare it. All data tables given below:

TABLE I. DATA FOR DIFFERENT SOLAR TRACKER

Dual Axis Tracker		**Single Axis Tracker**		**Fixed Panel**	
Time	***Power (% Watt)***	***Time***	***Power (%Watt)***	***Time***	***Power (%Watt)***
05:00 AM	00	05:00 AM	00	05:00 AM	00
06:00 AM	00	06:00 AM	00	06:00 AM	00
07:00 AM	32	07:00 AM	18	07:00 AM	10
08:00 AM	75	08:00 AM	45	08:00 AM	35
09:00 AM	85	09:00 AM	72	09:00 AM	55
10:00 AM	92	10:00 AM	81	10:00 AM	72
11:00 AM	92	11:00 AM	81	11:00 AM	83

12:00 PM	92	12:00 PM	80	12:00 PM	84
01:00 PM	92	01:00 PM	80	01:00 PM	86
02:00 PM	92	02:00 PM	81	02:00 PM	79
03:00 PM	92	03:00 PM	78	03:00 PM	68
04:00 PM	83	04:00 PM	65	04:00 PM	50
05:00 PM	72	05:00 PM	40	05:00 PM	27
06:00 PM	32	06:00 PM	20	06:00 PM	03
07:00 PM	00	07:00 PM	00	07:00 PM	00

B. *Simulation Curve*

We get this curve when plot these data. Here x-axis and y-axis indicate the time and power (% Watt) respectively. Blue marks for Dual axis solar tracker, green marks for single axis solar tracker and red marks for the fixed solar panel.

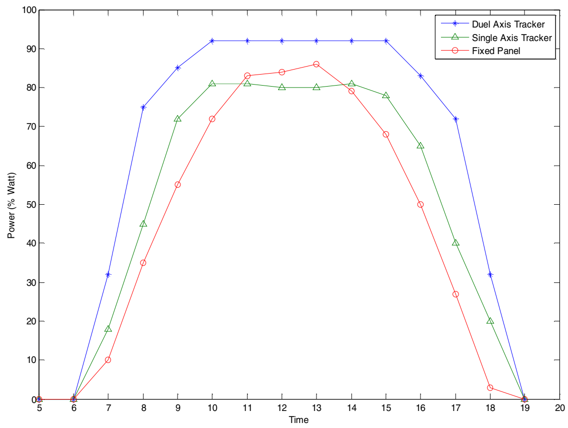

Figure 8. Performance Curve of Implemented System

C. *Implemented Design*

Our total implemented designs also have a solar panel also. The whole real system given below:

Figure 9. Real View of Implemented System

VI. CONCLUSION

After all we see that the dual axis solar tracker is much more efficient than other tracker. In fixed panel solar tracker we get picked at certain hour, then power remains decrease. In single axis, we get better performance for a few hours but its efficiency less than Dual axis tracker. In case of Dual axis solar tracker we get better performance. It gives constant power at maximum time of a day. It can move all angular directions with light intensity, whether single and fixed panel can't.

Now we can get better efficiency and better performance by making highly efficient solar PV cell.

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Design and Performance Analysis of a Hybrid Solar PV and Biogas Power Plant using PLC

Kazi Mohammad Arfatul Islam
Dept. of Electrical and Electronic Engineering
University of Science & Technology Chittagong
Chittagong, Bangladesh
Email: arfatul.islam10@gmail.com

Md Mizanur Rahman
Dept. of Electrical and Electronic Engineering
University of Science & Technology Chittagong
Chittagong, Bangladesh
Email: rusell968933@gmail.com

Tabassum Mekhola Khan
Dept. of Electrical and Electronic Engineering
University of Science & Technology Chittagong
Chittagong, Bangladesh
Email: tabassum.ustc@gmail.com

Mohammed Saifuddin Munna
Dept. of Electrical and Electronic Engineering
Premier University
Chittagong, Bangladesh
Email: munna.puc@gmail.com

Abstract— **This paper emphasis on hybridization of Solar PV and biogas power plant which is designed to run simultaneously with the help of Programmable Logic Controller (PLC). Bangladesh is affluent in almost all these resources especially in Biogas Energy and Solar Energy. Solar Panels along with biogas plant can be used to produce power in different areas of this country. The electrical energy can be extracted from solar energy directly by means of Photovoltaic cells. On the other hand biogas energy is first converted to heat energy through biogas engine and this heat energy in turn is used to drive a turbine to get the electrical energy. From the simulation result, which done in MATlab simulink Authors observed that the efficiency of proposed hybrid plant is higher in proposed hybrid Solar PV and biogas power plant rather than the summation the of efficiency of individual power plant. In the hybrid system energy has a higher reliability, can be cost effective.. The research work demonstrates how these schemes can be combined together to achieve the desired goal. It shows that how we can get continues power from a hybrid power plant, where the solar PV will run for eight (8) hours in a day and biogas plant will run for rest sixteen (16) hours.**

Keywords: Solar PV, Biogas, MATlab Simulink , PLC, power plant, hybridization.

I. Introduction

The world is facing its great crisis, energy crisis. **Renewable energy** is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight ,wind , rain , tides , waves, biogas and geothermal heat. Renewable energy replaces conventional fuels in four distinct areas: electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy services.

About 16% of global final energy consumption presently comes from renewable resources, with 10% of all energy from traditional biomass, mainly used for heating, and 3.4% from hydroelectricity. New renewable (small hydro, modern biomass, wind, solar, geothermal, and bio-fuels) account for another 3% and are growing rapidly. At the national level, at least 30 nations around the world already have renewable energy contributing more than 20% of energy supply. National renewable energy markets are projected to continue to grow strongly in the coming decade and beyond. Wind power, for example, is growing at the rate of 30% annually, with a worldwide installed capacity o f 282,4282 megawatts (MW) at the end of 2012[1].

Renewable energy resources exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy and energy efficiency is resulting in significant energy security, climate change mitigation, and economic benefits. In international public opinion surveys there is strong support for promoting renewable sources such as solar power and biomass power. The main problem today is the shortage of energy and environmental pollution.

In order to meet sustained load demands during varying natural conditions, different renewable energy sources need to be integrated with each other like solar ,wind ,ocean, geothermal ,biomass/biogas ,Bio diesel ,wave energy , fuel cell technologies ,waste of energy municipal waste/ liquid waste/Industrial waste ,small hydro. Thus we have seen that biogas is a promising tool for employment generation energy .self sufficiency and reduction of green house gases and recover global warming effect. Energy, Economy & Environment is the three inter-related areas having direct correlation for development of any nation. Per capita energy consumption is an index for development of any nation so we are tries to increase per capita energy consumption in Bangladesh with use of renewable energy source.

In Bangladesh the use of Solar and biomass energy are becoming more popular. But the biomass or biogas are mainly used for the cooking purpose only, where there are about 15,000 MW power are producing from biomass energy in India. By identifying such problems we tried to combine two different power plants (Solar PV+ Biogas) under one roof.

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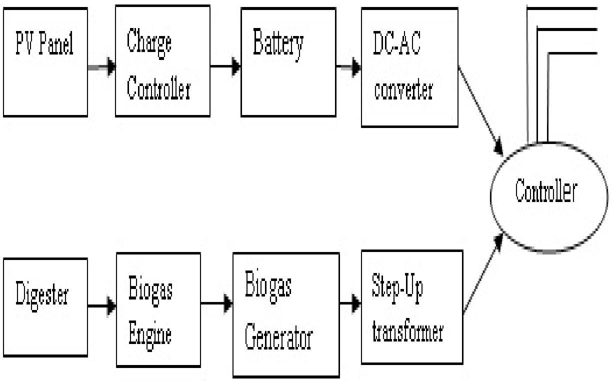

Figure 1. A schematic view of the goal of the thesis

Hybrid systems are usually a combination of two or more different power sources. Such as Photovoltaic with wind turbines, Photovoltaic with solar thermal, biogas and wind energy, biogas and hydro energy & Photovoltaic with Biogas etc.

Power generated by the PV array during the day is stored in the battery bank through an energy manager. During night the power can be produced from the biogas power plant. So that, consumer will get 24 hours continuous power in day and night. The resultant hybrid system thus offers an optimal solution at a substantially lower cost. It is ideal for electrification of remote villages in Bangladesh. Cutting edge technologies based on latest research to integrate dual power sources in the most ideal way. A diesel generator can be used as backup and emergency power source for the hybrid plant

The other form of power generation is usually a type which is able to modulate power output as a function of demand. Bangladesh is equipped to offer reliable off-grid and hybrid solutions for all energy needs for small area/ especially rural area, where powering critical loads are often a challenge. However more than one form of renewable energy to be used, e.g. wind/geo-thermal and solar/hydro/biogas. The photovoltaic power generation serves to reduce the consumption of non renewable fuel.

The solar generation is combining with biogas generation. The output is stored in the battery bank. This energy is drawn by the electrical loads through the inverter, which converts DC power into AC power. The inverter has in-built protection against short-circuit, overheating, low battery voltage and overload. The battery bank is designed to feed the loads up to a certain number of days with no sun or wind/biogas, depending upon the system requirement.

The solar panel is the power source of all photovoltaic installation. Photovoltaic (PV) are solid-state, semi-conductor type devices that produce electricity when exposed to light. The word photovoltaic actually means "electricity from light." Many hand-held calculators run off power from room light, which would be one example of this phenomenon. Larger power applications for this technology are also possible. Prime mover system is running by I.C. Engines use of biogas in diesel engines. Existing diesel engines can be modified to run on dual fuel while still retaining the ability to use diesel fuel only, Petrol engines: These engines can run on 100% biogas is a type of gas that is formed by the biological breakdown of organic matter in an oxygen deficient environment. It is counted as an eco-friendly bio-fuel. Biogas contains 60% methane and carbon dioxide. It can be employed for generating electricity and also as automotive fuel. Biogas can be used as a substitute for compressed natural gas (CNG) or liquid petroleum gas (LPG). Many companies are now manufacturing biogas generator in different power rating. We can also use these generators for our hybridization purpose [2].

Here, we tried to demonstrate how these schemes can be combined together to achieve the desired goal. It shows in figure 1, that how we can get continues power from a hybrid power plant. In the figure it is clear that the solar PV will run for eight (8) hours in a day and biogas plant will run for rest sixteen (16) hours. The maintain of the certain time period of the plant will be controlled by a Programmable Logic Controller (PLC)

II. Methods and Principles

A. Solar PV Design

Assumptions [3]*:*
As we assumed the plant for 1 Kw/ 1000W, here we calculated the specific values for 1 kW power plant. But, the values can be modified, classified and for larger or smaller scale power plant [3].
The PV panels are 100 W-p each
The Operating factor is 75
2. Combined efficiency =.81
3. Running hour= 8 h
4. Inverter efficiency = .90
5. Depth of discharge= .80
6. Battery voltage= 12V
7. Battery= 120 Ah
8. Inverter= 500 VA

- Total load= 1000W/1 KW
- PV panel:

Actual power o/p= 100*.75=75 wp
Power available for the use= 75*.81=60.75 wp
Energy produced by one 100wp panel in 8 hours=(60.75*8)=486wh
So. PV panel required= 8000/486= 17 panel
Battery Estimation:
Total watt-hour rating=8000/(0.90*0.80*12)=925.93
Battery required= 925.93/120= 7.71 = 8 battery.

B. Designing a 1kw biogas power plant [4]

As we assumed the plant for 1 Kw (1000W), here we calculated the specific values for 1 kw power plant. But, the values can be modified, classified and for larger or smaller scale power plant.

- <u>Total load</u>: the estimated total load is 1000W

- <u>Gas required calculation</u>:

  As we know, the average calorific value of biogas is about 21-23.5 MJ/m³, so that 1 m³ of biogas corresponds to 0.5-0.6 l diesel fuel or about 6 kWh or 0.16 m³, for 1Kwh. So we will need 0.16m^3 per kWh.

  Now, we will estimate the required gas for 24 hours. So that, we will have some backup gasses. So total gas required for 24 hours is,

(24*0.16)= 3.84m^3 gas required for 24 hours.

No. of animal (cows):

We can use different types of animals for the dung. But here we took the dung of cows as standard.
We know that,
No of gas produced from a fresh kg of dung=40litre/kg
Total amount of dung required=3840litre/40=96 kg.
So, no of cows required = 96/10= 9.6= 10 cows.
So we will need minimum 10 cows.

C. Digester design :

The digester design should be done very carefully. We will give slurry to the digester not only the dung. So we need the specific calculation of slurry.
Slurry= dung+water= 96+96=192 kg
Volume of slurry per day= 192/1090= 0.176m^3
Retention period= 25 days
Volume of digester= 0.176*25=4.40=5 m^3

III. EQUATION FOR BIOGAS DESIGN

This the main equation for our thesis works so that we can convert the gas into electricity [5].
1.POWER (the rate of doing WORK) is dependent on TORQUE and RPM.
2.TORQUE and RPM are the MEASURED quantities of engine output.
3.POWER is CALCULATED from torque and RPM,
By the following equation:
HP = Torque x RPM ÷ 5252
So, Torque= HP*5252/RPM
Again, 1 hp= 746 watt
By Solution,
Torque= 3501.3333 at 1500 RPM
Fig 2 shows the block diagram of working principle of biogas power plant.

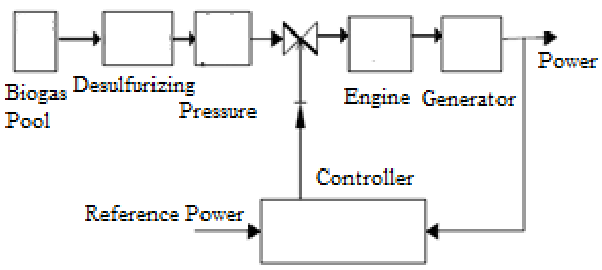

Figure 2. Block Diagram of Bio gas power plant

IV. PLANT DESIGN

A. Solar PV layout of MATLAB [6]

For the sake of simplicity of the simulation, here we showed the solar PV layout for 5 Watt power supply. But, it can be modified for any further change of the power.

(In figure 3) The solar cell can be represented by the electrical model shown in the figure. The solar cell is the basic unit of a photovoltaic module and it is the element in charge of transforming the sun rays (G) or photons directly into electrical power. The solar cell that is used is the P-N junction, whose electrical characteristics differ very little from a diode (D), represented by the Shockley equation (1).So the process of modeling this solar cell can be developed based on equations (1), (2)

$$I_D = I_0(e^{QV/AKT} - 1) \quad (1)$$

$$I = I_L - I_D \quad (2)$$

Where V is the solar cell output voltage, I is the dark saturation Current, Q is the charge of an electron, A is the diode quality ideality factor, K is the Boltzmann Constant and T is the absolute temperature of the solar cell.

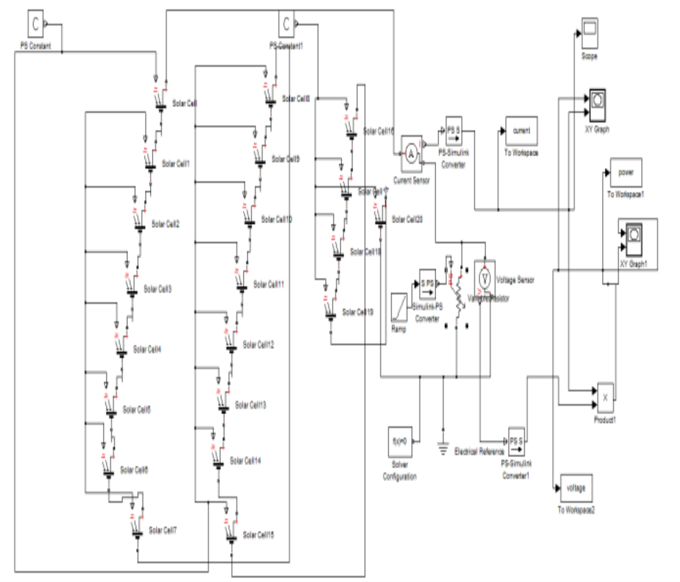

Figure 3. Simulink diagram of solar PV design

B. IV curve

Figure 4 shows the two important points of the current-voltage characteristic must be pointed out, the open circuit voltage V_{OC} and the short circuit current I_{SC}. Figure shows the maximum power is generated by the solar cell at a point of t he current-voltage characteristics where the product VI is maximum. This point is known as the maximum power point (MP P).

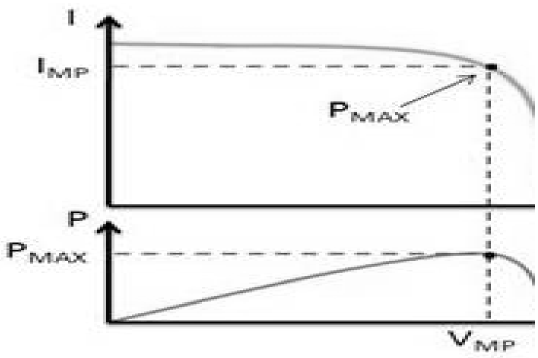

Figure 4. I-V curve for a solar cell shows Pmax and its relation to I_{MP} and Vmp

C. Biogas plant design in Simulink

The biogas power plant [7] is designed in three different vital parts Digester, Engine & generator.

In the biogas plant design, our main challenge was to make it variable for any kind of input and output. I.e; the same design will applicable for 1 kW/ 1 MW/ 100 MW and so on. And finally we found a solution for that design by developing a constant value which will add to the digester design. The value of the constant is 50.526 and is named as Arfat's constant.

1. Biogas layout of MATLAB- (Digester)

Figure 5 shows the biogas power plant in a block based design. The constant 10 shows the input of ten cows, the value 9.6 represents the output dung from 10 cows which are multiply further by two(2) to make slurry.

To get the real value of the gas for 24 hours which is 3.8 m3, we developed a constant value in the simulink. The constant value is 50.526. (contantt1). Then we got the output 3.8 m3.

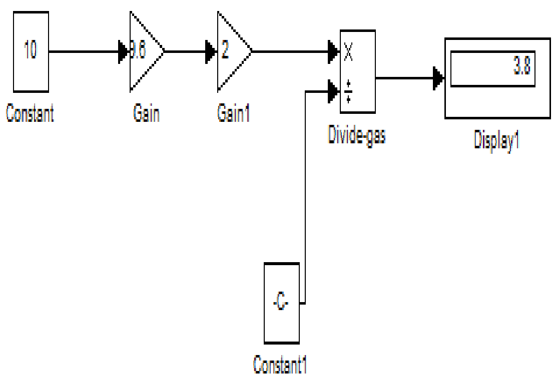

Figure 5. biogas digester design

2. Biogas layout of MATLAB- (Engine)

To run the engine, we have to create torque. In the following figure 6, it is shows that the engine created the desire torque, which is supplied to the generator, coupled to the engine shaft.

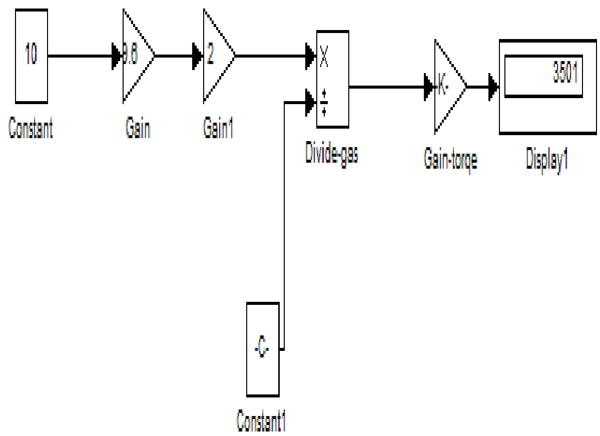

Figure 6. biogas engine design

3. Biogas layout of MATLAB- (Generator)

In figure 7, the constant2 represents the value of torque (1500 rpm) and the constant3 represents the value (5252) from the equation biogas power generation. The display2 shows the result for 1000 Watt or 1 KW power output.

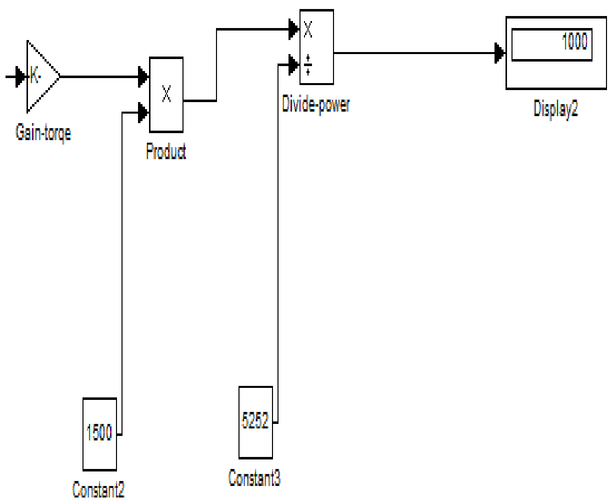

Fig 7: Biogas generator design

4. Biogas layout of MATLAB- full design

The full simulink block design is shown in the following figure 8.

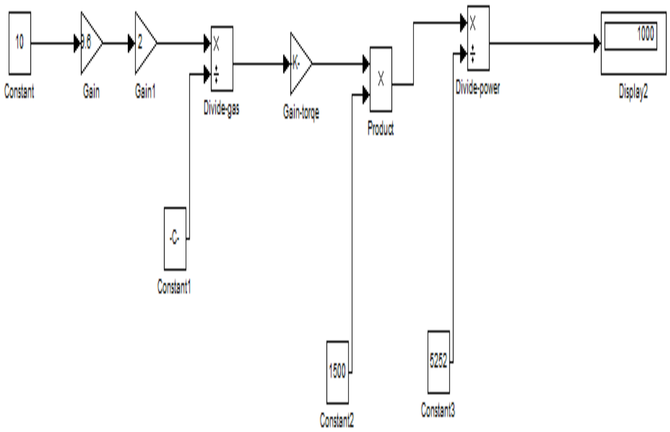

Figure 8. Biogas layout full design

V. RESULT IN PLC

The hybridization and the controlling are the same thing. We used Siemens S-200 for this simulation.

The symbolic representation in the PLC programming is [8]*:*

I0.0 = Start switch
I0.1= Stop Switch
I0.2 = Overload Relay1 (O.L)
I0.3 = Overload Relay2 (O.L)
M0.0 = Special Memory
Q1.0 = Output 1 (Solar PV Plant)*
Q1.1 = Output 2 (Biogas Plant)*
T37 = Timer 1 (8s / 80 ms represents 8 hours supply from Solar PV plant)
T38 = Timer 2 (16s / 160 ms represents 16 hours supply from biogas plant)

A. Programming in STEP 7-MicroWIN

1. *Network 1:* Figure 9 shows the ladder diagram for solar pv

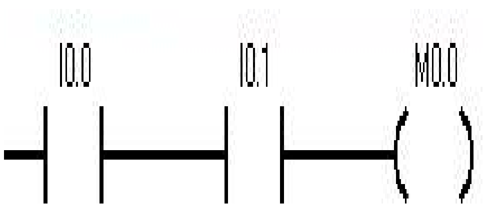

Figure 9. network 1 ladder diagram for solar PV

2. *Network 2:*

Figure 10 shows the ladder diagram for biogas plant

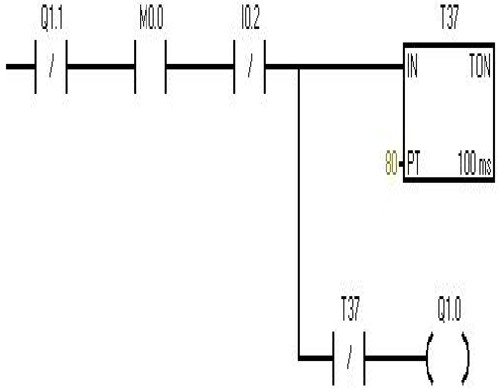

Fig 10: network 2 ladder diagram for biogas plant

3. *Network 3:*

Figure 11 shows the ladder diagram for the particular timer of the hybrid plant.

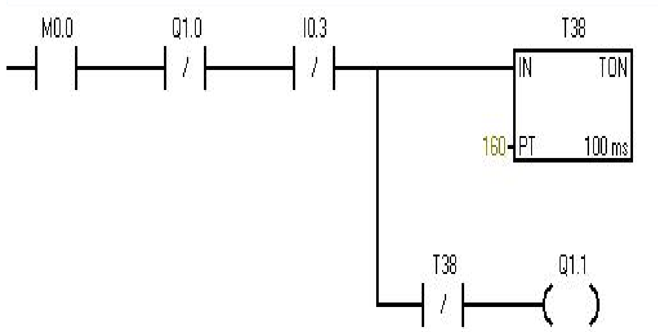

Figure 11. network 3 ladder diagram for the timer

B. Simulation in S7- 200

In figure 12 & figure 13, we observe that the start switch (I0.0) is a NO (normally open) contact & stop switch (I0.1) is also a NO (normally open) contact.

When we push the start button I0.0 is high. Same time I0.1 is also on high before, as the stop switch is a NC contact in field. So it can easily make contact with the memory M0.0 This memory (M0.0) is connected to the output1 (Q1.0) through an OL relay. The Timer1 T37 is attached to the output Q1.0. While I0.0 is high, the outputs Q1.0 starts and keeps operation for 8 seconds.

After 8 Seconds the output Q1.0 is stop and the next output Q1.1 is begin to operational. Q1.1 runs for 16 seconds. After 16 seconds Q1.1 is stop and again operates the Q1.0 8 s and vice versa.

For the continuous process of the plant for 24 s, we used a NC (Normally closed) contact of Q1.1 in network 2 and a NC contact of Q1.0 in network 3.

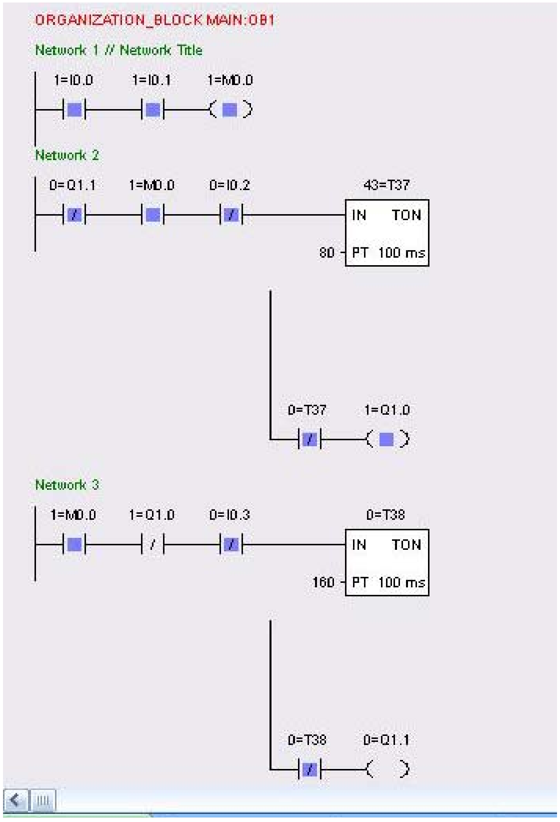

Figure 12. Simulation result in S7_200 PLC

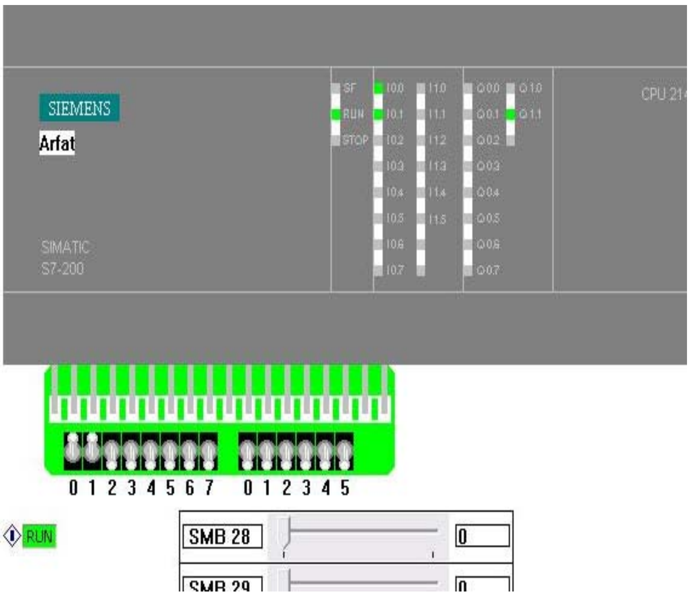

Figure 13. Controlling part of PLC

VII. Conclusion

To promote efficient technologies which could meet / supplement the energy demands of the people with locally available renewable energy Sources. Authors tried to develop the solar/biogas hybrid system will independently provide a stable power source and daily gas for medium/small area. Hybrid system will independently provide a stable power source from biogas and solar energy. This paper tried to economical evaluation of Hybrid Systems for electricity production. Larger biogas plants generate and feed electricity into mainstream power grids. These types of hybrid power plant can help us a lot to remove the loadsheding from our country and can a blessing to the small and medium industry.

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Shifting Generation of Energy of Solar PV Using OPTANG Method-Case Study Sandwip Area

Alimul Haque Khan & Kazi Rehnuma Zafreen
Electrical & Electronic Engineering
Bangladesh University
Dhaka, Bangladesh
Email: alimul_buet@yahoo.com

Asif Islam
Information Technology & Electrical Engineering
The University of Queensland
Brisbane, Australia
Email: asif038@gmail.com

Maidul Islam
Electrical & Electronic Engineering
Eastern University
Dhaka, Bangladesh
Email: maidul122@gmail.com

***Abstract*—The objective of this paper is to discover the amount of shifted energy produced by solar photovoltaic panel from lower demand period to higher demand period using the optimum tilt angle method. When the incident ray is at right angles to the panel plane, the output of a panel is highest. For maximum generation, the alignment of the panel should be changed according to the sun's position due to variations in the locus of the sun over the year. However, solar tracking system may not be suitable for this purpose as it requires high cost, maintenance and space. For an isolated area demand profile and generation profile may not be same and hence surplus or shortage will be occurred. It is hardly possible to use surplus energy considering certain demand profile constraints. Even, it is not possible to store the surplus energy of a season to any device for long time to use it for another season. Optimum tilt angle (OPTANG) method has been analysed for an isolated island of Bangladesh and shown that it is possible to shift the surplus energy to shortage season from surplus season.**

Keywords— Solar PV; micro-grid; optimization; penetration; tilt angle.

I. INTRODUCTION

There are many kind of renewable energy resources in which Solar PV is widely used in Bangladesh. The output power of a Solar panel is depended on angle between the incident ray and the panel plane. The maximum output of a Solar panel is obtained when the incident ray is perpendicular to the Solar panel plane. Moving sun causes changes in locus thus the angle of the panel should be changed according to the sun position for maximum generation. To change the tilt angle of the panel, single axis or double axes tracker is needed which becomes costly for maintenance; therefore not much appropriate. The default tilt angle may be termed as the average tilt angle at which solar panel is kept perpendicular for the maximum time. The maximum generation can be provided at the default tilt angle although the power generation from solar panel varies over the year as well as the consumption of an area is also varies.

A research has been done to optimize the tilt angle in such a way that the panel could be utilized as a shading device thus saving energy [3]. To achieve the maximum energy of sun, several types of tracker have been designed for PV panel, water heater, solar box oven and other as well considering the shading, raining and other climate factor [4]. A new approach to extract solar energy under cloudy conditions has been discussed in [5]. Another method to achieve the Optimal PV panel tilt angle based on solar radiation prediction has been articulate in [6]. Rather than using daily movement of the panel, monthly movement of panel is offered in [7]. Neural genetic algorithm based tilt angle optimization has modelled in [8].

The amount of generation and demand may not be linear relationship. Sometimes generation may be high but demand may be less. For an isolated area, it is hardly possible to use surplus energy considering certain demand profile constraint. Even, it is not possible to store the surfeit energy of a season to any device for long time to use it for another season.. However, by changing the tilt angle of a PV panel, energy transfer from surplus season to shortage season can be achieved. Different tilt angle will provide different pattern of generation over the year. Application of OPTANG [1] [2] method will not maximize the generation of energy over the year rather it will optimize the demand by shifting the energy to shortage season from surplus season.

II. SOLAR PV

The light and heat energy comes from the sun as a form of sunlight. What we experience as sunlight is actually solar radiation. It is the radiation and heat from the sun in the form of electromagnetic waves. Electromagnetic radiation reaches on earth as visible, ultraviolet and infrared light. In our daily life both light and heat of solar radiation can be utilized in many ways such as drying grains, drying clothes, generation of electricity, direct heating of water etc. Generation of electricity may be obtained by using the heat energy as a source to boil the steam for a steam turbine or by directly converting the light into electricity. Solar power can be classified into two categories, namely, solar thermal and solar photovoltaic (PV). However, only solar PV will be discussed in this paper for generating solar power. By using the principle of photovoltaic effect, solar cell produces electricity. Mobile charged particles are induced in the semiconductor by the incident energy of light which are then isolated by the device structure thus electricity is produced. The solar cells are being made from different materials and different structure in the quest of maximum power with minimum cost. However, the efficiency of commercial cells is less than half of the value tested at laboratories. Among the several types of solar cell, poly-crystalline and mono-crystalline solar cells are mostly available [9].

The effect of different load profiles on the optimum tilt angle is also investigated in [1] [2]. Using daily optimal tilt angle can increase the energy received than using optimal monthly tilt angle. Since altering the panel angle daily costs more effort so trade-off need to be made. In this investigation, it is found that, the maximum demand for an isolated grid is not met at the default tilt angle of solar panel;

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rather, it is subject to the demand profile as well as the generation profile. The idea about the best matching pattern of generation at different tilt angles with the demand profile could be best comprehended from their correlation coefficients.

III. IMPACTS OF ANGLE OF INCIDENCE

The numbers of incident photons become maximum when the incident ray is perpendicular to the plane of the solar panel. The number of incident photons become utmost Thus, the angle of incidence is a vital component. This can be described by the following equation [1].

$$I = I_o \cos(\alpha) \quad (1)$$

where,

α is the tilt angle, the angle between the incident ray and the area vector of the panel plane,

I_o= received irradiance when $\alpha=0^o$ and

I= received irradiance when α=other than 0^o

As the locus of the sun keeps on changing round the year so the incident angle varies accordingly. Therefore, this is another reason for the change of the incident angle of the ray. Very often maximum power point tracker is used to get maximum power output. Single axis sun tracker has been developed for better daily performance and dual axis sun tracker has been developed for better yearly performance. However, the expenses related with the sun tracker and the requirement of additional space has abolished the better performance of the sun tracker.

IV. THE OPTANG METHOD

OPTANG is a MATLAB based optimization routine which has been developped to find out the optimum tilt angle, where the demand will be met to its best possible match. The following key features were adopted in formulating the optimization routine [1].

Step 1*:* The total yearly demand profile and generation profile for veious tilt angle has been compared

Step 2: When demand is greater than the generation, it is considered shortage otherwise it is surplus. Thus both shortage and surplus are found for various tilt angles.

Step 3: The maximum demand is met when the shortage is minimum. The tilt angle for which the maximum demand is met is then found out.

Step 4: For a more real approximation, a random function is included for both the demand profile and generaion profile as follows:

$$\text{random\_demand} = \text{demand}*(1\text{-r} + 2*\text{r}*\ \text{rand()}) \quad (2)$$
$$\text{random\_generation} = \text{generation}*(1\text{-r} + 2*\text{r}*\text{rand()}) \quad (3)$$

These will assign +r% to –r% value of the demand or generation given at the look up table.

Step 5: Owing to the insertion of a random factor, the tilt angle at which the maximum demand is met, now varies slightly in random fashion.

Step 6: This iteration runs for n (Here n=1000) times.

Step 7: The frequency of satisfying the condition for meeting the maximum demand is found for various tilt angles.

The panel is ideally kept at a tilt angle equal to its latitude, which is about 23.5^0 for Bangladesh. This gives an overall higher output for electricity generation. For acquiring overall higher output electricity generation the solar panel is ideally kept at a tilt angle equal to its latitude, which is about 23.5^0 for Bangladesh. However, considering the load profile over the year, the best performance may not be found at the default latitude angle. This is an important analysis for maximizing the utilization of the output. For smaller and isolated system, the surplus energy is not utilized normally. On the other hand, shortages are to be met by an alternate approach. By changing the tilt angle, it is possible, to some extent, feasibility increases to shift the surplus energy for the season when there is shortage. The following analysis is targeted to have the minimum shortage for the isolated systems.

As the system is assumed to be isolated, there is no scope of utilizing the surplus, and the shortage must be met by an alternative source. The surplus energy can not be stored for long time for seasonal use. The analysed figure shows that during November to April of a year has a surplus and June to July has a remarkable shortage. However, it is technically and economically not feasible to store surplus of one season to use it for another season. It has been found that, by changing the tilt angle, it is possible to shift the curve to a suitable position, where the met energy demand will be maximum.

It has been noticed that the generation is lower in June to September and higher in October to May. By changinng the tilt angle it is possible to have higher generation during June to September, where the demand is higher, thus the shortage can be minimized. However, the surplus will also become less, but it is not a factor for an isolated system at all. The choice of a suitable tilt angle for erecting the solar panel is discussed here. The winter has a shorter day than night and the summer, a longer day. The winter should have the lower generation and summer should have the higher generation. However, the output also depends on the tilt angle. If the tilt angle is greater ($>23^0$) than the default tilt angle (latitude), the PV panel will generate more energy at winter and less energy at summer than those for the default tilt angle. For an angle smaller than ($<23^0$) the default tilt angle (latitude), the the PV panel will generate less enerrgy at winter and more energy at summer than those for the default tilt angle. By changing the tilt angle, it is possible to have closer generation pattern to that of the demand pattern.

V. ANALYSIS FOR SANDWIP - AN ISOLATED ISLAND

The results of this analysis for Sandwip based on method OPTANG are shown in Fig. 1 to 10. Fig. 1 shows the total consumption of few types of the customer in the existing microgrid of Sandip for the last three years 2011, 2012 and 2013 [10] [11]. The months are indicated by the index of the months from 1 to 36.

In this context, the location has been chosen as Sandwip, Chittagong, an isolated island. Analysis of this grid will provide more acceptable result for this program. In this analysis, the demand profile of several types of users of currrently running solar PV-diesel hybrid microgrid in Sandwip has been taken in account. The results of these analyses are shown in Fig. 1 to 10. Fig. 1 shows the consumption pattern of several types of user for the last three years (2011, 2012 and 2013).

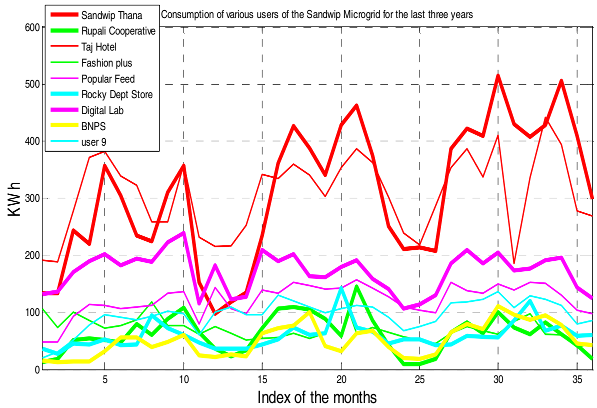

Fig.1 The consumption pattern of several types of user for the last three years (2011, 2012 and 2013)

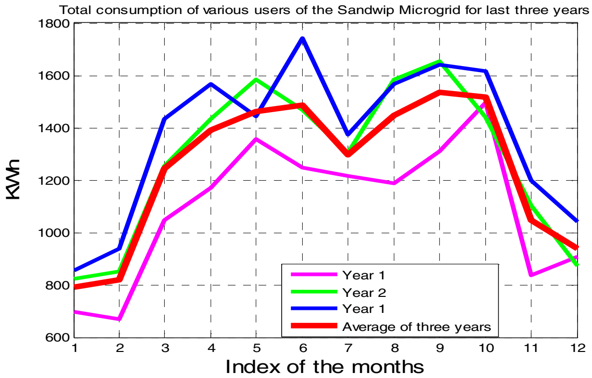

Fig.2: The total and average consumption of those users for the last three years (2011~2013).

Fig.3 shows the average consumption of the users for the last three years (2011, 2012 and 2013) as a separate figure for a clearer view.

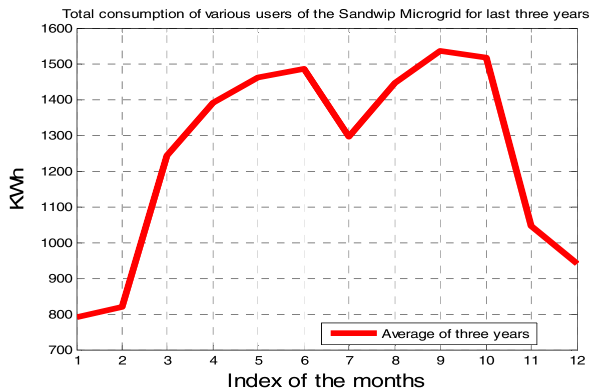

Fig.3: The average consumption of those users for the last three years (2011~2013).

This figure shows the approximate demand profile of 9 users of Sandwip microgrid. The actual demand profile is thus expected to be similar to Fig.3. Therefore, the actual demand of the microgrid will be a scaled-up version of Fig.3.

For avoiding complexity, the demand profile scaled up in such a way that it will have similar scale of previous analysis in [1] around 6500KWh of consumption per month. As the scale of demand profile is similar to the previous analysis, the scale of the generation profile thus, would be similar to that of the previous analysis. 50KW$_p$ of Solar PV panel is being considered at this analysis like the previous one. The output of the panel at Sandwip for the default tilt is shown in Fig.4 as well as the demand profile. Fig.4 shows the scaled up representation of the average consumption of the users for the last three years (2011, 2012 and 2013) have a closer range of demand pattern like that of the national demand analysis.

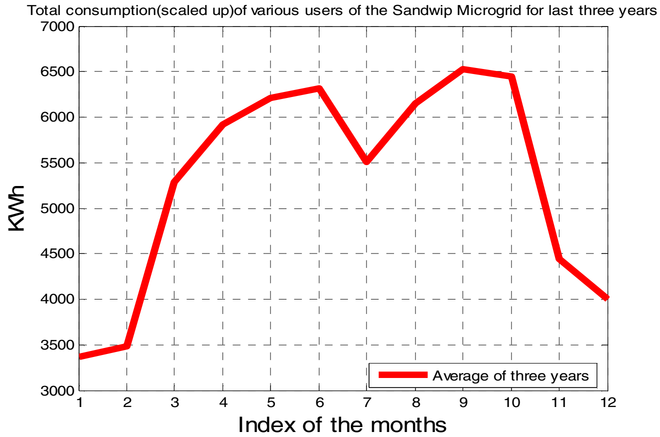

Fig.4: The scaled up representation of Fig.3.

The default tilt, optimum tilt, maximum generation of energy, maximum utilization of energy, random variation and the relationships among these have been discussed at the previous analysis. In the analysis of Sandwip, only the results are shown here. Fig.5 to Fig.10 show the results when the random variation is 0.01%, 0.1%, 1%, 2%, 5% and 10% respectively.

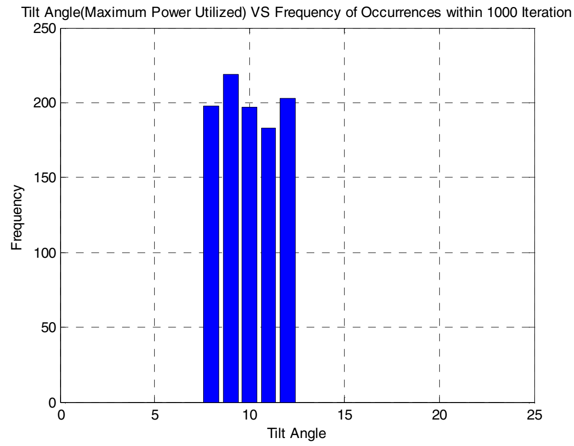

Fig.5: The number of maximum occurrence of minimum shortage for r=0.01% (tilt angle vs frequency of occurrences).

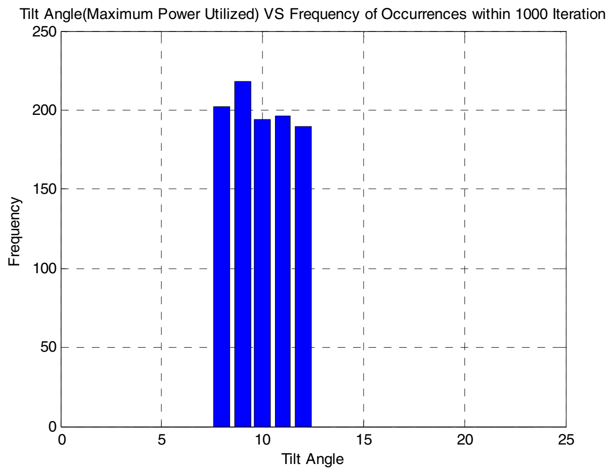

Fig.6: The number of maximum occurrence of minimum shortage for r=0.1% (tilt angle vs frequency of occurrences).

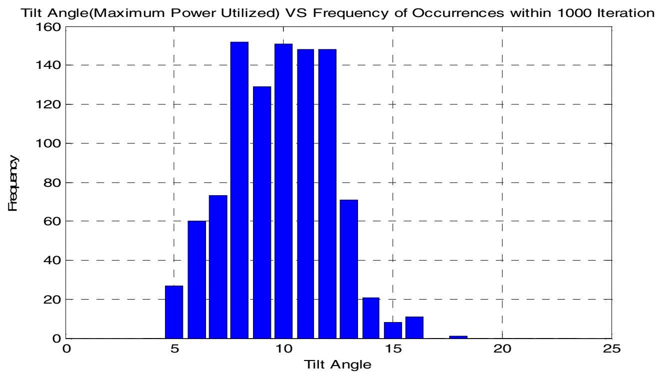

Fig.7: The number of maximum occurrence of minimum shortage for r=1% (tilt angle vs Frequency of occurrences).

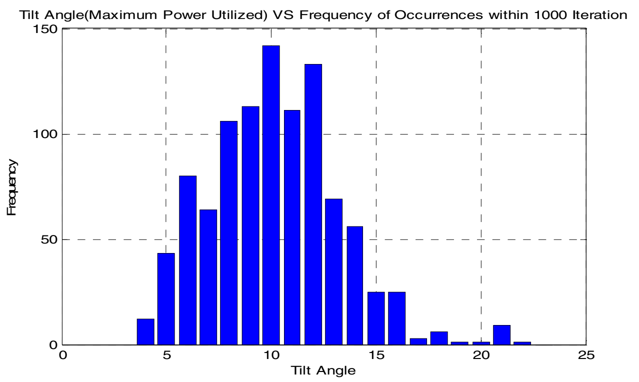

Fig.8: The number of maximum occurrence of minimum shortage for r=2% (tilt angle vs Frequency of occurrences).

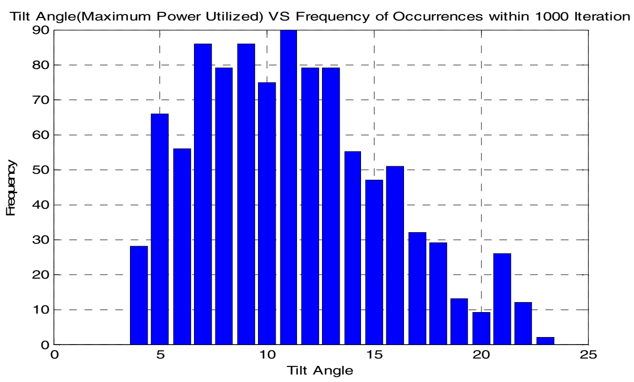

Fig.9: The number of maximum occurrence of minimum shortage for r=5% (tilt angle vs Frequency of occurrences).

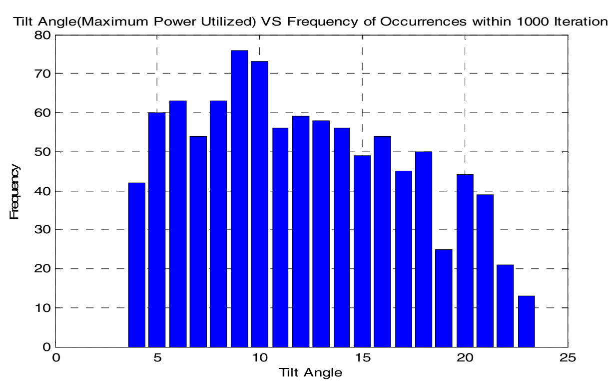

Fig.10: The number of maximum occurrence of minimum shortage for r=10% (tilt angle vs Frequency of occurrences).

For 0.01%, 0.1%, 1% and 2% of the random variation, in most of the cases, the minimum shortage occurance appears at the tilt angle of 8^0 to 12^0. In case of larger variation of the demand and generation such as for r = 5% and 10% the number of maximum occurance is still found to be around 7^0 and 13^0. These are shown in Fig.9 and Fig.10.

From the above analysis, it can be deduced that utilization of maximum power for a region may not be generated at a tilt angle of the default latitude. The default latitude will produce the maximum energy over the year, but maximum utilization of power will depend on tilt angle as well as the demand profile over the year. For a demand profile of microgrid in Sandwip and generation profile of Sandwip, the minimum shortage occurs for most of the time is at a tilt angle of 9^0 and around it. The demand, generation and surplus/shortage for default tilt (23^0) and optimum tilt (9^0) angles are shown in Fig.11.

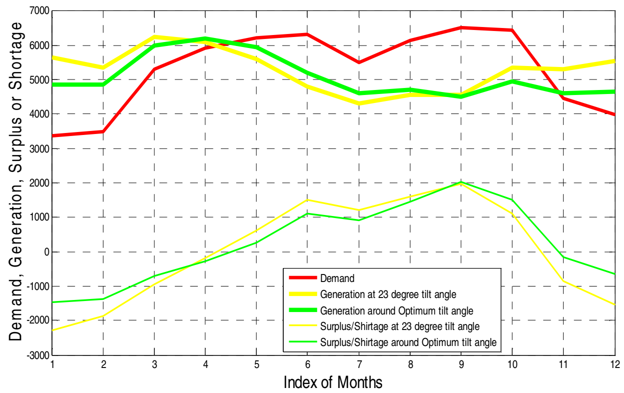

Fig.11 The demand, generation and surplus/shortage for 23^0 and 9^0 tilt angle.

Though the difference in output is not significant in percentage between the default tilt angle and optimum tilt angle, the amount will be larger for a larger system. It is however be noted that the change of tilt angle will not maximize the output of the PV panel, rather, it will minimize the shortage and maximize the demand met.

VI. RESULTS

The analyses have been done for the national demand profile considering the generation profile of Dhaka provided by the analysis of PVwatt, which is available at [12]supported by National Renewable Energy Lab (NREL). The result of the analysis for the demand profile of the microgrid of Sandwip and considering the generation profile of Chittagong is given here. The tilt optimum angle for this case is found around 9^0 tilt. Demand and generation for the default tilt angle (23^0) and optimum tilt angle (9^0) for the national load profile have been shown in Fig.12.

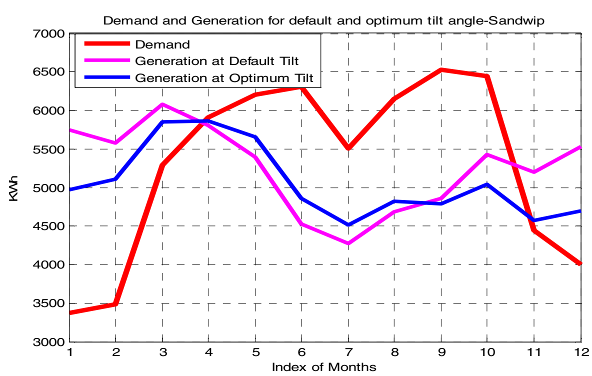

Fig.12: Demand and generation for the default tilt angle (23^0) and optimum tilt angle (9^0)-case study Sandwip.

It is also true for Sandwip microgrid that, the demand is higher from May to October over the year. At this period, the demand cannot be met by the solar panel, alternate resources of energy is needed. However, the curve for the optimum tilt is closer to the demand curve than that for the default tilt angle. Thus the demand met at optimum tilt will be more than that at default tilt. These are shown in Fig.13.

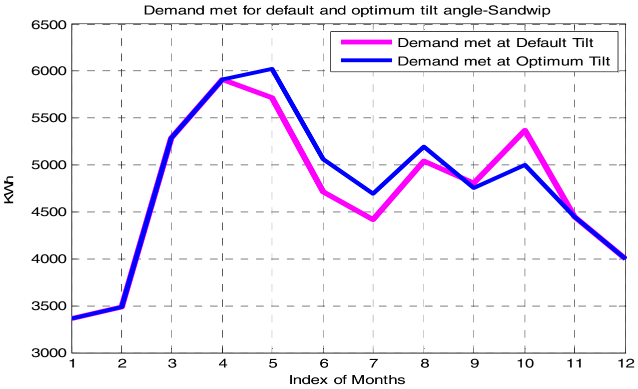

Fig.13: Demand met for optimum and default tilt angle-case study Sandwip.

As the demand cannot be met by solar panel for a period over the year, there would be shortage at that period. Shortage will be less for the optimum tilt. This is shown in Fig.14

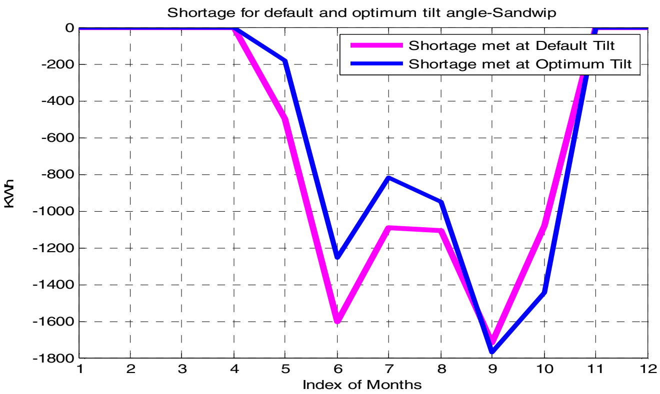

Fig.14: Shortage at default tilt and optimum tilt angle-case study Sandwip.

The results are summarised in numerical figures as follows:

(a) Yearly total demand: 63,641 KWh
(b) Yearly total Generation at 23^0 tilt angle: 66,244 KWh
(c) Yearly total Generation at 9^0 tilt angle: 63,844 KWh
(d) Yearly total shortage at 23^0 tilt angle: 70,95.5 KWh
(e) Yearly total shortage at 9^0 tilt angle: 64,14KWh
(f) Yearly demand met 23^0 tilt angle: 56,546KWh
(g) Yearly demand met 9^0 tilt angle: 57,227KWh

Although there is a trivial difference between the optimum tilt angle and the default tilt angle in percentage, for a larger system the difference will be significant.

VII. Conclusion

Like the previous analysis [1], here it is found that, the maximum demand for an isolated grid is not met at the default tilt angle of solar panel; rather, it depends on the demand pattern as well as the generation pattern. In July and near it the demand is higher and in November to February the demand is lower. However, the production pattern of electricity from solar PV does not match with the demand pattern. The idea about the best matching pattern of generation at different tilt angles with the demand profile could be best comprehended from their correlation coefficients. It is however, be noted that the change of tilt angle will not maximize the output of the PV panel, rather, it will minimize the shortage and maximize the demand met. This should be implemented in several isolated islands.

Acknowledgment

Special thanks goes to Mr. Kaysar Ahmed Sagor, Manager, Technical, Prokaushali Sangsad Ltd, Dhaka, Bangladesh for providing valuable information about Sandwip $100KW_P$ microgrid. We are also thankful to those people who provide us information about customer electricity usage.

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Biomass Energy an Alternative Solution for Bangladesh

Naznin Nuria Afrin[1]*, Shah Md. Rahmot Ullah[2], Khandaker Anamul Hoque[3], Abde Mayeen Shafi[4]
Dept. of EEE
[1, 2, 3, 4] University of Dhaka (Mymensingh Engineering College)
Mymensingh, Bangladesh
*nuriaafrin@gmail.com

Abstract—**Bangladesh has been experiencing several problems over the past few decades. Adequate amount of power generation in a sustainable way is an important issue for rapidly increasing population and economic development. Renewable energy can play an effective role to meet energy demand. Since it is an agricultural country, biomass is one of the potential renewable energy sources in Bangladesh. A large amount of cattle dung, Agricultural residue, poultry dropping, water hyacinth, rice husk etc. are available in Bangladesh which is used for power generation. Already some private organizations are producing power from the biomass. Biomass gasification has yet to consolidate its position compared to other techniques for exploiting biomass energy. In this paper, gasification techniques have been reviewed. This paper also presents the scope, potential and technologies related to the use of biomass resources.**

Keywords-biomass, gasification, rice husk, gasifier,electricity.

I. Introduction

Bangladesh is a densely populated country with almost 80% of them living in the rural area. But Only 38% of the population has access to the electricity. Now without the development of rural electrification it is quite impossible to fulfill the vision of Bangladesh Government of Providing affordable and reliable electricity to all is impossible. The main energy sources of Bangladesh are Biomass and Natural gas. Among the total energy consumption Biomass provides almost 70% [1]. Most of the energy is used at the rural areas are normally direct combustion of the Biomass Energy sources.

The original source of the energy present in biomass is the sun. Small 'factories' in plant-leaves called chloroplasts use solar energy (in the form of light energy, or photons), together with carbon dioxide from the air and water from the soil, to produce a range of compounds. These compounds include sugars, starches and cellulose collectively called carbohydrates. The original solar energy is stored in the chemical bonds of these compounds. Some of this stored energy is passed on to animals when they eat plants (or eat other animals). So plants, animals and animal excretions biomass can be seen as storehouses of solar energy. Biomass fuel is derived from three distinct energy sources: wood, waste, and alcohol fuels. Wood energy is deduced both from direct use of harvested wood as a fuel and from wood waste streams of wood. Waste energy is an origin of biomass fuel. The main contributors of waste energy are solid waste (SW), manufacturing waste and landfill gas. Biomass alcohol fuel, or ethanol, is derived almost exclusively from corn. Its principal use is as oxygenate in gasoline. Waste products from processes of the pulp, paper and paperboard industry are the source of waste energy also.

In Bangladesh a lot of rice is produced and the rice husk is a major bi-product of the rice-milling industries and in abundantly available. Rice husk is considered as a waste so there is no or less fuel cost. Among all other sources of biomass material, rice husk contains a high amount of organic volatiles. Gasification of biomass is one of the effective for the utilization of the renewable energy resource. There are many investigation on the fuel used, gasification type, kinetic and product specifications and uses concern the subject of biomass gasification.

II. Biomass Energy in Bangladesh

Biomass is the most significant energy source in Bangladesh which accounts for half (about 55%) of the total energy consumption in Bangladesh. They comprise of agricultural residues, mainly from rice and wheat plants, paddy husk and bran, bagasse, jute sticks; materials of tree origin like twigs, leaves and fuel wood; charcoal; and animal (cattle) dung. The total amount of biomass fuels consumed in the year 2000 was nearly 45 million tons (Van et al., 2005). Approximate land use pattern of Bangladesh is 64 %, agricultural land, 18%, forests, 8% human Settlement and 10% water and other. As per the statistics of the Food and Agriculture Organization of the United Nations (BER, 2004) available livestock in Bangladesh are shown in Fig. 1. It shows the livestock‘s production in Bangladesh since 1972. The production trend is so far ascending. The population growth rate is much higher than that of goats. The buffaloes and cattle production rate are almost remain same. Commercial poultry industry is emerging in Bangladesh. Estimate shows that poultry population is intensifying at the rate of 6.5% per year in the country (Huque and Stem, 1993). According to 2001 Census completed by the Department of Livestock Services(DLS) and the Poultry Sector Development Project (PSDP), there are approximately 22,570 commercial poultry farms housing 84,10,000 layers and 57,84,5000 broilers in Bangladesh. These poultry farms are producing

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approximately 4474 tons (1.63 million tons every year) of excreta every day in the country [2].

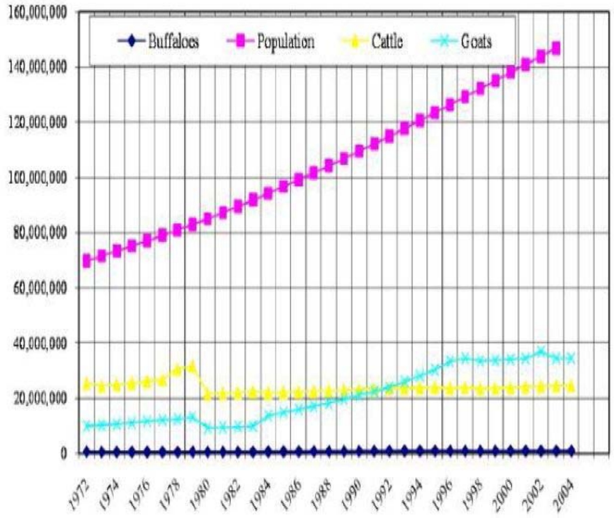

Figure 1. Livestock production in Bangladesh.

III. USES OF BIOMASS ENERGY

Green Power Technologies innovative process converts bio-waste into a renewable and clean biomass commodity that can be used to produce fuels, energy and other products [3].

- Used in the production of Cellulosic Ethanol.
- Used in the production of Bio diesel.
- Gasification process to produce synthesis gas (syngas).
- Co-firing at an existing power generation facility
- Standalone fuel for greenhouse boilers and cement kilns.
- Used at a Green Choice Bio-Recovery facility to produce steam and electrical energy required to operate the facility (The Green Choice process produces more biomass than it requires for operation).

IV. BASIS OF BIOMASS GASIFICATION

For power generation, biomass gasification technique consists of three major components; gasifier unit, gas production unit, internal combustion (IC) engine [4]. Through this technique rice can be a food as well as a source of electricity. The power derived from gasification of biomass and combustion of the resultant gas is considered to be a source of renewable energy. The calorific value of this gas varies between 4.0 and 6.0 MJ/Nm3 and the heating value is about 10 to 15 percent of natural gas [5]. The three different stages of total gasification procedure are:

1. Gasification process starts as auto thermal heating of the reaction mixture.

2. In the second stage, combustion gases are pyrolysis bypassing through a bed of fuel at high temperature of greater than 700 0 C.

3. Initial products of combustion, carbon dioxide (CO2) and (H20) are reconverted by reduction reaction to carbon monoxide (CO), hydrogen (H2), and methane (CH4).

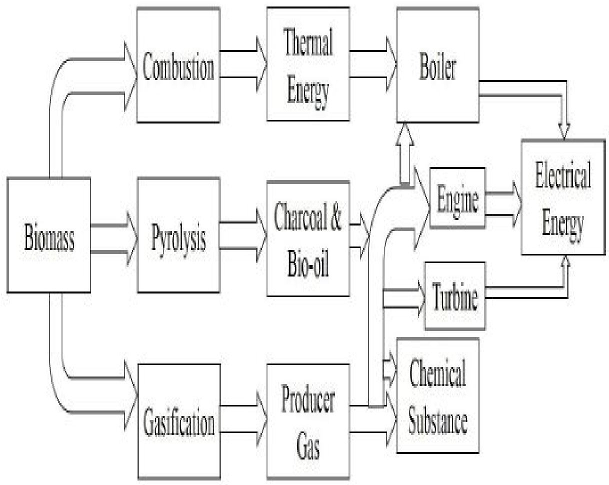

Figure 2. Flow diagram of conversion of Biomass into Energy.

Gasification technique is selected because of the following reasons,

1. This is cheaper for small scale industrial as well as power generation application.

2. Efficient than traditional rice mills.

3. Environment friendly due to reduced CO2 emission.

4. Time saving for collecting fuel.

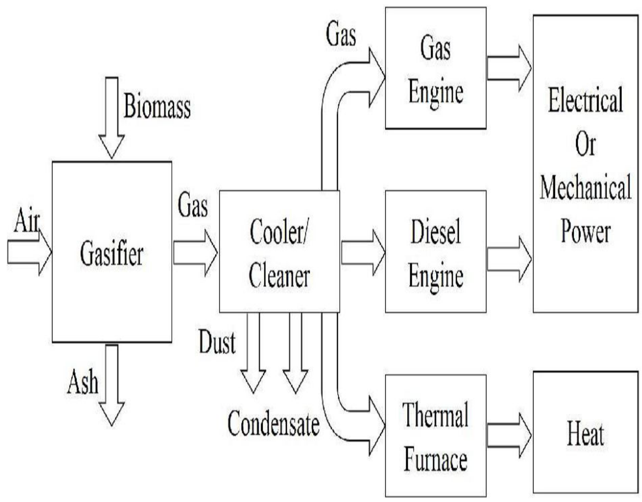

Figure 3. A flow diagram of Biomass Gasification.

V. Electricity Generation from Rice Husk Gasification

The outermost layer of the paddy grain is the rice husk, also called rice hull. It is separated from the brown rice in rice milling. Burning rice husk produced rice husk ash (RHA), if the burning process is incomplete carbonized rice husk (CRH) is produced. Around 20% of the paddy weight is husk. In 2008 the world paddy production was 661 million tons and consequently 132 million tons of rice husk were also produced. While there are some uses for rice husk it is still often considered a waste product in the rice mill and therefore often either burned in the open or dumped on wasteland. Husk has a high calorific value and therefore can be used as a renewable fuel. Several types of gasifiers are available in the existing market [7].

Some of them are fixed-bed updraft and downdraft gasifier, fluidized bed gasifier and bubbling bed gasifier. Among them the downdraft gasifier is a comparatively cheap and the produced product gas in this type of gasifier contains low tar [8]. fixed-bed downdraft gasifier is recommended for smallscale rice husk biomass plant. The schematic diagram of electricity generation from rice husk is shown below,

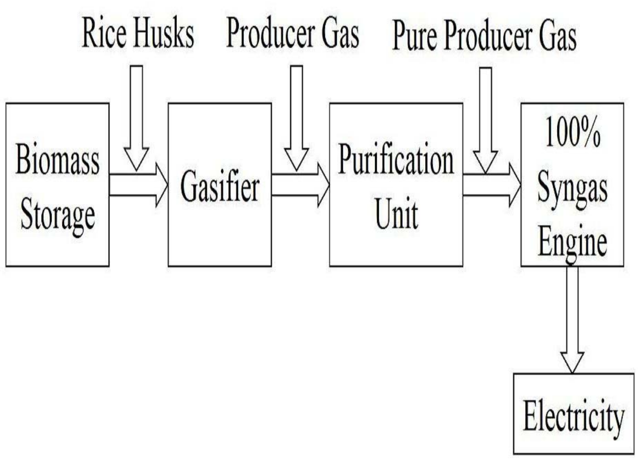

Figure 4. A flow Electricity generation by rice husk gasification.

VI. Prospect of Biomass in Bangladesh

Biomass is the major source of energy in Bangladesh. Over three-fourth of the total population of the country depends on biomass for cooking, crop drying and winter heating. So, in terms of population coverage, biomass stands important of all energy sources (Rahman, 2001). Biogas production from biomass is a proven technology. There is no risk of failure of gas production from biomasses if proper design and supervision are ensured. Recently most of the commercial banks in Bangladesh are convinced and have taken decision to provide loan for the construction of Biogas plants. Local Government Engineering Department (LGED) and some non-government organizations of Bangladesh have come forward to encourage peoples to use biomasses as an alternate energy source. Especially LGED has declared subsidy for constructing biogas plant.

Bangladesh has been facing a power crisis for about a decade, mainly because of inadequate power generation capacity compared with demand and the ageing infrastructure of many existing power generation facilities. Figure 2 shows that for the last couple of years actual demand could not be met due to the deficit in electricity generation. Though the installed capacity has increased considerably, due to shortage of available generation capacity, the actual demand could not be met over the past few years. Because of this, even with maximum generation the endemic power crisis in the country could not be solved. Moreover, only 20% of the total population is connected to grid electricity 25% in urban areas anda mere 10% in rural areas where 80% of the total population resides. Currently, most power plants in Bangladesh (representing 84.5% of the total installed capacity) use natural gas the main commercial primary energy source, with limited national reserves as a fuel (Hossain and Badr, 2007). Electricity supply to low-load rural and remote areas is characterized by high transmission and distribution costs and transmission losses, and heavily subsidized pricing and it may have a substantial short-term impaction the economy. Biomass fuels could be the best cost effective solution for the rural and remote areas in Bangladesh. About 85% of national electricity generation is originated from natural gas, with nearly 45% in direct use in agricultural production. Chemical fertilizer factories are exploring about 34.5% of natural gas, whereas biomass can replace natural gas from both of the sectors of Bangladesh. Bio product of biogas plant is improved organic fertilizer. This fertilizer contains organic component like Nitrogen, Phosphorus, Potassium and Micro Nutrients.

VII. Applications of Biomass Gasification

The syngas generated from biomass gasification can be used heat production as well as for the generation of mechanical and electrical power. Compared to other gaseous fuel, producer gas gives greater control over power level when compared to solid fuel producer gas is cleaner and efficient. Syngas can be used for further processing to liquid or gaseous fuel.

Heat: Gasifiers offers a flexible option for thermal control, as they can be retrofitted into existing gas fueled devices such as ovens, furnaces, boilers, etc. Fossil fuels can also be replaced by syngas. The heat value of syngas is around 4-10 MJ/m3.

Electricity: Currently Industrial-scale gasification is primarily used to produce electricity from fossil fuels such as coal, where the syngas is burned in a gas turbine. Gasification is also used industrially in the production of electricity, ammonia and liquid fuels (oil) using Integrated Gasification Combined Cycles (IGCC), with the possibility of producing methane and hydrogen for fuel cells. IGCC is also a more efficient method of CO2 capture as compared to conventional technologies. IGCC demonstration plants have been operating since the early 1970s and some of the plants constructed in the 1990s are now entering commercial service.

Combined heat and power: In small business and building application, where the availability of wood is sustainable 250 1000 kW and new zero carbon biomass gasification plants have been installed in Europe that produce tar free syngas from wood and burn it in reciprocating engines connected to a generator with heat recovery [9]. This type of plant is often referred to as a wood biomass CHP unit but is a plant with seven different processes: biomass processing, fuel delivery, gasification, gas cleaning, waste disposal, electricity generation and heat recovery.

Transport fuel: The producer gas can operate Diesel engine in dual fuel mode. In case of 80% high load and 70%-80% under normal load variations the diesel substitution can be easily obtained. Spark ignition engines and SOFC fuel cells can operate on 100% gasification gas. Mechanical energy from the engines may be used for e.g. driving water pumps for irrigation or for coupling with an alternator for electrical power generation. Small scale gasifiers existed for 100 years, there have been few sources to obtain a ready to use machine. Small scale devices are typically DIY projects [9].

Renewable Energy and fuels: Principally, gasification can proceed from just about any organic material, including biomass and plastic waste. The syngas, producing from gasification can be combusted. Alternatively, if the syngas is so clean that it may be used for power production in gas engines, gas turbines or even fuel cells, or converted efficiently to dimethyl ether by methane via the Sabatier reaction, methanol dehydration, or diesel-like synthetic fuel via the Fischer–Tropsch process. In many gasification processes most of the inorganic components of the input material, like metals and minerals, are retained in the ash. In some gasification processes (like slagging gasification) this ash has the form of a glassy solid with low leaching properties, but the net power production in slagging gasification is lower (sometimes negative) and costs are higher.

VIII. CONCLUION

Gasified biomass replaces fossil fuels for generating electricity or heating. This makes use of locally available resources and provides local jobs, while also cutting greenhouse gas emissions. Small-scale generation enables off-grid villages to access electricity for the first time. Families can replace smoky kerosene lamps with brighter electric light, and use phone chargers, radio and TV at home. New businesses that need electric power for machinery can be started, and existing businesses can extend their working hours with better light. It is easier to regulate the heat production from gas than from wood, so producer gas is useful in rural industries where careful temperature control is required – like briquette production (above), cardamom drying and silk reeling. Used in this way, producer gas does not require the amount of cleaning that is needed to burn it in an engine. 1.3 billion People in the world don't have access to electricity, most of them in low-income countries. Even in India, where about three quarters of the population have some access to the mains grid, many parts of the country have frequent and lengthy power cuts. Biomass gasification has a continuing role in providing access to electricity, and an increasing number of companies in Asia and elsewhere are producing gasifiers for this purpose. Governments also recognize the value of gasification in using local agricultural residues to replace high-carbon and increasingly expensive fossil fuels.

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An Efficient Wind Speed Sensor-less MPPT Controller Using Artificial Neural Network

M.M. Atiqur Rahman

A.H.M.A. Rahim
Life Senior Member, IEEE

Department of Electrical and Electronic Engineering
Ahsanullah University of Science & Technology
Tejgaon, Dhaka-1208, Bangladesh

Abstract: **An artificial neural network (ANN) based maximum power point tracking (MPPT) algorithm has been developed. The proposed ANN based controller has the ability to estimate wind speed by tracking the maximum power point (MPP) and the optimal rotor speed with very low error compared to the conventional MPPT methods. The algorithm is based on two series neural networks, one for wind speed estimation and the other for tracking maximum power point. The method demonstrates remarkable performance in estimating wind speed under rapidly changing wind conditions. It can also predict MPP accurately avoiding undesired oscillations around maximum power point. The algorithm does not require any mechanical sensor for wind speed measurement. Nonlinear time domain simulations have been carried out to validate the effectiveness of the proposed controllers in terms of wind speed estimation and MPPT under different operating conditions. Simulation results confirm the effectiveness of the MPPT controller in tracking the maximum power point under rapidly changing wind conditions.**

***Keywords*: ANN, MPPT, Renewable energy, Optimal rotor speed, Wind energy**

I. INTRODUCTION

Over the past few decades there has been significant increase in global demand for electricity. Many traditional and conventional methods are used for generation of electrical energy, most of which have adverse effect on environment. Because of the environmental concern with fossil fuel, search for clean energy has got very high priority. Renewable energy (RE) is one of the best sources of clean energy that have a very low environmental impact compared to the conventional energy sources. Wind, solar, tidal, wave, geothermal and bio-fuels are some of the renewable energy sources which have received attention. One of the easily available renewable sources is wind energy. Wind is mostly available at all time, but primary focus would be given to installation of plant on a region where the wind blows at sufficient speed. The variable speed wind turbines are becoming more popular due to its capability to extract maximum power at different velocities. The wind turbine generator is required to be operated in variable speed mode to extract maximum wind power. Usually for MPPT, anemometer is used to determine the wind speed and based on the measured wind speed; the maximum power point can be tracked. The anemometer is costly and required numbers of anemometer in different locations for accurate measurement of wind speed. To achieve maximum power the rotor should always operate at optimal speed corresponding to the particular wind speed.

Since the efficiency of the wind turbine system depends on how accurately the maximum power point can be tracked, the determination of the optimum speed for varying wind conditions have been extensively researched over the past twenty five years. Various algorithms such as tip speed ratio (TSR) control [1]-[3], power signal feedback (PSF) control [4]-[6], hill-climb search (HCS) control [7],[8], etc. are reported in the literature. Perturbation and observation technique is a simple and well used method, but the tracking performance is very slow and it may give rise to continuous oscillation around operating point [9]-[10]. Artificial Intelligence Techniques like Artificial Neural Network (ANN) [11] and Fuzzy Logic [12] have been used to overcome these problems as they have the ability to deal with non-linear objective functions. Neural networks can be used for MPPT problem [13] based on the ratio of mechanical power and turbine rotation speed. This will take care of uncertainty in parameters and also avoid oscillation. A neural network based control can be used to track MPP for both the dynamic and steady states, and to estimate wind velocity fast and accurately, without using anemometers [14]. Many methods have been proposed for ANN based MPPT of wind. Most of the methods used ANN for wind speed estimation and evolutionary algorithms (EA) such as GA, PSO for maximum power point tracking. In [15], ANN and PSO are used together to estimate the wind speed and to track the maximum power point respectively. The use of ANN along with PSO makes the procedure computationally burdensome. This study has developed an improved tracking algorithm using Neural Networks (NN) principles. The specialty of this technique is to estimate both the wind speed and maximum power point using neural network. The method determines the MPP and the corresponding rotor speed for any change in wind velocity with very little error. Simulation results clearly indicate the effectiveness of the proposed algorithm.

II. WIND ENERGY

The wind turbine mechanical output is related to the wind speed V_w and can be expressed as,

$$P_m = \frac{1}{2}\rho A C_p V_w^3 \qquad (1)$$

Where, ρ is the air density and A is the swept area by the turbine blades, V_w is the velocity of wind. As the swept area increases the power also increases. As a result the higher area machines give more power compared to the lower area wind machines. Wind power is related to the cubic function of wind velocity as is shown in fig. 1.

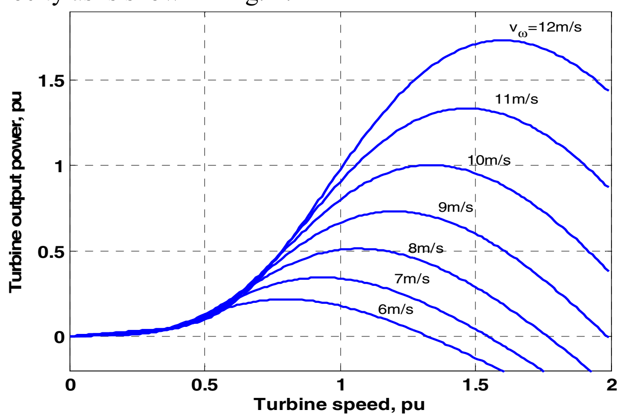

Figure 1: Speed vs. power output characteristics of a wind turbine

The wind power captured by wind turbine depends on power co-efficient (C_p) expressed as,

$$C_p(\lambda,\beta) = 0.5176\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right)e^{\frac{-21}{\lambda_i}} + 0.0068\lambda \qquad (2)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \qquad (3)$$

Here, λ is the tip speed ratio and β is the blade pitch angle. The value of λ can be calculated using the following relationship,

$$\lambda = \frac{\Omega R}{V_w} \qquad (4)$$

III. MPPT STRATEGY

The maximum power point tracking concept is illustrated clearly in Fig. 2. It can be observed that the maximum power which can be captured at different wind speeds vary along the solid-line shown in the Fig. 2. For example far a particular wind speed, B represents the maximum power while the corresponding rotor speed is ω_r* at point B. The tracking problem is to find the optimum speed ω_r which will yield power P_m* at a certain wind speed V_w.

The artificial neural network is employed in this work to determine wind speed V_w and optimum turbine speed ω_r* from the measurement of power output.

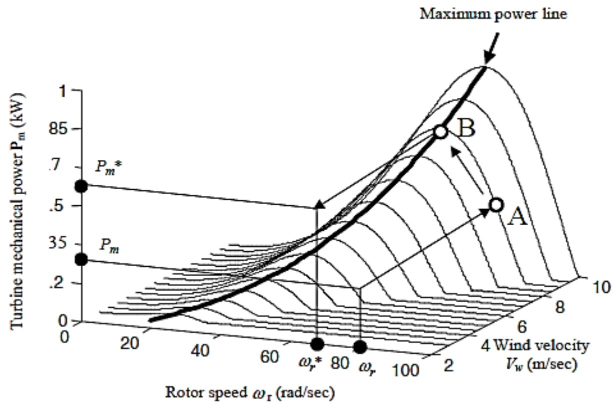

Figure 2: Wind turbine power curves [14]

IV. ARTIFICIAL NEURAL NETWORK (ANN)

Feed forward back-propagation algorithm is used to train the proposed MPPT controller as shown in Fig. 3. This type of ANN is devised, where the information moves both in forward and backward direction. A set of inputs is provided to a hidden layer by different strength of connections or weight function, and then finally passed to the output layer. During learning process, back propagation network use gradient-decent search technique to adjust link weights between nodes to minimize the error of ANNs. Back propagation algorithm is very popular and used successfully in many applications like pattern recognition, location selection, performance evaluations and so on.

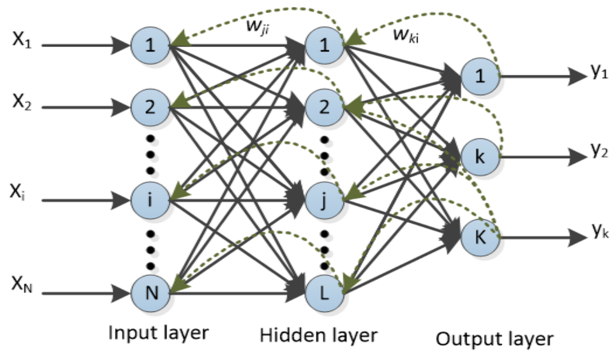

Figure 3: Feed Forward Back Propagation

If the dimension of input is j there would be j weights, as a result the net signal available to the neuron would be given by u_k in (6). The output for neuron V_k is best expressed as sigmoidal function as in (7). The final actual output is given by (8)

$$u_i = \sum_{j=-1}^{n} x_j w_{ij} \qquad (6)$$

$$V_k = \frac{1}{1+e^{(-u_i)}} \qquad (7)$$

$$Y_i = \frac{1}{1+e^{(-s_i)}} \qquad (8)$$

The sum of squared error or cost function (E) is given as square of difference of target output t_i and y_i actual output described by (9)

$$E = \frac{1}{2}\sum_{m-1}^{M} E_m = \frac{1}{2}\sum_{m=1}^{M}\sum_{i=1}^{l}(t_i^m - y_i^m)^2 \qquad (9)$$

The weights are updated from minimization of the cost function by gradient descent method. In back-propagation networks the initial weights and biases are selected randomly by deploying maximum and minimum value of input. These weights are continuously updated, for i^{th} neuron the j^{th} weight update equation is given in (10).

$$w_{ij}(t+1) = w_{ij}(t) + \eta \left(\frac{\partial E_m}{\partial w_{ij}(t)}\right) \quad (10)$$

where learning rate is denoted by η, $w_{ij}(t)$ is the old weight, $w_{ij}(t+1)$ is the new weight.

In this study two series networks are used for ANN based MPPT as shown in Fig. 4. Based on the operating turbine power and rotor speed, network-1 estimates the wind speed. The estimated wind speed input for network-2 is used to determine maximum power point and corresponding optimal rotor speed.

Figure 4: Proposed ANN based MPPT controller

V. RESULTS AND DISCUSSIONS

The ANN developed in this study using two series networks was tested for given wind speed profile shown in Fig. 5. The given (original) speed is shown by the solid lines and the neural network output is represented by the dotted lines. It can be seen that the predicted wind speed variation completely overlaps the original one. Fig. 6 shows the difference between the given and estimated values. As can be seen the maximum difference is 0.11 m/s.

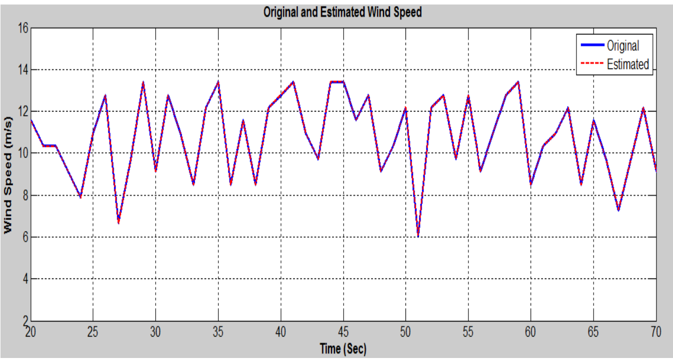

Figure 5: Original and estimated wind speed

In Fig. 5, simulation result shows the error in wind speed estimation for ANN based wind speed estimator. It can be noticed from the graph that the wind velocity is well estimated with small errors, the maximum error is only 0.11 m/s.

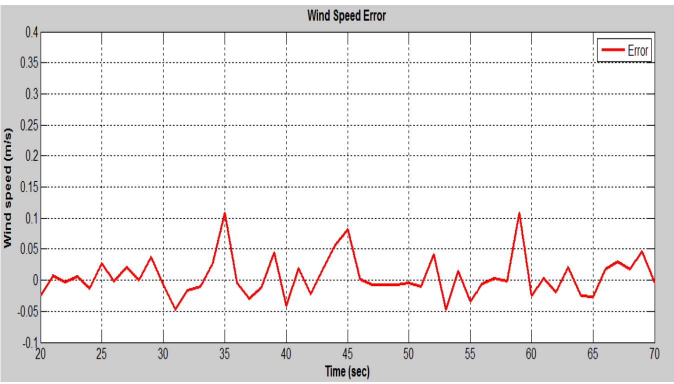

Figure 6: Wind speed estimation error

Fig. 7 shows the original and estimated maximum power points. The results shown in Fig 7 & Fig. 8, demonstrates that the proposed MPPT controller has the ability to track maximum power point under rapid change in wind conditions with very little error.

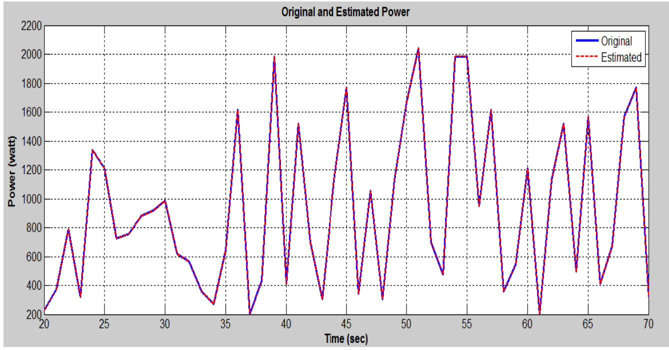

Figure 7: Original and estimated maximum power

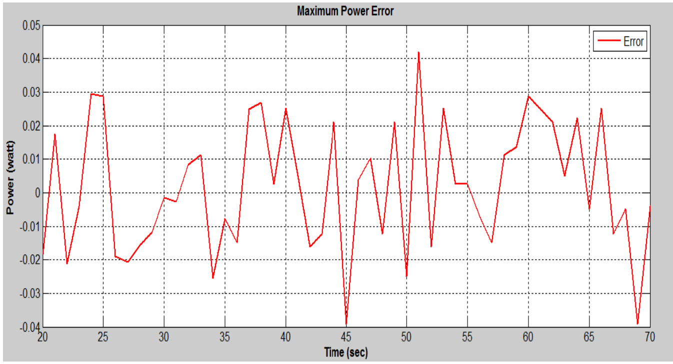

Figure 8: Maximum power estimation error

Fig. 9 shows the original and estimated optimal rotor speeds. Fig. 10 shows the errors in optimal rotor speed estimation. The results, demonstrates that the proposed MPPT controller has the ability to track optimal rotor speed efficiently under rapidly changing wind conditions. The maximum error is only 4.1x 10^{-4} rad/sec.

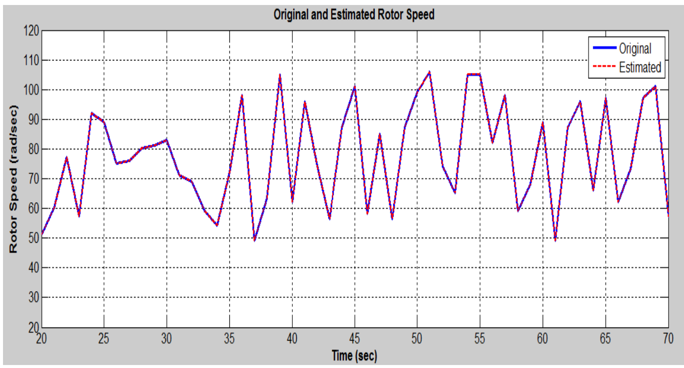

Figure 9: Original and estimated optimal rotor speed

Figure 10: Rotor speed estimation error

Comparison with reported results

The proposed ANN based MPPT algorithm is compared with the previously presented results [12]. The study considers a variable speed small wind generation system to evaluate the performance of the proposed and reported algorithm. The generator rating of the wind is 1.4 kW and radius of the turbine blades is 1 m.

Fig. 11 and Fig. 12 show the original and estimated wind speed by the proposed controller with the reported results.

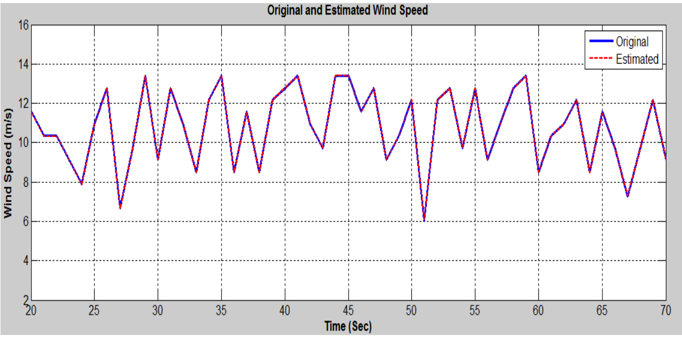

Figure 11: Original and estimated wind speed

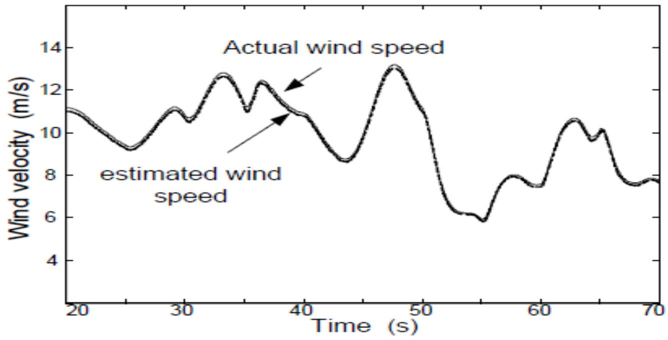

Figure 12: Original and estimated wind speed [14]

Fig.13 and Figure 14 show the wind speed estimation error using proposed controller and the reported controller. The maximum error in wind speed estimation for the proposed controller is 0.11 m/s, while the same for the reported results is 0.25 m/s.

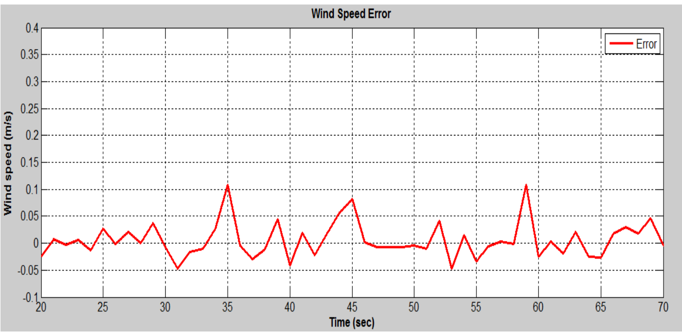

Figure 13: Wind speed estimation error

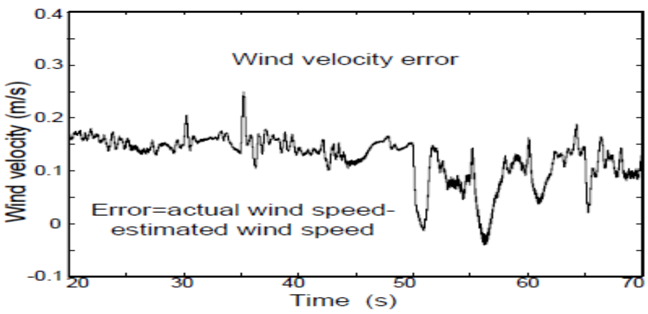

Figure 14: Wind speed estimation error [14]

The original and estimated optimal rotor speeds using proposed controller and the reported results are shown in Fig. 15 and Fig. 16 respectively.

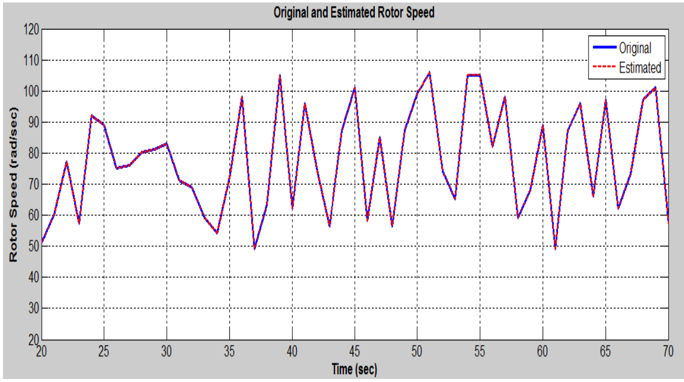

Figure 15: Original and estimated optimal rotor speed

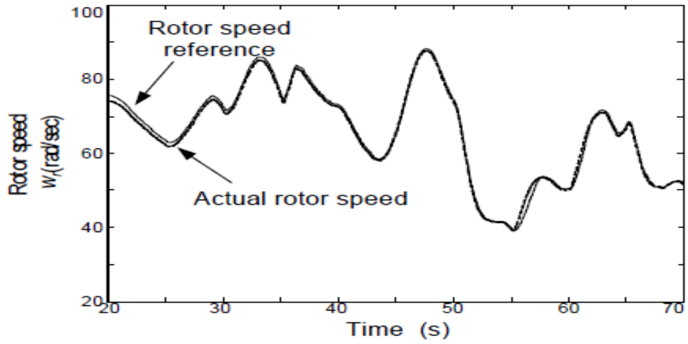

Figure 16: Original and estimated optimal rotor speed [14]

From Figure 16 it is evident that maximum rotor speed error for the presented result around 1 rad/sec, for the proposed controller it is 4.1 x 10^{-4} rad/sec as shown in Fig.17.

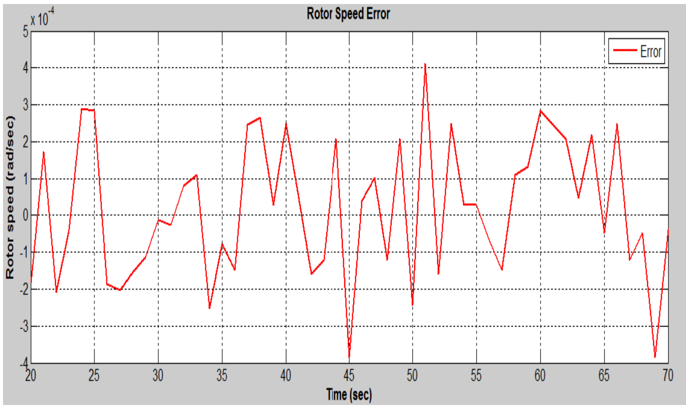

Figure 17: Rotor speed estimation error

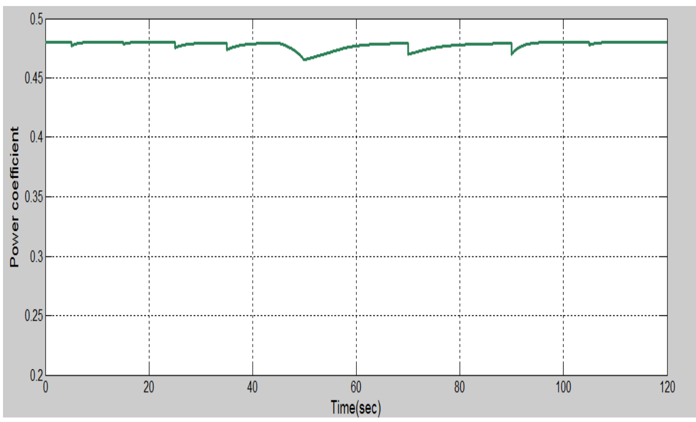

Figure 18: Change in power coefficient for random wind speed variation

Fig. 18 shows that the proposed MPPT controller is able to maintain the optimal value of power co-efficient with the change in wind speeds.

VI. CONCLUSIONS

An artificial neural network based maximum power point tracking algorithm is presented. The proposed MPPT algorithm does not require any mechanical sensor for wind speed estimation. It also does not require any pre-knowledge of the system. Tests under rapidly changing wind conditions has shown that MPPT controller is very accurate in maximum power point tracking and yields optimum value of power coefficient (C_p). The feasibility of the proposed ANN controller is validated and the simulation results exhibit the robustness, fast response, and exact wind speed estimation. The obtained results demonstrate that the proposed controller has better dynamic and steady state performance than the conventional method as well as the reported ANN based MPPT technique.

ACKNOWLEDGMENT

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Feasibility Analysis of Solar DC Nano Grid for Off Grid Rural Bangladesh

M. Mahmudul Hasan Sajeeb*, Md. Aminur Rahman, Shaila Arif
Department of Electrical and Electronic Engineering, Ahsanullah University of Science and Technology
141 -142 Love Road, Tejgaon I/A, Dhaka – 1215, Bangladesh.
*mahmud.sajeeb08@gmail.com; aminur.rahman.eee@gmail.com; shaila221228@hotmail.com

Abstract—**Due to the gradual reduction of fossil fuel, renewable energy resources have become the next best alternative to meet up the accelerating demand of electricity. Among all kinds of renewable energy resources solar energy is the best suited source of power for the perspective of Bangladesh. Nano grid is a vital element of smart grid which is one of the talked topics around the world facilitating the system reliability with distributed generation. Solar DC Nano grid is a modern renewable technology which can efficiently be used to meet up the power demand for off grid rural areas. In this paper we have represented a rudimentary discussion about Nano grid, its advantages and challenges, all necessary survey data about an installed DC Nano grid in Kushita district and how solar DC Nano grid can be an essential driving element to combat future power demand in rural areas of Bangladesh.**

Keywords—Nano grid, Micro grid, Smart Grid, DG (Distributed Generation), SHS (Solar Home System) etc.

I. INTRODUCTION

Power is considered to be the most important strategic inputs for socio-economic development and rapid industrial growth. In case of developing countries like Bangladesh, energy crisis poses a great hindrance in the path of future infrastructure development. It is also regarded as one of the widely discussed and vastly concerned issues because the fossil fuel is being depleted gradually. Among the fossil fuels gas is the main resource for the generation of power in our country but it is on the way to be depleted. Coal can be a potential source of energy but its extraction process is still in rudimentary level [1]. Considering the ever increasing price of fossil fuel and its environmental aspect renewable fuel sources are the obvious choice.

Among all the renewable technologies, solar photovoltaic (PV) is the most potential, favorable and promising one which converts solar energy into electrical energy, including or excluding battery backup. The energy received by the earth surface form the sun in the form of radiation is known as solar energy. Solar radiation is strongly dependent on the atmospheric condition, time of year, the angle of incidence of sun rays on the earth surface and other related geographical aspects. Situating in between 20.30 ◦-26.38 ◦ of north latitude and 88.04^0-$92.44^0$of east, environmental situation in Bangladesh is very much favorable for solar energy harnessing and most of the flat land of the country is open to bright sunshine most of the time of the year as summer time is dominant here.

As a part of energy development campaign, IDCOL (Infrastructure Development Company Limited) has started to establish SHS (Solar Home System) in rural areas of Bangladesh [1]. In SHS the household owner generally drive two or three lights, one fan and sometimes one TV which aggregately don't exceed 100 Wp. But nowadays some companies of Bangladesh have started to establish Solar DC Nano grid which provide electrical energy to the households from a central source of PV system with sufficient battery backup and constituting a 220 volt DC grid. A number of households take electricity from the grid through a prepaid energy meter.For the SHS, any excess power generated due to bright sunshine or long hours of sunlight cannot be utilized and is therefore wasted. In contrast, for the solar Nano-grid, any excess power generated from the central location, can be effectively utilized for small commercial or industrial needs like shops, cottage industry, irrigation etc. Consequently, from both a technical and operational point of view, the Nano-grid due to its small size, short transmission distance and centrally located generating unit, may be a good option compared to home or mini/micro/standalone systems.The DC grid system is more cost effective and reliable avoiding the inverter for AC conversion.For our research purpose we have investigated a DC Nano grid installed by Solar Intercontinental (SOLARIC) Limited in Doulatpur, Kushtiya district[2]. We have taken necessary data and analyzed the Nano grid from every aspect.

II. CONCEPT OF NANO GRID

The concept of Nano-grid [2] is based on the idea of SHS in which the basic electricity needs of the households (consumptive load) are met, but at the same time it proposes the incorporation of some small scale agricultural or commercial applications (like irrigation). This takes advantage of the fact that houses are frequently clustered together in rural areas in groups of 40-50 houses within a diameter of less than 500m. In the Nano-grid system, a basic 1.5 to 3 kWp, PV system is installed in a small cluster of households within a short radius of each other (ideally 230-250m) and power is distributed to the households from this system. The generation and storage of this system is 48 Volt DC. System has a dc to dc converter and its output is 220 Volt dc. This system has an option of DC (220V) to AC (220V) conversion. The payment method for the consumer is paid per unit energy by using

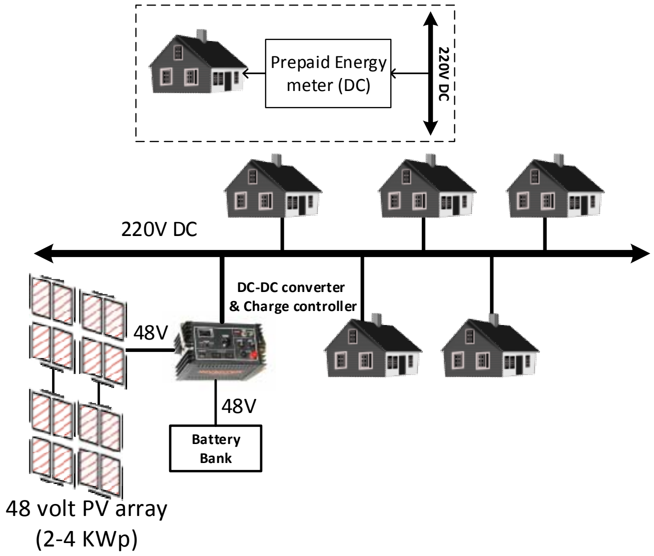

Fig. 1: Typical example of Nano Grid.

prepaid energy meter. The fig-1 in the following represents a typical DC Nano grid.

III. Advantages of Nanogrid

Nano grid is featured with the following advantages [2]:

a. Scalable at all level (DC, High Voltage)
b. Starting load could be small to reduce the cost of installation and then scaled up as the load grows.
c. Unlike AC grid, Scaling up the generation is simple (just adding in parallel). No synchronization is required.
d. Any standard load can be used.
e. No maintenance is necessary by the end customer.
f. Prepaid meter makes collection significantly easy.

IV. Challengs of Nano Grid

1. Switching arc: Interaction of dc current has persistence arc which reduces the operating life of the switching device.
2. Shocking hazard: High voltage DC in the rural areas has higher potential of shocking hazards.
3. DC to DC conversion loss: This system converts low voltage (48V) to high voltage DC (220V). Any conversion has inherent loss.
4. Power limitation: It is difficult to realize high power DC to DC conversion in the range of 100KW.
5. Underground cabling requires special attention in terms of quality and size of cable, fault isolation, thermal resistance of the soil, compacting etc.

V. Over Come to the Challenges

1. Solid state relay in low power range (20A, 220V) is available to overcome this issue. No need to use magnetic relay anymore. There is no arching issue with Solid State Relay.
2. Proper wiring and workmanship can reduce the hazards of shocking.
3. High quality converter (more than 90% efficiency and very low static loss) mitigates the energy loss due to conversion. In general, DC-DC converters are more efficient than its counterpart DC to AC converters known as inverter.
4. For small systems (few KW), this is not a significant issue and this problem can be overcome by parallel operation of several systems.
5. Low power (typically less than 1KW) system is significantly easy and simple to use underground cabling. Also with DC system, the electrical shielding is not required which improves the thermal characteristics of the cable for cooling.

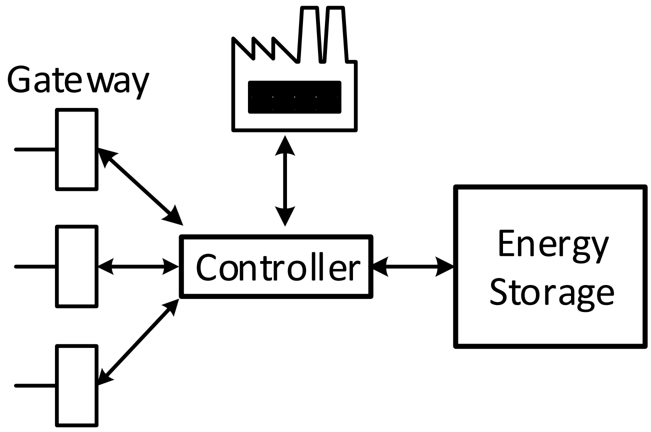

Fig. 2: Gateway control of Smart grid.

VI. Nano Grid as an Essential Element of Smart Grid

Smart grid is one of the discussed topics at present. Nano Grid is an inseparable part of smart grid. Blackout, low frequency oscillations, voltage collapse etc. various types of power system contingencies are critically scrutinized by the experts and the concept of smart grid has been emerged which incorporates various automatic sensors to monitor the grid.As new clean green energy technology like solar/wind power is gaining popularity now, the consumers can also produce some power for their need,which in turn directs the concept of two way power flow.In the developing word the concept of Nano grid is gaining popularity. Some system use solar and wind source, which is not always reliable due to the variation in weather pattern and thus a backup system had to be used in combination. The backup system used in the grid increase the cost of the project significantly. The problem can be eradicated by connecting the Nano grids with intelligent control system to form a micro grid [3] which can be seen in Fig. 3. Nano and micro grids can be connected in the smart grid using 'gateways'. Each gateway controls the Nano or micro grid system which can have any primary fuel sources like solar, wind geo-thermal etc. The controller uses the data from the gateways to divert power from mainpower plant to the Nano/micro grid or from one micro grid to another. If necessary the controller can store power momentarily to be

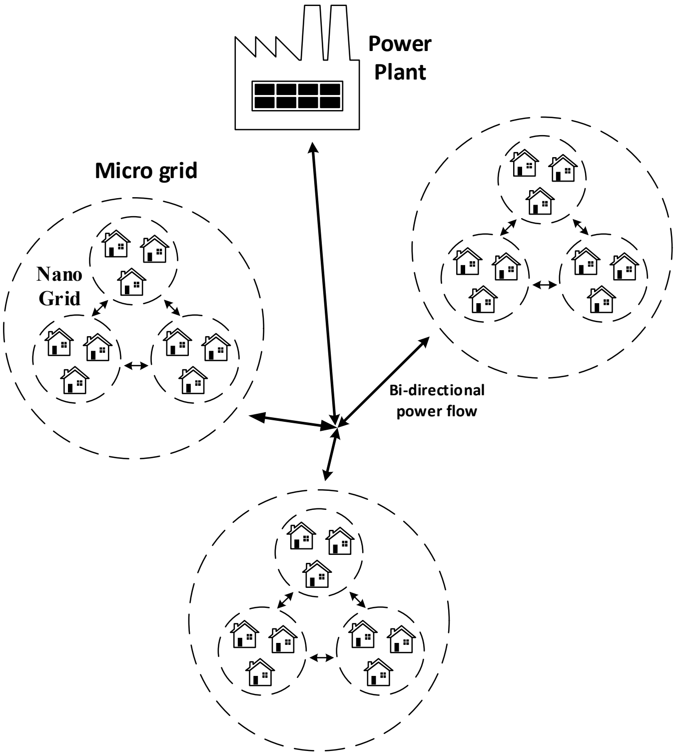

Fig. 3: Nano grid connectedly forms microgirds

utilized later [4]. Also the Nano and micro grid work autonomously which ensure the fault tolerance and reliability of operation.

VII. Survey of Nano Grid in Kushtiya

A. Brief About the Nano Grid:

We investigated the Nano Grid of Doulatpur, kushtia district which was installed by Solar Intercontinental (SOLARIC) Limited. The Nano Gird has been set up on the house of a certain consumer from which all the households are served solar electricity in 220 volt DC form. In this arena the end users are clustered in 300m long and 100m wide land. Here 16 batteries have been used. Four 12 volt 130 Ah batteries are connected in series to make 48 volt. Four strings of 48 volt batteries are connected in parallel to increase current capacities. The panels are 250 Wp, 24V.Two panels are connected in series to make it 48V. Then this is connected as multiple strings. The connection of batteries and panels are given in Fig-4.

The distribution network for the 20 houses has been done using 4 RM and 2.5 RM wire.Considering the cluster of houses and their load demand, voltage drop in wire and cost, these wires was found to be most favorable. From the cost breakdown of the project it is clear that the cost of the copper wire is significant and good wiring practice need to be ensured to minimize the wiring cost without disturbing the system voltage. The system has the option of using inverter to drive AC load but inverter is not used, because inverter makes the system less efficient as it has own watt loss. Also the elimination of inverter can reduce the system cost by 25 % [5].

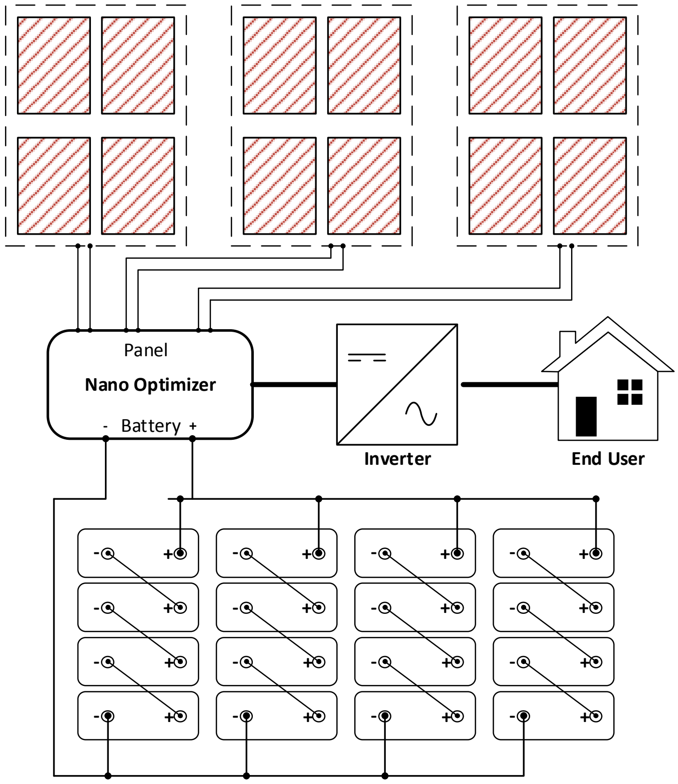

Fig. 4: Batteries and panel connections of Nano Grid

Considering the efficient usages of the loads the company provides 12 volt DC fan, light and TV. Consumers have been given 220V to 12V converter to drive the load as the grid is 220V.

B. Cost Calculation of the Nano Grid:

The overall cost of the Nano grid project turns out to be moderate considering the generation capacity. But little cost can be reduced in different installation schemes. Cost of the pre-paid energy meter can be eliminated by using different payment scheme or implementing flat rate for fixed load or by controlling load consumption from source. Also Due to the remote location of the installation, the backup generator is used for emergency situation which in many situations can be removed completely. The cost calculation is elucidated below.

TABLE I
COST CALCULATION OF THE NANO GRID

Item	*Specification*	*Quantity*	*Amount (BDT)*
Solar Battery	130AH	16	2,06,400
Solar Panel	24V/250 Wp	12	1,95,000
Nano Optimizer	3KW	1	45,000
DC-DC converter	3KW	1	60,000
Digital Pre paid Energy Meter	300W	50	1,25,000
Led Bulb/Fan	5W/14W		83,600
Cable (panel, distribution network)			80,276

Different Mounting for battery/panel/ optimizer			60,000
Various small accessories for installation (tape, channel, Screw, Junction Box etc.)			40,077
Backup Generator	3KW	1	30,000
Transportation, food and accommodation			30,000
Total			**955,353**

C. Load Graph:

A typical energy generation and consumption trend can be seen in Fig. 6 and the peak load requirement can be seen in Fig. 7. The data was taken during July, 2014. From the solar irradiation data of the area it is clear that only December and January have less solar irradiation in kushtiya which means the data from July 2014 can be used as a relatively good reference for the overall calculation.

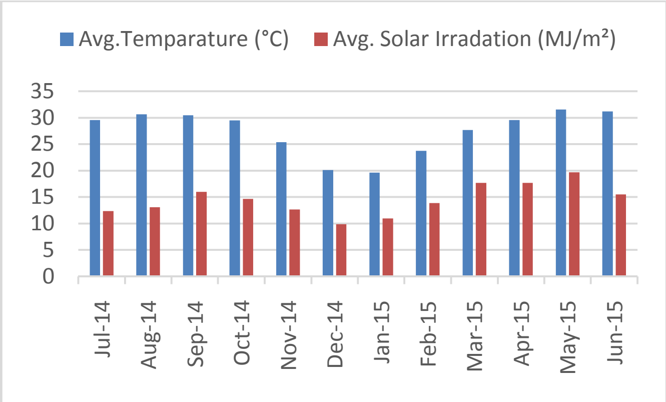

Fig. 5: Average solar irradiation and temperature of Kushtiya, Bangladesh

By analyzing the data the limitation of the setup can be seen. From hour wise consumption trend and peak load from Fig.7 and Fig. 8 it is quite clear that the peak load requirement never exceed the maximum 3KW peak capacity of the system butthe KWh consumption is higher than the generation. By analyzing the solar irradiation, temperature data and PV panel output data it is obvious the problem is due to the cooling load duringthe summer time. During the summer time the average temperature of the area exceed 30degree and due to the high relative humidity of the area, cooling load (fan) is increased significantly. This energy deficit can be solved by increasing the energy storage capacity.

D. Shortcomings of the Installation:

The system is optimized for the particular cluster of homes and the wiring is done based on the load requirement and minimum voltage drop. For covering bigger area the wire need to be replaced with higher gauge wire to ensure low loss and high load demand. In the investigated Nano Grid there is no proper protective scheme against any lightening hazards. Proper grounding or earthling is inevitably required into the deep ground approximately 30 to 40 feet. But this protective installing will add extra expenditure to the system. So, lucrative compromise between grounding expenditure and total expenditure should be drawn.

VIII. Future Prospect of Nano Grid in Bangladesh

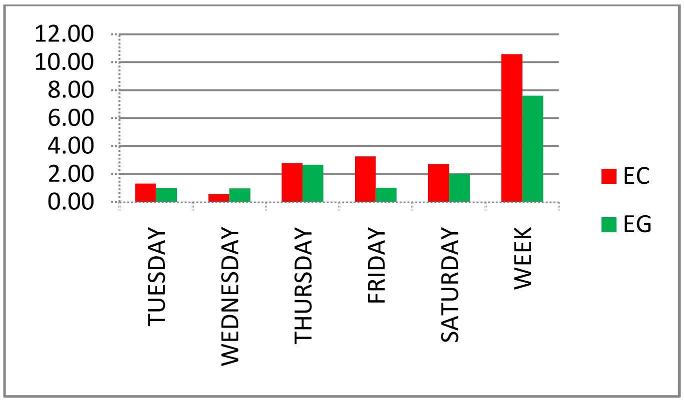

Fig. 6: Typical Energy generation and Energy consumption of the system (in KWh)

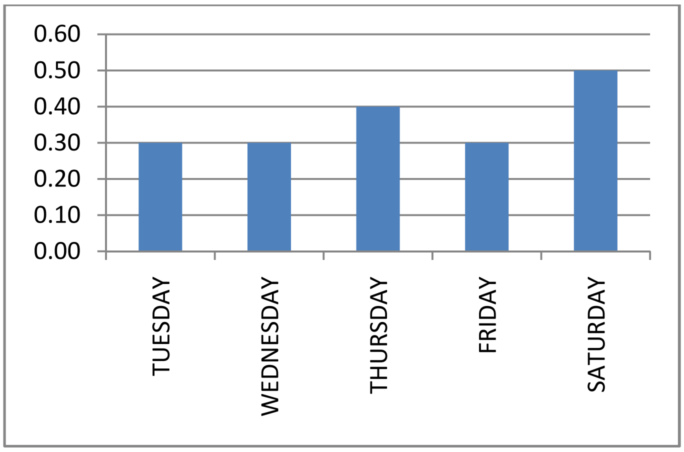

Fig. 7: Peak load requirement over a week (in KW)

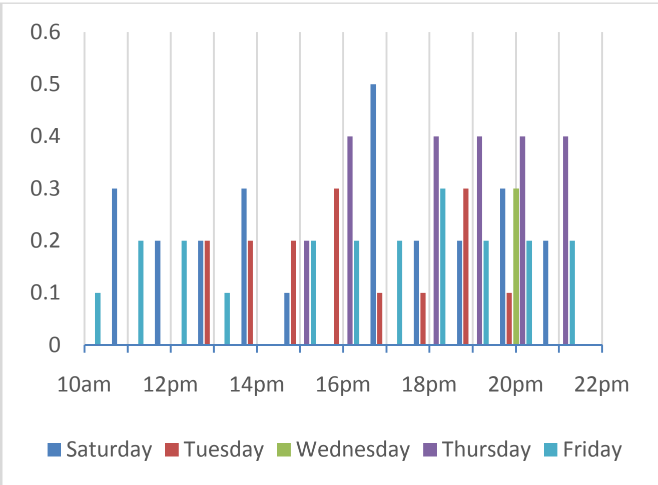

Fig. 8: Load variation during the day

Nano grid can be a significant strategy to combat against rural electricity problem if properly cared. Solar water pumping system, refrigeration, and electric cooking can also be implemented by using Nano grid [5]. But for those cases Nano grid capacity should strictly be maintained incorporating proper or efficient panels and batteries. Battery capacity should be compatible enough to the system. Instead of lead acid batteries dry cell batteries can be used as lead acid batteries have the problems of changing distilled water. For pumping system, the pump must have to be low loss pump having lower consumption of power otherwise aggregated load consumption can exceed Nano grid capacity and thus leading to the system failure.

IX. CONCLUSION

Energy deficiency is a notable problem in off grid rural areas of Bangladesh. A country's development can easily be presumed by measuring its per capita consumption of electricity [6]. Although urban areas are completely electrified by the national grid, still there are so many villages which are deprived of electricity. In this off grid areas, Nano grid is really an outstanding power solution scheme to be adopted within the limit of village people. Our investigated Nano grid is yet costly. The government and concerned organizations suchas IDCOL (Infrastructure Development Company Limited), Brac, Grameen Shakti etc. should proceed to popularize the Nano grid in off grid rural areas cost effectively. After that we can expect a successful power solution in the whole country reducing extra pressure on the national grid.

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Design, Implementation and Cost Analysis of a Solar Powered Water Pump for Multistoried Building

Mohammad Rejwan Uddin
School of Engineering & Computer Science
Independent University Bangladesh
Dhaka, Bangladesh
E-mail:rejwanuddin@yahoo.com

Mohammad Rabiul Hossen
School of Engineering & Computer Science
Independent University Bangladesh
Dhaka, Bangladesh
E-mail: sumon94ctg@yahoo.com

Khosru M Salim
School of Engineering & Computer Science
Independent University Bangladesh
Dhaka, Bangladesh
E-mail: khosrumdsalim@yahoo.com

***Abstract*- Electric motors are used to pump water in multistoried building. Total power consumed by those motors is huge in urban area. By implementing a renewable energy source to run those motors can save energy from national grid. The purpose of this paper is to provide information about planning and installation of solar powered water pumping systems by using Thin Film PV (Photo Voltaic) Module. 20 panels of 95 Watt are mounted by using movable concrete pillar for flexibility. A 3D design was created by using SketchUp 3D to bring perfection in mounting solar panels. A three phase inverter is used to operate with higher output voltage of Thin Film PV Module. To avoid starting torque and maintenance cost, a three phase 2 HP AC water pump is used for pumping water. A four storied building is considered to lift water from reserve tank on ground. The system has been tested successfully in delivering 500 liter water in 17 minutes to the over head reserve tank at broad sunlight. Total cost for installing this project is also analyzed in this paper.**

Keywords: Water Pump, Thin Film, Photo Voltaic, Multistoried Building.

I. INTRODUCTION

The increasing demand of electric power and shortage of present energy resources lead today engineers and scientists to think about the alternative sources of energy, the sunlight is a potential sources for generating electric power [2]. The irradiance in Bangladesh varies from 3.5 kwh/m^2/day to 6.5 kwh/m^2/day at an average of 5 kwh/m^2/day [1]. These indicate that there are good prospects for solar thermal and photovoltaic application in the country. Based on that, in recent years, it is increasingly used to generate power. The use of solar energy is attractive for solar home system application also. Solar home system are quite, need no fuel and require very little maintenance [3]. Like other power sources, it does not emit any Ozone gases and could play a very important rule to protect the environment. Other advantages of a PV (Photo Voltaic) system are: free energy, reliable power, flexibility and quick installation.

Around 70-80% power is consumed by electric motor around the world [4]. Besides industrial motor, huge power is consumed by home appliance water pump and it is almost 20% of total power taken by motor [4].

Most multistoried building (5-10 storied) uses 1.5-3 HP water pump 6-8 hours daily [5].

People are indeed of two types of water pump in urban area of Bangladesh [5].

- Water Pump: This is the most common water pump used for lifting water from reserve tank to roof top tank. It can lift water usably 40 -100 feet.
- Deep Water Pump: It is been used where WASA (Water and Sewerage Authority) unable to provide regular water. Water is collected from the deep ground level of water. Submersible pump or pumps that can lift water from deep are usually used for this purpose. Its suction length varies from 100-600 feet.

The wattage of those pumps is 1.5 KW to 5 KW. Therefore, 6 hours run time daily will draw 9 KWH to 30 KWH of power. After the month, a huge power will be consumed by those motor. Solar PV module could be the supplier of this required power which will be reliable, cost effective and source of zero emission.

By installing Thin Film Photo Voltaic Module to run three phase water pump, could be a good solution for lifting water up to 10 storied building. Thin Film PV can produce power by attenuating shadow effect. For lower starting torque, a three phase motor will draw less power than single phase motor to lift same amount of water. A three phase low cost inverter is used to run the motor by inverting photo voltaic DC to AC.

A design of 2 KW thin film solar PV module (*Fig-1*) is shown here. Sketch Up 3D software was used for this design. Although, the initial installation cost is higher but for 5-10 years of life time, the average cost will be lower.

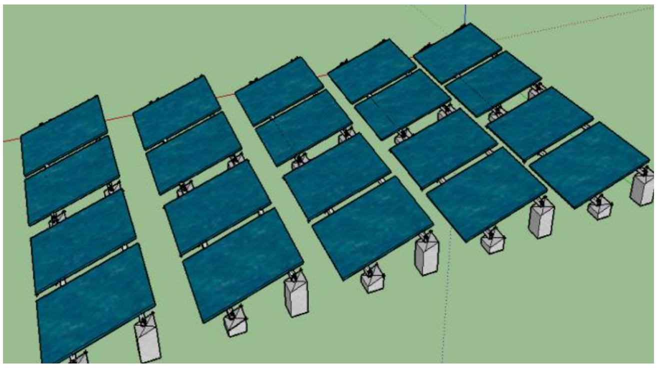

Figure1. Initial design of 2 KW Thin film PV Module

II. SOLAR POWERED WATER PUMPING SYSTEM CONFIGURATION

There are two basic types of solar-powered water pumping systems, battery-coupled and direct-coupled [8]. To give a cost effective solution, a direct coupled solar powered water pumping system is installed. This system consist of photovoltaic (PV) panels, pump controller or inverter, pressure switch, tank and AC water pump (*Fig-2*).

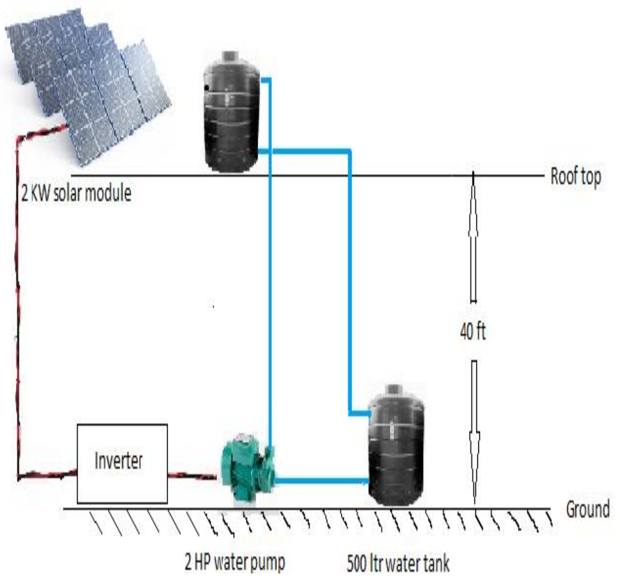

Figure2. Solar powered water pumping system

During day light, the PV module produce electric DC power that is inverted to 3 phases AC by a smart inverter. The amount of water pumped is totally dependent on the amount of sunlight hitting the PV panels and the type of pump. Because the intensity of the sun and the angle at which it strikes the PV panel changes throughout the day, the amount of water pumped by this system also changes throughout the day.

For instance, during optimum sunlight periods (late morning to late afternoon on bright sunny days) the pump operates at or near 100 percent capacity with maximum water flow. However, during early morning and late afternoon, pump capacity may drops by as much as 25 percent or more under these low-light conditions.

During cloudy days, pump performance will drop off even more. To compensate for these variable flow rates, a good match between the pump and PV module(s) is necessary to achieve efficient operation of the system. The inverter also can track the peak values to run the motor with a constant supply. Direct-coupled pumping systems are sized to store extra water on sunny days so it is available on cloudy days and at night. Water can be stored in a larger-than-needed watering tank or in a separate storage tank and then gravity-fed to smaller watering tanks.

Water-storage capacity is important in this pumping system. Two to five days' storage may be required, depending on climate and pattern of water usage. Storing water in tanks has its drawbacks. Considerable evaporation losses can occur if the water is stored in open tanks, while closed tanks big enough to store several days water supply can be expensive. Also, water in the storage tank may freeze during cold weather [9].

This design is completed by installing a roof top solar module on floor six. Two tank of 500 liter are used here. One is for storage and another one is as reserve tank (*Fig2*).

III. Thin-Film PV Module

Three types of technologies (Mono crystalline, poly crystalline, Thin Film) are available in the solar market. Among them, thin film has few more advantages like better performances with the shade coverage, dirt and snow than other technologies available in market. It is also cheaper than the conventional panels [6].

For less shadow effect, Thin Film PV can be mountain on a fixed structure. An array can easily be mounted on a trailer to make it portable. A tracking array follows the sun across the sky. A tracker will add at least $400 (USD) to $800 (USD) to the cost of a system, but can increase water volume by 25 percent or more in the summer time, compared to a fixed array [7]. To reduce cost, a fixed structure could be installed in terms of Thin Film PV. An angle of 15 to 20 degree should maintain to get better output according to the geographical position.

The main disadvantage of thin film is that it has less efficiency than other PV panels. And also it does not last as long as mono and poly crystalline panels do [7].

IV. PUMP AND INVERTER

3 phase induction motor is considered because of its vast advantages over single phase AC and DC water pump. Single phase AC motor required an initial starting torque which consumes huge power for startup. Whereas 3 phase induction motor can start with a lower initial torque. On the other hand, DC pump is expensive and its maintenance cost is higher. Life time of a DC pump is lower than an AC pump [10]. Pumps are classed as either displacement or centrifugal, and can be either submersible or surface types. Displacement pumps use diaphragms, vanes or pistons to seal water in a chamber and force it through a discharge outlet. Centrifugal pumps use a spinning impeller that adds energy to the water and pushes into the system, similar to a water wheel. Submersible pumps, placed down a well or sump, are highly reliable because they are not exposed to freezing temperatures, do not need special protection from the elements, and do not require priming. Surface pumps, located at or near the water surface, are used primarily for moving water through a pipeline. Some surface pumps can develop high heads and are suitable for moving water long distances or to high elevations [10].

The pump controller protects the pump from high- or low-voltage conditions and maximizes the amount of water pumped in less than ideal light conditions. An AC pump requires an inverter, an electronic component that converts DC electricity from the solar panels into AC electricity to operate the pump.

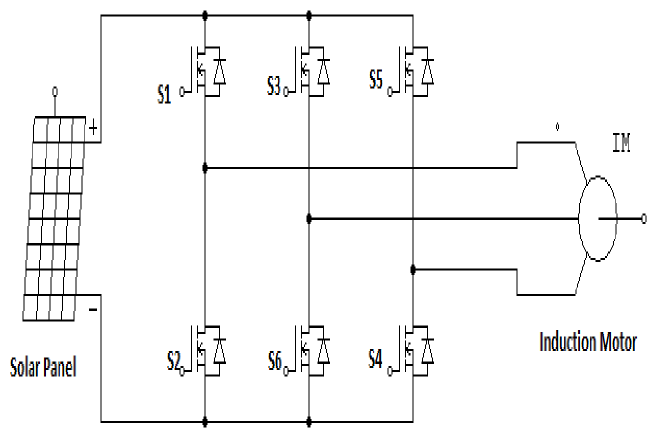

Figure3. Conventional Three Phase Inverter

V. DESIGNING AND INSTALLING SYSTEM

A. <u>Mounting Structure</u>: Mainly two ways to mount solar modules: either on a fixed structure or on a tracking structure [7]. Fixed mounts are less expensive and tolerate higher wind loading but have to be carefully oriented so they face true south (not magnetic south) [7].

Movable 30 pillars are designed to mountain 20 solar panels. There were combinations of four types of pillar shown in *Table 1.*

TABLE1. Pillars Specification

Pillar type	Length	Width	Height	Position
Type 1	8 inch	8 inch	14 inch	Upper both side
Type 2	10 inch	10 inch	14 inch	Upper middle
Type 3	8 inch	8 inch	6 inch	lower both side
Type 4	10 inch	10 inch	6 inch	Lower middle

In the upper side, two types pillar of size 8*8*14 inch (Length= 8 inch; Width= 8 inch; Height=14 inch) and 10*10*14 inch (Length= 10 inch; Width= 10 inch; Height=14 inch) were used. Two different size of 8*8*6 inch (Length= 8 inch; Width= 8 inch; Height=6 inch) and 10*10*6 inch (Length= 10 inch; Width= 10 inch; Height=6 inch) of pillar were used in the lower side (*Fig-4).* Total 6 pillars used to mountain 4 panels.

The pillars are constructed in such way so that each panel has an angel of 18.2 degree. 2 frames used for two panels to mountain them on pillar. We put bolt inside of each pillar to hold frame.

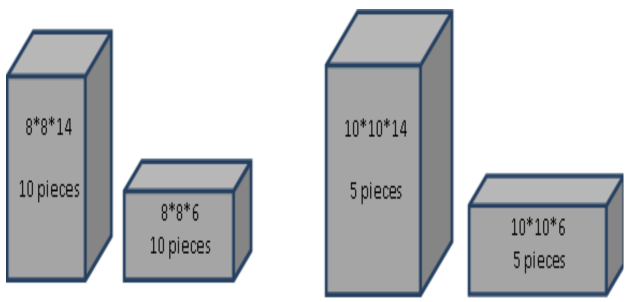

Figure4. Types of pillars

Thin Film PV module used for this project is 20kg of weight. Length is 4 feet and width is 3.4 feet. All pillars and frames designed to give them strong support.

Figure5. Installed 2 KW Thin Film Solar PV Modules.

Specification of Thin Film Solar Panel used for this project is given below (*Table2*).

TABLE2. Specification of Thin Film Solar Panel

Specification of Thin Film PV Module	
Power, W	95 W
Open Circuit Voltage, Voc	71 V
Short Circuit current, Isc	2.25 A
Maximum peak Voltage, Vp	53.5 V
Maximum peak Current, Ip	1.78 A

B. Tank and Pipe Installation**:**

Two 500 litter tanks used to lift and stores water. One putted on the ground as reserve tank, and another one was installed on roof of the fourth floor as storage. To lift water to four storied (40 feet) building, 60 feet pipe of 1 inch were used (*Fig.6 & Fig.7*).

Figure6. Uppor Tank (on 4th floor) and Storage Tank (on ground)

Figure 7. Installed Pipe

C. Pump and Inverter Installation:

TABLE3. Three phase motor specification.

Specification of 3-phase Motor	
Ratings	2 HP / 1.5 KW
Operating Voltage	400 V
Current Ratings	3.9 A
RPM	1500
Suction/Delivery (Meter)	17/25

In the above table (*Table3*), specification of the motor is given. This motor can suck water from 17 meter deep and can through water above 25 meter height. For testing purposes, a 3 phase inverter was setup closed to motor. It can handle 2 KW of power for input voltage of 300-400 VDC with corresponding 3-phase output. Installing a solar pump is a complex task, combining elements of electrical work, plumbing, and heavy construction. To get a cost effective solution, all task and installation has done very carefully.

VI. COST

Here, the cost of 20 panels and its mounting pillar with water pump and inverter is discussed. It's required an initial high investment. But considering the life time of 5-10 years, the average cost is lower [11].

a. Cost for 20 Thin Film Solar Panels:

Equipment	Quantity	Unit price (Taka)	Ratings (Watt)	Taka
Thin Film Solar Panel	20	65	95	**1,23,500**

b. Cost for mounting structure:

Equipment	Quantity	Unit Price(Taka)	Taka
Concrete	12 Bags	55	660
Sand	12 Bags	20	240
Cement	4 Bag	450	1800
Labor	2 persons	700	2000
Pillar frame	30 pcs	70	2100
Screw (6")	40 pcs	35	1400
Screw (1")	120 pcs	6	720
Conveyance			1520
			Total = 10,440 Taka

c. Motor and Inverter Cost:

Equipment	Quantity	Unit Price(Taka)	Taka
Water pump (3 Phase, 2 HP, 1.5 KW)	1	13,000	13,000
Inverter	1	15,000	15,000
Conveyance			600
			Total =25,600 Taka

The above tables show the total cost of installation of solar powered water pump. To install 2 KW Thin Film Solar PV Module with 2 HP water pump and inverter, total cost will be **1, 59, 540 Taka.**

By designing and installing movable concrete pillar, the mounting cost of 2 kW solar Thin Film PV module is decreased almost 1/3 compared to the conventional mounting.

VII. CONCLUSION

Design, installation and cost analysis of a solar powered water pump has been described here. This system lifts water to four storied building and takes 17 munities to fill up 500 liters Tank. Thus the water pumping rate is around 29 litters/minute. On an average sunny day, by 6 hours running, the system can pump 10440 litter of water from ground to roof of a four storied building. With an initial investment of Taka 1, 59, 540 ($1,994), one can have a very good water pumping solution for multistoried building. Solar power for water will be cost-competitive with traditional energy sources for high rise building, if the total system design and utilization timing is carefully considered and organized to use the solar energy as efficiently as possible. The output of a solar pumping system is very dependent on good system design derived from accurate site and demand data. By reducing power loss in conversion of power and loss in pump, can enhance the flow rate of water. Further modification will enable this project to pump water up to ten storied building (120 feet).

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Efficient Hybrid Renewable Energy System for Industrial Sector with On-Grid Time Management

Md. Mehedi Hasan,[1,#] Aman Abdulla Tanvir,[2] S.M. Shahnewaz Siddiquee[3] , Ahmed Zubair[4,5,*]
[1]Department of Energy Systems Research, Ajou University, Suwon, Republic of Korea
[2]Department of Applied Science, Saint Mary University, Halifax, Canada.
[3]Dept. of Electrical and Electronic Engineering, International Islamic University Chittagong, Bangladesh
[4]Dept. of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh
[5]Dept. of Electrical and Computer Engineering, Rice University, Houston, Texas, USA

[#]mehedi1989@gmail.com, amantanvir@yahoo.com, [*]ahmedzubair@eee.buet.ac.bd

Abstract **–Hybrid renewable energy systems shows a great potential for electricity generation in Bangladesh. Hybrid renewable energy system can be set up such a way that the electricity will add to national grid connection and it will eventually reduce the pressure of electricity demand from national grid. Abundance of renewable energy sources in the form of solar energy provides opportunities of renewable energy based hybrid energy system in the industrial areas of Bangladesh. This work is an in-depth scenario and analysis of the renewable hybrid energy system in Tongi industrial areas of Bangladesh. This study is also includes co-production of diesel generator, solar PV and grid system. Optimization of hybrid renewable energy systems looks into the process of selecting the best components and its sizing with appropriate operation strategy to provide cheap, efficient, reliable and cost effective alternative energy. This paper analyzes all the conditions and constraints of the renewable energy integrated grid connection system with compensation and proposes an optimal combination of energy components for compensating regular grid failure in industrial area with minimizing the pressure of electricity demand from national grid and minimizing the life cycle cost. The final optimization result from HOMER shows that the cost of energy (COE) for 0 hour , 1 hour , 2 hour , 3 hour , 4 hour , 5 hour , 6 hour , 7 hour , 8 hour and 9 hour compensation is respectively $0.092, $0.098, $0.106, $0.113, $0.123, $0.133, $0.144, $0.152, $0.159 and $0.163.**

Keywords- Industrial Areas of Bangladesh; Hybrid Energy System; Renewable Energy; Green energy; Standalone Energy System.

I. INTRODUCTION

For the development of a country electricity is vital element along with the demand of electricity is increasing rapidly due to rapid industrialization and population growth. To satisfy this demand for electricity more fossil fuels needed to burn in power plants which causing rapid depletion of fossil fuel reserves. More over burning these fossil fuels causes emission of green-house gases. In Bangladesh the electricity generation is not enough to satisfy its demand. The daily electricity generation which totally comes from national grid is not much to meet the industrial demand. So grid electricity failure is a common issue which hampers the industrial production process. The shortage of electricity generation makes it difficult to reach the economic goals of the country. Electricity access rate and utilization of electricity are the indicators economic growth of a country. Bangladesh is a developing and over populated country it has about 160 million peoples as reported about 50% peoples can access electricity which is not good for wealthy economy. Due to high demand, maximum generation of 3218 MW in 2001-2002, 3458 MW in 2002-2003, 3622 MW in 2003-2004, 3751 MW in 2004-2005, 3812 MW in 2005-2006, 3718 MW in 2006-2007, 4130 MW in 2007-2008, 4037 MW in 2008-2009,4996 MW in 2009-2010, 4698.5 MW in 2010-2011, 5174 MW in 2011-2012, 6350 MW in 2012-2013 which could not remove power crisis in the country [1]. At present power demand in Bangladesh is about 7500MW and generation is 6000-6500 MW [2]. Demand is estimated to exceed 10,000 MW by 2015 [2]. As there is huge difference between generation and demand of electricity, people of Bangladesh is experiencing a significant amount of load shading at every day.

Again Bangladesh relies heavily on fossil fuels for its energy specially on gas resources. Natural gas is used as fuel for 76% of the energy generation [2]. But the present proven reserve would be depleted by a decade. Around the world coal is still a main fuel for power generation. Bangladesh has sufficient high quality coal resources. But the coal mining is at its initial stage [2].The exploration of gas and coal continues to remain uncertain. Except renewable energy resources all are not eco-friendly as like as oil, coal, gas etc though the fossil fuels are not available in our country. Need to reduce the environmental impact of fossil fuel based energy system is driven by the renewable energy which are the current resurgence of interest in the use of that energy. Harvesting energy on a large scale is undoubtedly one of the main challenges of our time. So, that's why the researcher are working with this kind of technology where the consumers could meet their demand properly by using off grid power generation smart grid systems [17-18] for developing their economic position. Even in coastal areas peoples could make developed the economy by using off grid hybrid power generation system [17].

Various works is being done to study the possibility of using renewable energy with hybrid system as alternative of diesel

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generator [4-5]. Hybrid power systems considerably reduce the need for storage of fuel, fuel consumption cost, and greenhouse gas emission [6-7] also the hybrid grid connected energy systems has huge advantage such as save money with net metering, the utility grid is a virtual battery, less expensive than off grid systems and smart solar held lot of promise [19]. Performance analysis of solar-wind-diesel hybrid system has been carried out by several researchers [8-9]. Optimization of sizing of solar-wind hybrid system has been investigated [11-14].

Alternative way of energy generation in Bangladesh is the need of time. Renewable energy is also considered as green or clean energy, because it does not produce toxins or pollutants that are harmful to the environment. At present the renewable energy is the most popular energy sources for electrification to the local areas of Bangladesh where could not reach electricity till today from the national grid. Renewable energy resources like solar, wind, hydro and tidal could be utilized in some areas of Bangladesh to establish renewable energy based power generation stations. Renewable energy is also considered as green or clean energy. The industrial area in the Dhaka city and outside of Dhaka city such as Tongi, Narayangonj part of Bangladesh has a huge potential of establishing solar combined diesel generator and grid connected power generation.

Tongi is situated between $23^0$49' North latitude and $90^0$40' East longitudes and the area in the northern part of Dhaka has huge potential area establishing power generation. Tongi is a thana of Gazipur district in Bangladesh. The annual average solar radiation is 4.57 $kWh/m^2/d$ is suitable for setting up solar energy system [3]. There are many garments industry in Tongi about 2000 factory which contributes our economic growth. Government cannot fulfil their energy demand which is essential for whole day. Bangladesh government and several other non-government organizations have been working on setting up single renewable resource based energy system.

On grid with compensation of hybrid renewable energy system is the most efficient and reliable energy source than the energy source which based on single renewable energy such as Solar or wind energy source. The system will reduces the load demand on grid and save fuel as well as natural resources. It is also economical and eco-friendly which contribute in balancing of environment. On-Grid Time Management for Efficient Hybrid Renewable Energy System can be launched to meet energy demand of this industrial area. This work a design of On-Grid Time Management for Efficient Hybrid Renewable Energy System is presented. At first, the hybrid energy system that has been established all over the world is reviewed. Then, methodology of analysis of this work is described in details. The data of energy resource collected from various reliable sources are presented here. The energy resource data analysis procedure is discussed. Then the designed hybrid energy systems are provided. After that selection process of the efficient components which are used in the hybrid system are described. Detailed economic analysis of the proposed system is also carried out to validate the design and presented here. On-Grid Time Management for Efficient Hybrid Renewable Energy System based on solar energy, natural gas and diesel fuel are also done here. This study shows renewable hybrid system is the most cost effective. Analysis of hybrid energy system for Bangladesh like this work has not reported yet. From this work, the proposed hybrid system shows tremendous prospect in Bangladesh.

II. RESEARCH METHOD

In our work, On-Grid Time Management for Efficient Hybrid Renewable Energy System is proposed for an industrial area of Bangladesh. This system design can be applied to other industrial areas of Bangladesh and other developing countries as well. For planning a hybrid energy system, firstly the most suitable energy resources are found out by analyzing the resources. After that using the best suitable energy resources a hybrid energy system is designed. For the optimal planning of sizing of different components of the system the simulation software HOMER (Hybrid Optimization Model for Electric Renewables) is employed. HOMER performs the energy balance calculations for each system configuration that can be considered. The system cost calculations are done studied which account costs such as capital, replacement, operation and maintenance, fuel, and interest. This economic analysis is carried out to determine the feasibility of the proposed system. Comparison with compensation 0 to 9 hour off grid connection energy systems is studied for confirming the practicability of the proposed system.

A. Energy Resources

In this energy system design, the selection of energy sources is determined by giving priority to renewable sources such as solar. Sometime it called infinitive energy that means renewable energy which come from nature. The solar energy be converted electricity from light. It has potential to provide unlimited supply of electricity for our industries. Moreover the use of such green energy is increasing worldwide because it does not produce any kind of pollution such as carbon [15-16]. This energy system process will be good for the location of our study because the amount of solar energy present is enough for electrification. Natural Gas is major fuel used in Bangladesh to produce electricity but at present the price of gas is rising. The gas transmission line is also connected to the study location. The gas can be used as a fuel and Diesel is used as the fuel for power generation from fossil fuel.

B. Solar Energy Resources in Tongi industrial area

The sun rays mean solar energy that reaches the earth being converted to energy through different processes. Sunlight can be converted to electricity. Photovoltaic systems use solar cells or panels to convert sunlight directly into electricity. Solar irradiance, measure of incoming solar

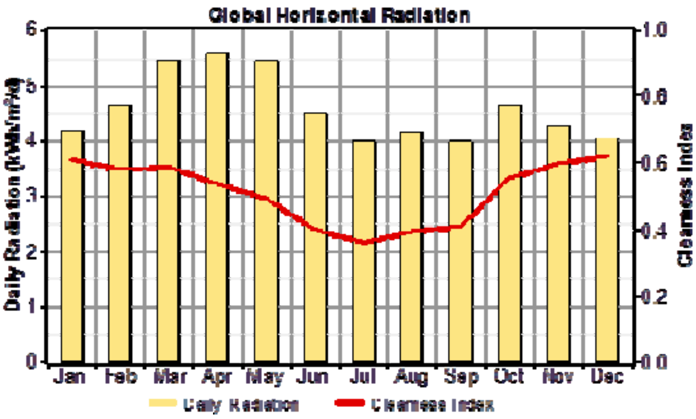

Figure 1. Monthly averaged daily radiation and cleaness

radiation, of Bangladesh is very good for the purpose of electricity generation. The monthly averaged global radiation data has been taken from NASA (National Aeronautics and Space Administration) 4.566 kWh/m^2/d and clearness index is a measure of the clearness of the atmosphere has an average value of 0.497 for Tongi industrial area. Figure 1 shows the monthly averaged values of clearness index and daily radiation.

C. Design of Hybrid Energy System

This hybrid combination power system for Tongi is designed where diesel generator and grid system by natural gas has been combined with solar power generation. Diesel generator and grid connection has been chosen for its operating feasibility, uninterrupted power connection, low cost and easy installation. The system will run by on grid time management to meet full load demand in the industry. Only standalone the diesel generator and PV couldn't fulfill the total load demand. So the solar-generator-on grid time management power model is the most cost effective system.

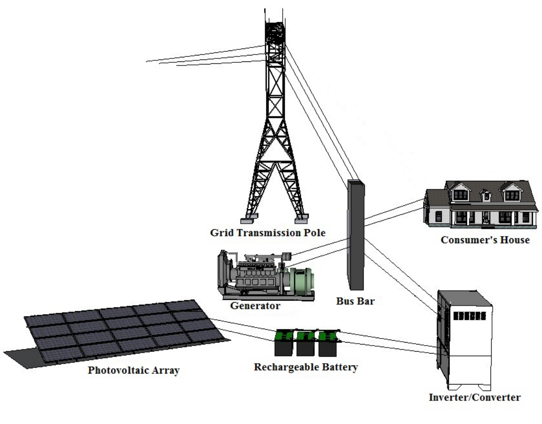

Figure 2. Single line diagram of hybrid energy system

D. System components

The cost of PV module including installation has been considered as $ 7278. Life time of the modules has been taken as 25 years. 6.9 kW PV modules, Sun module SW 230 POLY V2.0 PALLET, are considered. PV modules output is DC and is connected to DC bus. For all the system, Surrette 6CS25P battery with energy storage capacity of 6.94 kWhr, is used for design of the hybrid system. Converter is used to convert from AC to DC and DC to AC. Inverter efficiency is taken 90% and rectifier efficiency is considered 85%. Diesel generators operate in parallel with the solar energy system to increase the maintenance flexibility, efficiency and distribute the electric load more optimally. Capital cost for per 10 KW of diesel generator is considered $5364 and there is no cost of grid connection on the system [10].

E. Economics and Constraints

The energy system that is designed in this work has assumed to have 25 years. Annual interest rate is considered 10%. The constraint that is applied is 50% of the load should be from the renewable energy.

F. Electrical Demand profile

In this study, after doing necessary survey of an industry power consumption is assumed about 3.8 MWh per day for analyzing the electrical demand for Tongi area. A base line load of 3.8 MWh/day is considered for simulation and a deferrable load of 80kWh/day/month is taken. Randomness of the daily consumption is kept as 15%. And variability of hour to hour is considered as 20%. Figure 3 and figure 4 shows the baseline load profile and deferrable load profile of the system

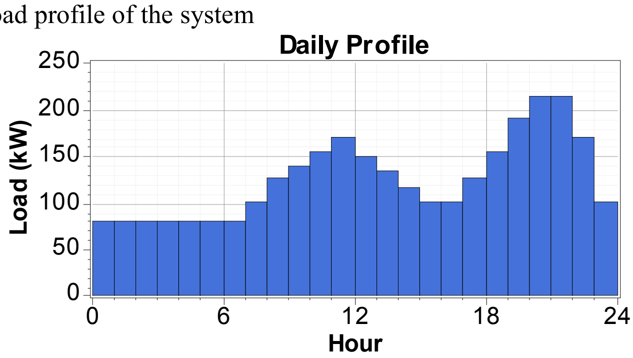

Figure 3. Baseline load profile of a day

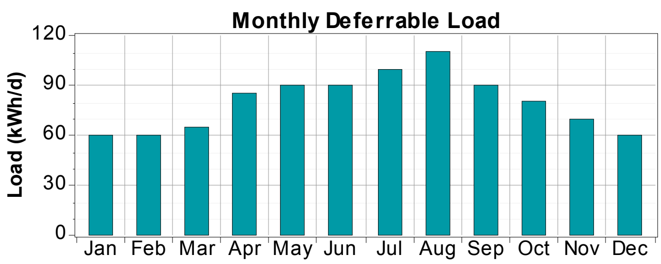

Figure 4. Deferrable Load Profile

TABLE 1. COST OF SYSTEM WITH COMPENSATION

Grid off(hour)	Cost of with compensation($)
0	0.092
1	0.098
2	0.106
3	0.113
4	0.123
5	0.133
6	0.144
7	0.152
8	0.159
9	0.163

In figure 5, X axis shows number of hour that grid is disconnected from our proposed plant Y axis shows the cost of energy per KWh.

III. COST COMPARISON AND RESULTS ANALYSIS

In the table 2 shows the comparison of cost by hour on grid time management system with compensation. And figure 5 shows the curve presentation of cost to the system. The COE is $0.092 per kilowatt hour for compensation by zero hour off grid. In addition to the same way of one hour off grid, two hour off grid, three hour off grid, four hour off grid, five hour off grid, six hour off grid, seven hour off grid, eight hour off grid and nine hour off grid the COE are $ 0.098, $0.106, $0.113, $0.123, $0.133, $0.144, $0.152, $0.159 and $0.163 for compensation. The propose system run by on grid time management system with compensation. Below the comparison table 1 shows per unit energy cost of the system.

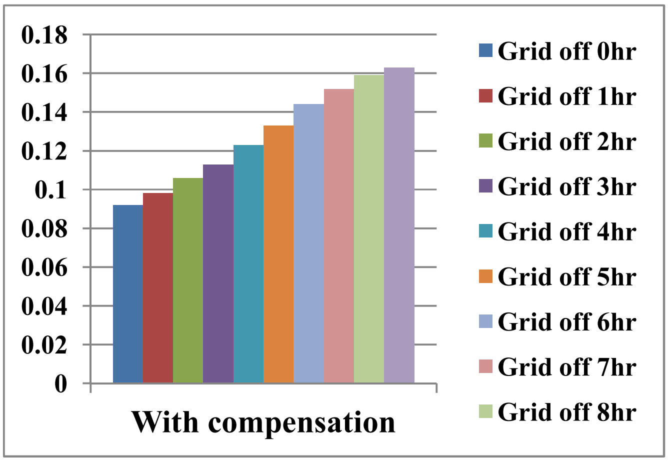

Figure 5. Cost of System with compensation by time management

TABLE 2. OPTIMUM SYSTEM ARCHITECTURE OF SOLAR GENERATOR-GRID HYBRID SYSTEM WITH COMPENSATION

System component	Size(kw) of Power system									
	0 Hour	1 hour	2 hour	3 hour	4 hour	5 hour	6 hour	7 hour	8 hour	9 hour
PV	500kw	400kw	500kw	500kw	500kw	500kw	500kw	500kw	500kw	500kw
Grid	150kw	150kw	150kw	150kw	150kw	150kw	150kw	150kw	150kw	150kw
Generator	-	100kw	100kw	100kw	150kw	150kw	150kw	150kw	150kw	150kw
Battery	195	-	60	60	120	60	165	210	210	210
Converter	200kw	200kw	180kw	180kw	200kw	180kw	200kw	220kw	220kw	220kw

TABLE 3. NET ANNUALIZED COST OF 0 HOUR OFF GRID WITH COMPENSATION

System Component	Capital Cost ($)	Replacement Cost($)	Operation &Maintenance Cost($)	Fuel Cost($)	Total Cost($)
PV	527,391	0	6,578	0	533,969
Diesel Generator	-	-	-	-	-
Grid	2	0	29,818	184,653	214,437
Battery	195,000	65,544	35,400	0	295,944
Converter	80,000	14,364	9,077	0	103,441
Others	8,000	0	1,362	0	9362
System	810,393	79,908	82,235	184,653	1,157,189

A. *Economic Analysis*

HOMER analyzed the system according to the COE (cost of electricity) of that hybrid energy system. However, Other factors which influence the analysis are capital cost, operating cost, renewable energy factor, total NPC (Net present cost) and diesel consumption rate. Table 3 shows the net annualized capital cost, replacement cost, operation and maintenance cost and fuel cost of different system components to the system. After optimization the grid tied time management optimal hybrid energy system, the least cost of COE and total system cost found from zero hour off grid connection than other optimization results. The total system cost about $1,157,189 where there was no diesel fuel cost because of 24 hours grid connected with the system.

B. *Environmental Effects*

Our proposed Solar-grid-diesel hybrid system reduces gas emission by a significant amount due to reduced fuel consumption. This reduction in gas emission is determined using HOMER software. The emission for this system has been decreased by 80 percent from the on grid time management based energy system. Table 4 shows the total emission of the system are very poor amount of Carbon Di-oxide gas emit from our hybrid energy systems as reported.

TABLE 4. TOTAL EMISSION BY DIFFERNT SYSTEM CONFIGURATION WITH TIME MANAGEMENT

Hourly Compensation / Pollutant (kg/yr)	Carbon Di-oxide	Carbon Mono oxide	Unburned hydrocarbon	Particulate matter	Sulfur di oxide	Nitrogen Oxide
0 hr compensation	461,611	1,556	172	117	1,219	13,881
1 hr compensation	584,390	1,802	200	136	1,426	16,079
2 hr compensation	558,514	1,738	193	131	1,374	15,513
3 hr compensation	568,813	1,742	193	131	1,379	15,540
4 hr compensation	563,682	1,721	191	130	1,364	15,358
5 hr compensation	612,221	1,801	200	136	1,433	16,073
6 hr compensation	605,060	1,789	198	135	1,423	15,966
7 hr compensation	594,092	1,748	194	132	1,391	15,596
8 hr compensation	614,596	1,775	197	134	1,416	15,841
9 hr compensation	626,240	1,780	197	134	1,422	15,885

IV. CONCLUSION

At present Bangladesh is distressing from acute electricity problem. In the modern civilization electricity has become one of a basic need where economic growth fully depends on electricity. Severe scarcity of power in Bangladesh has become a threat to its economical development. In the industrial areas where grid failure is very common , on load grid time management system consisting hybrid power electric sources like solar PV and diesel generator can be a potential solution. Though the use of such renewable sources is already in process but standalone renewable energy system cannot supply entire load demand and also renewable sources financially less viable. So on grid time management of solar-grid-diesel hybrid energy system can be cost effective solution for the industrial regions of Bangladesh. It also will reduce the pressure on grid. Moreover this on grid time management hybrid system reduces the production cost for supplying energy to the industrial areas and reduce the emission of greenhouse gases as well which help to trim down the environmental pollution.

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Developing a Sustainable Peer-to-Peer Network Infrastructure for Rural Areas

Farhan-Bin-Tarik[1], Walid-Bin-Habib[2], Rawdah Mahmood[3]
Department of Electrical & Electronic Engineering, University of Dhaka, Bangladesh
[1]farhan143tarik@gmail.com
[2]walid.habib.1994@ieee.org
[3] rawdahmahmood@gmail.com

***Abstract*— The necessity of information and communication technology beggars description. But in developing world, proper ICT facilities have not been achieved yet, especially, in the rural or remote areas. In this paper, an incentive has been presented to develop a sustainable peer to peer network for those areas. The connected peers will be able to share important information shared without the requirement of any special central server. For better communication and access to internet, directory center can be connected to broadband (if available) or mobile network based internet. Since energy crisis is a major problem in developing countries, alternative power system with renewable sources has been proposed. The deployment of energy-efficient ICT with the optimization of renewable energy also sets the way towards green growth and sustainable development.**

Keywords- P2P; energy efficient networking; green ICT; green growth; technology for rural people

I. INTRODUCTION

The twenty first century has observed massive technological changes around the globe. Introduction of ICT in every sector has transformed the thought and way of our lifestyle. But as much as fast the ICT is growing energy consumption has become a major issue. So an Energy efficient model is required for complete infrastructure to reduce functional costs while maintaining vital Quality of Service. Energy optimization can be achieved by minimizing energy consumption by communication devices, protocols, networks, end-user systems, and data centers [1].

In the past days the major concern regarding energy consumption was the maintenance costs and performance. But now-a-days it's at the same time important to look after the costs and its impact on environment. So design of a new network and network system is critical to support the expected traffic growth, new applications, new services for future communication networks and environment friendly. Eco-net Project was coordinated at the Telecommunication Networks and Telematics Lab at the University of Genoa which has demonstrated several ways to adapt a network's capacity and resources to traffic loads and requirements. Research results come out of ECONET's research [2]:

1. green technologies for the network device data plane (standby and dynamic power saving);
2. green strategies for the control plane;
3. the green abstraction layer [3].

In order to cope with fast modernization and sustainable development, the rural communication structure can be made easier by re-arrangement and reformation. A peer-to-peer network can come out fruitful for this purpose even under the absence of internet in remote areas.

II. THEORETICAL ASPECTS

A. Peer-to-Peer Network

The term Peer-to-Peer (P2P) system is an alternative model of client-server (CS) based distributed computing system. It is a file sharing system where the resources are shared without the requirement of any special central server and each client takes part simultaneously in exchanging resources they own [4]. P2P is a very strong networking technology that can replace the present client-server model having lots of advances over it. In P2P system the resources and services are distributed equally among all users making benefits of direct accessing of data or shared files any time whenever needed. Though the model traces back past but its huge advances over present CS system has emerged as a viable model of applying the technology in many promising sectors. Millions of users can be connected deploying P2P networking in a very time efficient way as it doesn't combine the resources of each users individually rather leverage their collective power to the benefits of all [5]. The main feature of this system is decentralization [6]. Therefore P2P has many implications of time saving, robustness, reliability, efficient use of resources and ease of access [7]. Internet has three fundamental assets- information, bandwidth & computer resources which are mostly unutilized due to the traditional CS system. P2P system can be a very efficient tool in distant learning process utilizing these assets of internet. Web-based concerted tools for example Helpmate and other web conferencing applications demonstrate that the potential of P2P systems for distance learning and research is large [7]. To describe the system P2P architecture contains nodes in the network that act as both the client and server. Nodes are autonomous can provide and create data [8].

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Any node can initiates connection [8]. Peers are connected to the nodes and the resources readily available in the nodes can be accessed by other peers. Thus it ensures the simultaneous and multiple internet connections between peers [4]. For distance education on sustainable development P2P is a very strong and popular file sharing technology. As it doesn't have any copyright or virtually management administrative issues peers can easily share the resources they have for the peers who seek. So resource sharing for the peers is very easy in P2P system and enabling benefits from the system is also viable in this system [4]. Unreached people who live in remote areas, can't take part in direct education and sustainable development can be the most promoted section of this user friendly platform.

A. Green ICT and Green growth:

Alternative term of Sustainable ICT refers to the energy efficient way of computing or using ICT. San Murugesan includes in his paper "Designing, manufacturing, using, and disposing of computers, servers, and associated subsystems-such as monitors, printers, storage devices, and networking and communications systems-efficiently and effectively with minimal or no impact on the environment"[9] [10]. Gartner estimates that "The global information and communications technology (ICT) industry accounts for approximately 2 percent of global carbon dioxide (CO2) emissions, a figure equivalent to aviation" [11]. The environmental impacts come in much the same way the impacts come from any equipment- manufacture, use and disposal. Green ICT has specific challenges in all the areas of: [12]

- Production method of the materials/ ICT equipment
- The conditions in which they are manufactured and the energy in this process
- Transportation
- The energy required in the usage of them
- The disposal of them at the end of their life time

Green ICT encourages taking into account that if the product is:

- sustainably produced
- lasts longer
- consumes less energy
- is used in an efficient way
- is disposed of responsibly.

The concept of green growth is relatively a new term, one of the strategies that has been adopted to achieve sustainable development in the Asia and the Pacific Region [13]. The approach focuses on greening conventional economic systems and developing green economy i.e. it synergies the economy and environment. Green growth is considered as one of the strongest tools of sustainable development. It is a key to green economy as well as sustainability. In other words, green growth discards the traditional convention of "grow first, clean up later" and discourages investment decisions that entrench communities and countries in environmentally damaging, carbon-intensive systems. Rather, it seeks to spur investment and innovation in ways that give rise to new, more sustainable sources of growth and development. Significantly, the expansion of green ICT can play a big part in ensuring green growth. The potential benefits of green growth are many, especially in the developing countries. Formulating green growth will ensure the sustainable management of natural assets, new economic growth opportunities, mitigating climate change and its affects, new development sources etc. For example: Low carbon green growth can turn the crisis we are experiencing into opportunities by operationalizing double dividend: more growth and employment and less environmental hazards. Improving eco-efficiency through green growth is showing in "Fig. 1."

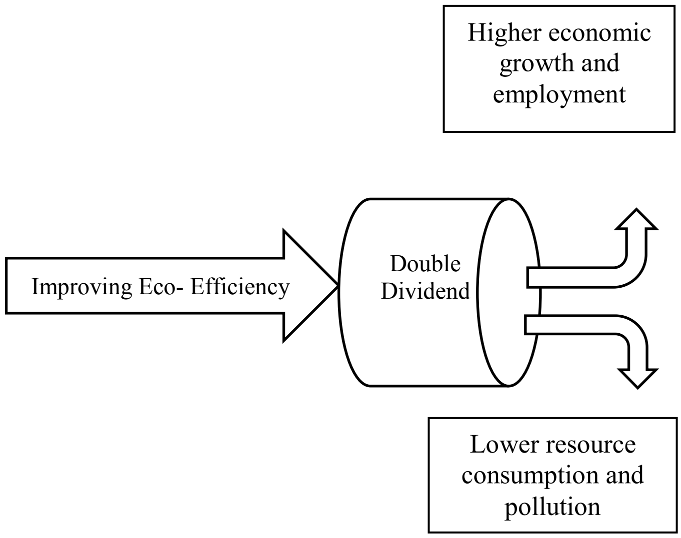

Fig. 1. Operationalizing double dividend formulating eco efficiency

III. TECHNICAL ASPECTS

A. Why Peer-to-peer Network?

A peer to peer network is more reliable because the central dependency is eliminated in this design. Failure of one peer doesn't affect the functioning of other peers. Moreover, it provides better reliability, less costing and easy configuration. In peer to peer network, there is full-time system administrator is not needed since every user acts as the administrator of his own machine. Users have full control over their shared resources.

B. Spatial and Technological Prerequisite

The proper setup of the network mostly depends on site attainment and construction issues. This is because the access to many rural areas are vastly inconvenient, at the same time, energy supply is also inadequate. For this reason, the following two spatial and technological prerequisites come under consideration.

- Energy opportunity: To promote greener energy solution, the model emphasizes in availing renewable energy source. That is why the area should be considered such that there exists an abundance of at least one type of renewable energy.
- Opportunity for general-purpose technology: General purpose technology refers to a new method of producing that is significant enough to have a prolonged and comprehensive impact. Electricity and information technology (IT) probably are the two most important GPTs so far. As stated above, for energy purpose, importance is given on renewable sources and this peer to peer incentive should come out as an effective innovation in IT.

C. Theoretical Framework:

1) Sectors of Application: Ensuring successful networking will bring breakthrough in rural areas. People in the rural areas will come to the benefit of distant learning. Boys and girls will equally get the benefit of education. Just not the academic teaching from different institutions, the people will get a convenient way of leaning technical education. The peer to peer network can bring prompt future scope for e-health, e-communication system. Moreover, the introduction of internet enabled server can play a massive role to provide an easier access to internet to the rural people.

2) Network Modeling: Users that are ready to share their resources become peers. A network is thus formed including all the peers. When a peer in the network has a file to share, it makes it available to the rest of the peers. Any interested peer can view and download it from the network. The peers are connected to themselves and all with a directory center. Directory center is connected to the internet which shares the internet to the connected peer via wireless router. The energy solution is provided by optimized renewable sources. The basic network model is shown in "Fig. 2".

D. Challenges

In developing countries, people face a lot of problems especially in rural areas being separated from advantages of urban areas. Some of the known challenges are:

- Shortage of Power;
- Expense of maintaining power costs;
- Location of areas;
- Difficult to access and transportation;
- Lack of skilled manpower;
- Availability of electronic devices
- Sparsely populated and scattered population cluster.

Initially if the challenges can be met the network can be made in a rural area. To cope with the challenges system innovations have been introduced to the system with the association of possible approaches from government and private sector.

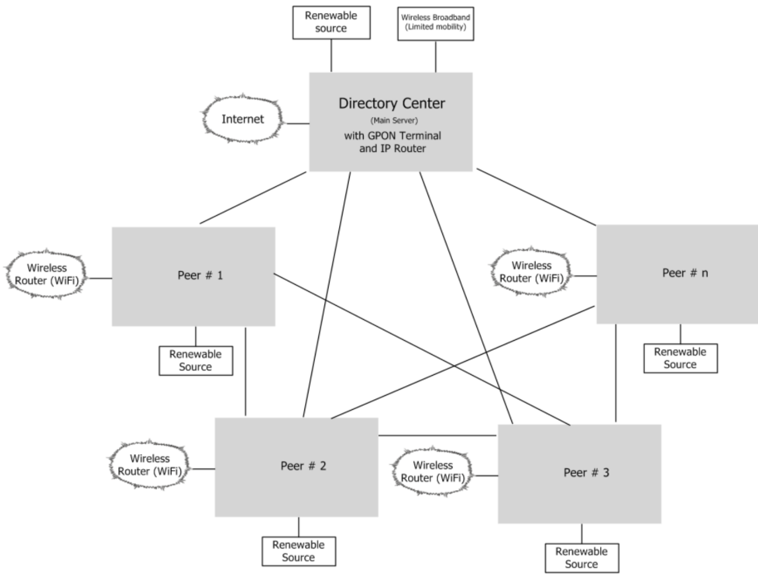

Fig. 2. Basic network modeling

IV. SYSTEM INNOVATION

Renewable advancement is an evolutionary process that will involve profound hi-tech and social innovation (system innovation). So it is imperative to develop new objectives and hypothesis and also to translate them into new goods and services.

A. Enabling Sustainable Energy Sources:

Enabling sustainable energy sources can play a vital role in the event of energy crisis the developing countries. At the same, with a view to green growth and sustainable development, the use of renewable energy needs to be practiced. New grids can be set up using renewable energy sources for daily purpose. An optimized alternative system can provide electricity at a competitive price to the people and reduce the emission of pollutants.

An alternative power system can be designed for the network setup purposed solely with photovoltaic cells. A hybrid power system can also come out handy consisting of wind turbines, photovoltaic arrays and as backup, a diesel generator in a remote area. To complete the system and to store the produced electricity, batteries and converters are connected.

B. Enabling Environment:

An innovational environment paves the way for start-ups and growing companies and allows collaborators to take decisions about new goods and services from an early stage. This makes it certain that major social challenges such as underdevelopment and poverty, demographic ageing and rejuvenation and shortages of energy and natural resources are addressed by them. Besides social service, the expansion of this project can come out as an alternative option of business and e-commerce.

V. Future Scopes And Possible Approaches From Govt. & Private Sectors

Developing countries are giving relentless efforts and making investments in research and development on information and communication technologies. Both public and private sector organizations are investing funds for research and development. Government of Bangladesh has started to take efficient approaches towards digitizing the country.

The private sector has a significant role to play in the development of a country. The contribution from the private sector may come in many forms including the expansion of the projects, technical advancement through research and development, financial investment and active think tanks across the world.

Now-a-days the required quality of economic growth is becoming more concerning issue than the ever increasing economic growth. This can be accomplished only if government, private sector and civil society actors cooperate with each other. To achieve this and to build adaptive capacity and resilience to some of the most pressing challenges facing the region inclusive and adaptive governance approaches will be needed.

Cooperative work from both public and private sector can be succeeded in following areas:

- Introducing ICT based technical knowledge in each sectors.
- Ensuring Power maintenace and energy security in the areas.
- Introduce training center in rural areas.
- Introduce training and shortcourse on Green ICT, Green Growth and give information on environmental hazards and risks.

VI. Conclusion

A strong information and communication network can act as a pillar; a new interconnection is flourishing between neighborhood and international activities, along with a shared responsibility for the greater whole. All this has been possible for the internet and spreading of information and communication technology. The energy efficient peer to peer network can be a good incentive for this purpose at the same incorporation of renewable energy will pave the way towards green growth. The possibility for mobilizing the awareness and imagination of the masses to generate ideas for sustainable development, both in and beyond their own existing environment can be established through this. In order to develop sustainable goods and services, an effective and energy efficient ICT network hardly has any alternative.

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Roadside Power Harvesting for Auto Street Light

Mrinmoy Dey, Tawhida Akand and Sadeka Sultana

Department of Electrical and Electronic Engineering
Chittagong University of Engineering and Technology
Chittagong-4349, Bangladesh
mrinmoycuet@yahoo.com, tawhidacuet@yahoo.com, sadekazinia@yahoo.com

***Abstract*—Present development of the world is measured by the amount of energy consumption. Energy of today world is generated from conventional energy sources mostly which are decreasing day by day. Moreover, these conventional energy sources causes pollution and responsible for global warming of the world. To solve these problems, researchers are trying frequently to explore new sources of energy which are clean, environment friendly, sustainable. This research is focused on auto lighting on street lights utilizing the jerking pressure which is wasted during the vehicles passes over speed breaker in roadside. In this work, the amount of electricity generation depend on spring constant, displacement of rack, number of vehicle, weight of the vehicle, gear ratio and number of gear combination are addressed as well as the techniques to increase the efficiency of the system is discussed. In response of public demand, number of vehicles is increased day by day for transportation facilities and hence this system can fulfil the demand of electricity in roadside and small area also. Auto street lights secure safety to the passer-by at roadside and raise awareness towards the new technology.**

Keywords—Energy consumption, global warming, sustainable, speed breaker.

I. Introduction

Now a day the world is facing a problem of diminishing the fuel stored in the world. The energy stored in earth is decreasing and the demand is increasing rapidly. As a result, it has become a severe problem to fulfil the demand. According to various statistics, the production of fossil fuel will start to decrease after 2015. In Bangladesh only about 32% of the total population has access to use electricity and 6% to natural gas. But in rural area only 22% has electricity without gas supply [1].To meet the demand of energy new sources of energy is important for sustainable development in a country. Moreover, conventional energy sources are liable to emit carbon dioxide. As a result, the temperature of the earth is increasing day by day. The carbon dioxide creates earth thermal blanket and the radiated heat from earth cannot pass to the atmosphere. So, renewable energy sources are needed to reduce the carbon dioxide emission and meet the future energy crisis.

Many researchers are trying to develop system to meet the roadside energy consumption via clean, environment friendly and sustainable way. C. K. Das et al. showed the possibility of tapping the wasted energy in the road speed breaker using roller mechanism [2]. Researchers of Kshatriva College of Engineering, Chepur, Armoor, Nizamabad implemented a power generation system from speed breaker by rack and ratchet mechanism [3]. A system using road transport pressure to generate electricity developed by Md.Saiful Islam et al. [4]. Abdul Razzak Pathan et al. proposed power generation system through speed breaker using rack and pinion mechanism [5]. A system developed by Shakun and Asthan to produce electricity from speed breakers using roller mechanism [6]. A paper was published on IOSR Journal of Electrical and Electronics Engineering named design of power generation unit Using Roller Mechanism [7]. Alok Kumar Singh et al. implemented a system for electricity generation through speed breaker based on spring coil mechanism [8]. Researchers of Rajshahi University of Engineering & Technology designed a system to generate electricity using road transport pressure [9]. D. Venkata Rao et al. designed a power generation system using speed breaker [10]. Aniket Mishra et al. published a paper on electricity generation from speed breakers [11]. Electrodynamics based models by Ankita and Meenu Bala to generate power from speed breaker [12] have also been suggested, but can't be used a large scale very easily due to its cost and complicated calculation.

In this research work, the developed system is effective as efficiency can be increased by increasing the displacement of rack length, gear combination and rotation of the dynamo. Moreover, by changing the ratio of gear and the number of rack, efficiency be controlled highlights the greater flexibility of the system.

II. Methodology

Power can be produced from conventional and non-conventional energy sources. But power generation from vehicle pressure limited to the rack-pinion, spring-coil, crank-shaft and roller mechanism. Rack-pinion mechanism is used to generate electricity using speed breaker in this work. Fig. 1 and Fig. 2 show energy conversion from potential energy to rotational energy and rotational energy to electrical energy respectively.

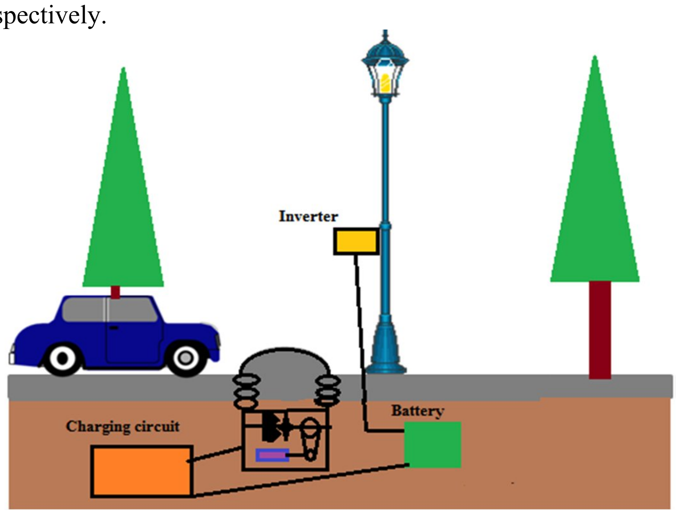

Figure 1: Potential energy conversion to rotational energy

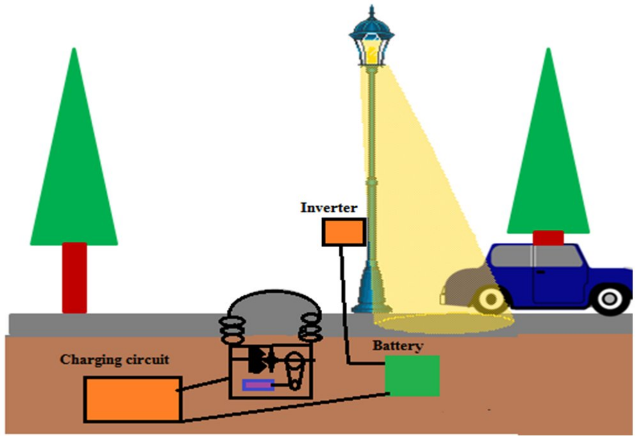

Figure 2: Conversion of mechanical energy into electrical energy

III. System Design & Operation

In this research, vehicle pressurizes the speed breaker causes the potential energy which is converted into rotary energy by rack and pinion. Consequently, this rotary energy rotates dynamo that generates electrical power which is being stored through battery using charging circuit. The whole system is represented by a block diagram shown in Fig. 3.

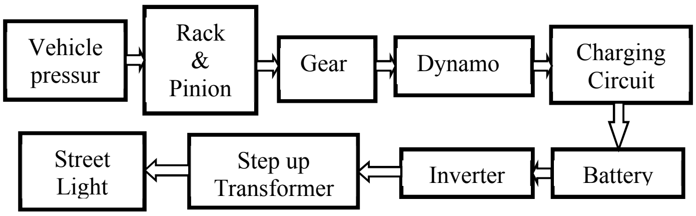

Figure 3: Block diagram

The mechanical design is shown in Fig. 4 and when vehicle hits speed breaker that squeezes the spring causes movement of the rack downward which rotates the pinion, pulley and gear. This rotary motion is converted into electrical energy by dynamo and its rotation is controlled by the ratio of small gear and large gear diameter. When the vehicle crosses the speed breaker, the expansion of springs takes the speed breaker at previous state.

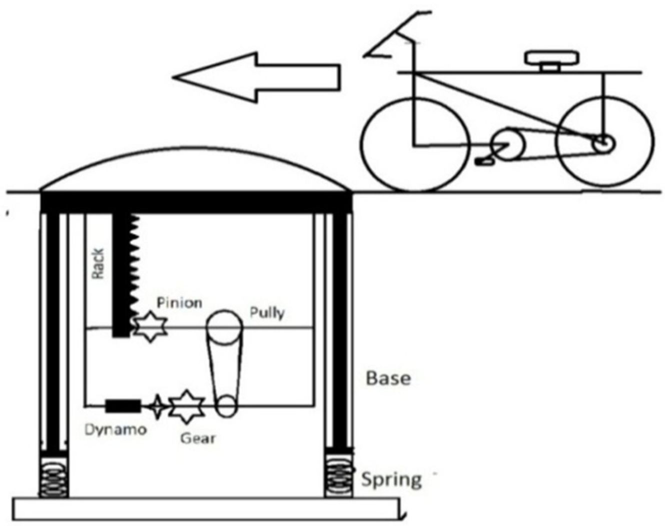

Figure 4: Mechanical design

The charging circuit charges a 12 V battery. The Inverter circuit converts this DC voltage into AC voltage and dark sensing circuit is used to sense the night. Then it switches the inverter so that the street light lit on.

IV. System Construction

Speed breaker, rack and pinion combination, springs, freewheeling bearing, gear combination, micro generator, charging circuit, battery, dark sensing & switching circuit, inverter circuit, step up transformer and street light are used to design the system in this research work. Fig. 5 shows the mechanical set up of the system.

Figure 5: Mechanical setup

A. *Speed Breaker*

It is the upper portion of the device which is made of iron and curved in shape. The main principle of this speed breaker is to sustain the pressure of vehicle and squeezes it when vehicle passes through it. Vehicle pressure is working as mechanical force in this work.

B. *Rack and Pinion*

A rack and pinion is a type of linear actuator that comprises a pair of gears which converts rotational motion into linear motion and vice versa . The linear gear is called rack and the circular gear is called pinion. Force is applied on the linear gear rack which causes pinion rotation. Thus, the mechanical force is converted into rotational force. The higher the length of rack displacement, the higher the voltage is generated.

C. *Spring*

There are four helical springs below the speed breaker. These springs are squeezed when vehicle pressurizes upon it and it bring speed breaker at normal position at the moment of pressure released. The smaller the spring coefficient, the higher the voltage is being generated.

D. *Gear combinations*

In order to increase the number of rotation one or more gear combination is used. Three gear combinations are used to design the system.

E. *Belt*

To rotate the dynamo, it is tied by a belt with third gear combination's small gear.

F. Dynamo

Dynamo is an electrical generator that produces direct current with the use of a commutator. The dynamo uses rotating coils of wire and magnetic fields to convert mechanical rotation into pulsating direct electric current through Faraday's law of electromagnetic induction. A dynamo machine consists of a stationary structure (stator) which provides the constant magnetic field and a set of rotating windings called the armature which turns within that field. The motion of the wire within the magnetic field creates electrical current.

G. Hole

To place the setup, a hole is need. The hole size is same size of the mechanical setup with clearance. The clearance in this work is 4 inch. The mechanical setup is standing on ground level.

H. Protection and water drainage system

To protect the setup from extra pressure of soil, humidity and temperature of soil, it is covered with polythene which is available, not erosive and cost effective. For better coverage wood box or steel box can be used which can tolerate greater pressure having no erosion. Water drainage system is a great problem for this system. For this reason, the whole system is sealed with rubber so that water cannot enter into the system.

I. Charging circuit

Charging circuit is used to charge the battery. Fig. 6 shows the charging circuit used to charge the battery. In this work, lm 317 is a regulator and RV1 & R1 are used to set the voltage. Green and red LED indicate the charging mode and full charged condition of battery respectively. D1 is a 13 V zener diode and when the voltage is greater than 15 V, then red LED is lit.

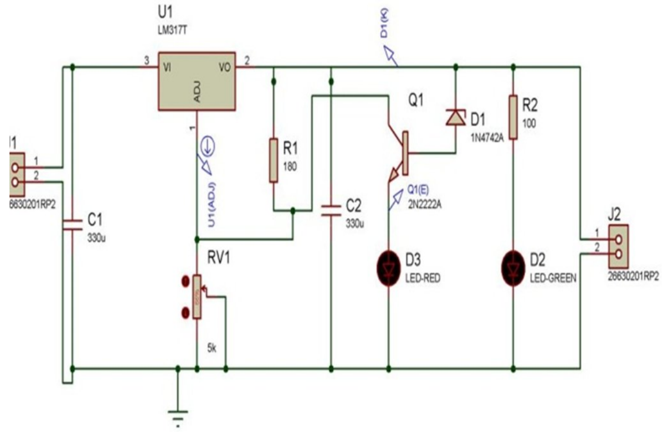

Figure 6: Charging circuit to charge the battery

J. Dark sensing circuit & inverter circuit

LDR and comparator are used to sense the dark and quick sense respectively. Relay is used to switch high voltage and the inverter is self-commuted voltage source square wave inverter. 555 timer is in astable mode and used for switching the flip-flop. RV2 is used to control the frequency. R3 & C1 both create the time for switching and R1 & R2 provide a voltage divider for the flip-flop circuit's clock. A flip-flop IC (IC 4013) and D-type flip-flop are used in this circuit arrangement. Fig. 7 shows the dark sensing and inverter circuit.

K. Step up transformer

Step up transformer is a type of transformer which stepped up the AC voltage. In this system, there are more turns on the secondary coil than the primary coil as voltage is proportional to turn ratio. Flip-flop circuit converts 12V DC to 15V AC. Step up Transformer makes the voltage to 250 V AC from 15 V AC.

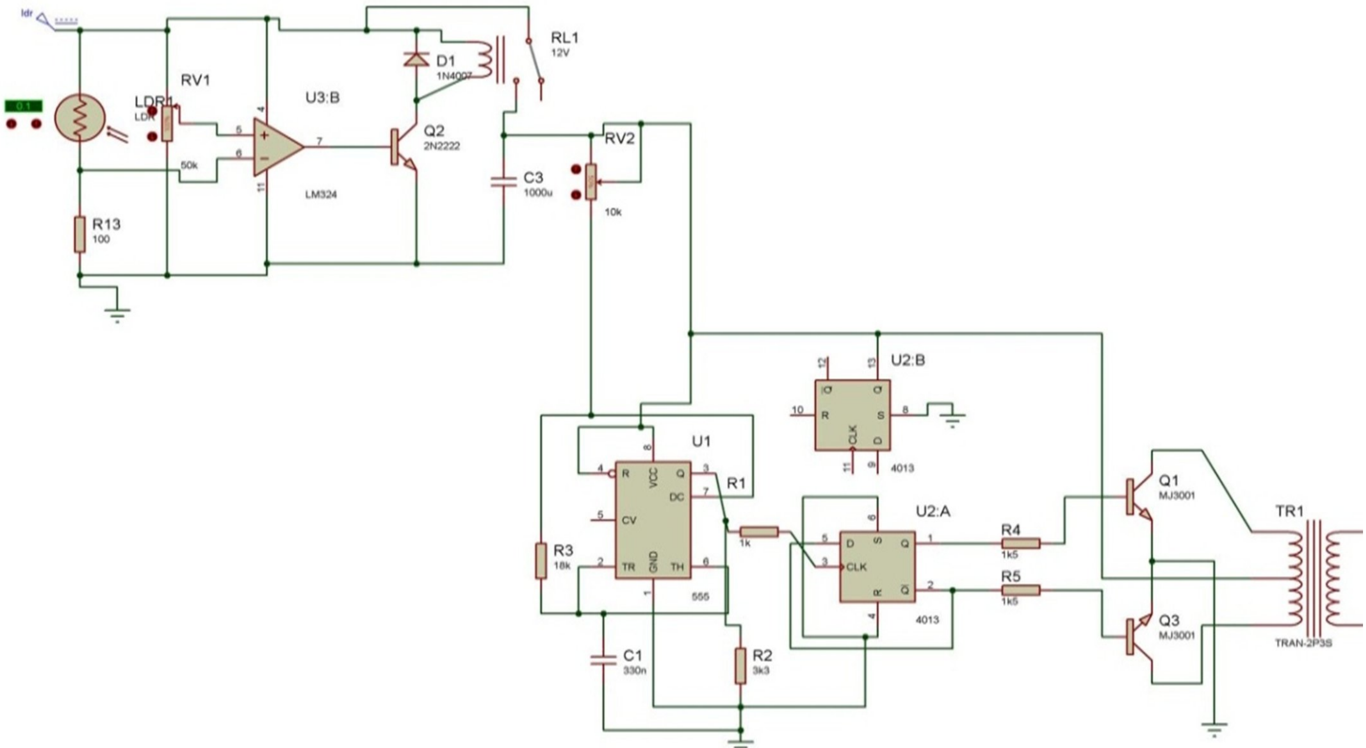

Figure 7: Dark sensing and inverter circuit

L. *Street light*

A street light is a raised source of light on the edge of a road or walkway. Modern street lights are high intensity discharge lamps [13]. These lights require 220V AC and 50 Hz for the operation to lit on.

V. SYSTEM IMPLEMENTATION

This system is implemented in Chittagong Collegiate School (CCS) situated in Ice Factory Road, Chittagong-4000, Bangladesh on 3 July 2015. Fig.8 shows the implementation of the system.

Figure 8: System implementation

VI. COST ANALYSIS

The different essential components with respective quantities and cost are given to implement the system in Table I. The wiring, installation and maintenance cost is considered approximately. The cost of these components may be varied depending on its brand, quality and place.

TABLE I: COST ANALYSIS

Equipments	**No. of set**	Price (**BDT**)
Rack	1	300
Pinion	1	400
Gear	3	1000
Dynamo	1	2000
Belt	1	60
Chain	1	100
Spring	4	200
Body	1	1000
wiring		200
Installation and maintenance cost		1000
Miscellaneous		500
Total Cost		6,760

VII. RESULT ANALYSIS

A. *Theoretical Analysis:*

Rotation of pinion is expressed by

$$n = \frac{l \times N}{L} \quad (1)$$

Where, n is the number of rotation of the pinion
N is number of rotation of the pinion for total length
l is the displaced length of rackin meter
and L is the total length of rack in meter

In this system, rotation of pinion,

$$n = \frac{1.2 \times 2.1}{20} = 0.1275$$

Generated voltage per rotation is expressed by

$$V_g = n \times R_G \times V_r \quad (2)$$

Where, V_g is the generated voltage per rotationin volt
n is the number of rotation of pinion
R_G is the gear ratio
and V_r is the rated voltage in volt.

Generated voltage per rotation measured in this work

$$V_g = 0.1275 \times 7.2 \times 12 \approx 11$$

In this system, efficiency is expressed by

$$\eta = \frac{V_g \times I}{m \times g \times l} \times 100\% \quad (3)$$

Where, is the efficiency of the system
I is the current through the system in mA
m is the mass of the vehicle(cycle) in kg
g is the gravitational acceleration in ms^{-2}
and l is the displaced length of rack/time.

Efficiency measured in this system

$$\eta = \frac{8 \times 60}{60 \times 9.8 \times 0.0002} \times 100\%$$
$$= 4.085\%$$

B. *Practical Analysis:*

Generated voltage is increased with the increase of number of vehicle passing over the implemented system. The result of the research work upon the implemented system is summarized in Table II.

TABLE II:
RELATION OF VOLTAGE &CURRENT AND NUMBER OF BI CYCLE PASSING

Observation no.	Number of vehicle passing	Voltage (Volt)	Current (mA)
1	1	7.19	8.09
2	1	4.48	6.52
	2	10	5.5
3	1	4.9	8.41
	2	9.07	7.4
	3	13.08	1.03
4	1	7.15	8.09
	2	9.7	3.74
	3	10.77	7.33
	4	16.48	4.8
5	1	8.9	8.04
	2	10.82	8.98
	3	15.88	1.98
	4	17 .76	5.74
	5	19.87	0.89

Fig. 9 shows the relation between the experimental generated voltage and number of vehicle passing over the system. When more vehicles pass through the speed breaker, then the value of voltage generation is increased.

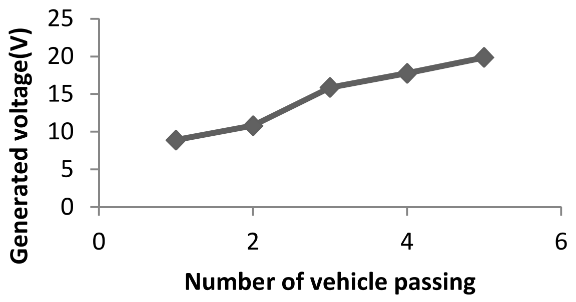

Figure 9: Relation between generated voltage and number of vehicle passing

VIII. ADVANTAGES

The following benefits can get using this technology:

- Pollution free power generation
- Low installation cost
- Low maintenance cost
- No manual work necessary during the process
- Simplicity.
- No fuel transportation problem
- Energy available all the year round

IX. CONCLUSIONS

The implemented system is non-conventional and the way of power generation technique is clean, environment friendly, cost-effective and safe. This system will reduce power crisis and load shedding also. If the street lights are self-powered, then no need to take power from any high rated power plant. It does not require wiring from power plant as the location of system implementation adjacent to the street light.

ACKNOWLEDGMENT

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Alternative Technology for Cooling

Kutub Uddin
Department of Physics
Jagannath University
Dhaka, Bangladesh
E-mail: mdkutub@yahoo.com

Takahiko Miyazaki, Bidyut Baran Saha, Shigeru Koyama
Interdisciplinary Graduate School of Engineering Sciences
Kyushu University, Fukuoka, Japan

Abstract— To provide thermal comfort to the human being many types of cooling technologies are available in the market. These technologies are more essential in the region where the average ambient temperature is high. But every system has some limitations especially for environmental aspect and energy consumption. Open literature shows the available commercial cooling technology used almost 45% of electricity consumed in a house. To keep the system running a lot of fossil fuels need to be burned as a result the volume of greenhouse gases into the air increases. This study introduces a new technology which is emerging as viable alternatives of conventional vapor-compression systems and is known as adsorption cooling system. This system is environment friendly since it uses natural refrigerants and it is driven by low temperature waste heat or solar energy that is why it can solve the existing challenge of global warming and energy crisis.

Key words: *global warming, adsorption, cooling, waste heat*

I. Introduction

Cooling needs are found to be directly proportional to the standard of living of people. The demand of cooling, refrigeration and comfort air-conditioning are increasing at a faster rate especially in developing countries where the people are being capable of buying the technology. According to open literature, the energy consumption for air-conditioning using conventional cooling technology has been estimated to be 45% of the whole households and commercial building [1].

Conventional vapor-compression systems consume a lot of electrical energy; consequently, it leads to the burning of lot of fossil fuel causes higher rate of greenhouse gas production. On the other hand, refrigerants used in these systems also contribute to greenhouse gas emission. Some of the refrigerants, like CFCs (chlorofluorocarbon) and HCFCs (hydro-chlorofluorocarbon), cause depletion of stratospheric ozone layer as well. Developed country already changed their regulation to restrict the utilization of refrigerants which has higher ODP (ozone depletion potential) and GWP (global warming potential). So there is an urgent need to find possible alternative which can address these issues together.

Heat driven refrigeration cycles have the potential to address these problems. Plenty of low grade waste heat, e.g. automobile engine exhaust, industrial waste heat, geothermal heat can be used to drive the refrigeration cycle in lieu of electricity. Use of solar energy in cooling and refrigeration sector has an added advantage because of the availability of solar radiation is almost in phase with the requirement of cooling [2]. Tropical country like Bangladesh can be the potential user of this technology.

Nomenclature

W	Adsorbate uptake per kg of adsorbent [kg/kg]
W_{max}	Maximum uptake [kg/kg]
W_{min}	Minimum uptake [kg/kg]
T	Temperature [K]
T_{eva}	Evaporation temperature [K]
T_{con}	Condensation temperature [K]
P	Pressure [kPa]
P_{eva}	Evaporation pressure [kPa]
P_{con}	Condensation pressure [kPa]
V	Valve
h_{eva}	Evaporation enthalpy [kJ/kg]
C_p	Specific heat [kJ/kg K]
Q_{sh}	Sensible heat [kJ]
Q_{dh}	Desorption heat [kJ]

II. Study of Heat Driven Adsorption Cooling Systems

Adsorption refrigeration and heat pump systems powered by waste heat with utilizing environment friendly adsorbents and refrigerants pairs received great attention now a day. Before 1970s, the studies of adsorption process extensively considered for gas separation, purification and catalysis. Very few study found where the adsorption processes was tried to use for cooling system. And the studies did not lead to commercialize the technology because of its emergence and the use of CFCs as refrigerant.

After 1990s, environmentalist raises their voices against the emission of CFCs which is identified as the major contributor to deplete the ozone layer around the globe and adds to the greenhouse effect. Montreal Protocol on Substances Depleting the Ozone Layer (1987) and five amendments on Montreal Protocol has provided the schedule to reduce the use of CFCs. Therefore, many countries took the initiative to replace the traditional vapor compression refrigeration. Considering all aspect, research to use the adsorption and absorption phenomena in cooling technology got momentum. Now a day, this study is undertaken with objective of rational use of primary energy, by using solar energy or waste heat to run the refrigerators or heat pumps along with the use of totally environment friendly refrigerants, which means refrigerant has no ODP and GWP.

III. WORKING OF ADSORPTION COOLING SYSTEM

A. Principle of adsorption

The heart of an adsorption process is usually a porous solid which provides a very large surface area (3000 m^2/g) and large pore volumes and therefore large adsorptive capacity [3]. The surface of the solid material is usually unsaturated and unbalanced. When surface is brought into contact with gas, there is an interaction between the unbalanced molecular forces at the surface and the gas molecular forces. That is because; solid surface tends to satisfy these residual forces by attracting and retaining on its surface to the molecules, atoms, or ions of the gas. This results in a greater concentration of the gas or liquid in the near vicinity of the solid surface than in the bulk gas or vapor phase, despite the nature of the gas or vapor. The process by which this surface excess is caused is called adsorption [4].

The adsorption process may occur in two ways; physisorption, and chemisorption, depending on the constraining force during the adsorption. In the physisorption process, the adsorbate molecules are attracted to the adsorbent surface by the weak van der Waals force which are similar to the molecular forces of cohesion. There are not any changes in the chemical composition of the adsorption pair. The chemisorption process involves valence forces arising from sharing of electrons between the adsorbent and the adsorbate atoms. This results in a chemical reaction and forming a complex surface compound. The forces of these formed bonds are much stronger than the Van der Waals force. It should be mentioned that the adsorptive action is physical for almost all of solid adsorbents which are commonly used in adsorption cooling systems.

B. Adsorption cooling system over conventional system

The simplicity of operation is the attractive feature of the adsorption cooling system. Fig. 1 shows schematic diagram of basic cooling system. For conventional system (Fig. 1a) the refrigerant is evaporated in the evaporator by taking the heat from the space to be cooled and the vapour is compressed by the mechanical compressor to a higher pressure. The refrigerant is then condensed into liquid in the condenser by rejecting heat.

For adsorption cooling system (Fig. 1b) the mechanical compressor is replaced by the thermal compressor. The adsorbent containing the refrigerant (right bed in Fig. 1b) is heated by the solar collectors or waste heat and the adsorbed refrigerant is expulsed as vapour and condenses in the condenser. The condensed refrigerant is then transfer to the evaporator via expansion valve, leading to a lower pressure area. The refrigerant evaporates in the evaporator, taking up the heat from the chilled water and finally adsorbed in cooled adsorbent part (left bed in Fig. 1b). The adsorption heat is evacuated by the cool water. For continuous cooling production two sorption bed is operated properly.

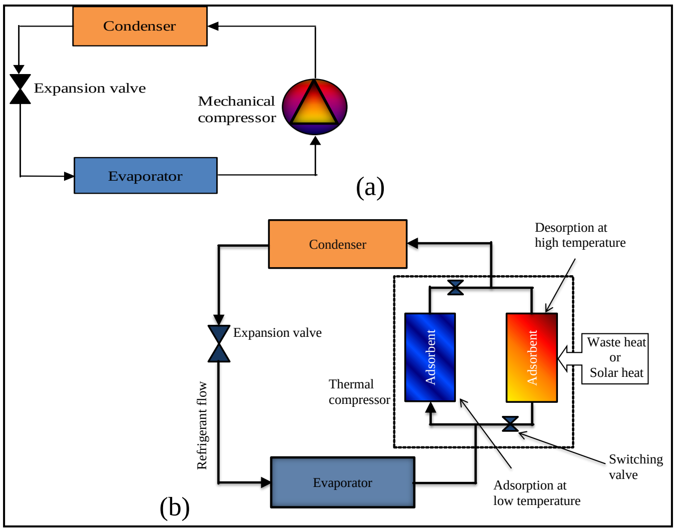

Fig. 1: Schematic diagram of cooling system, (a) conventional vapor compression system (b) adsorption cooling system.

C. Performance investigation of the system using equilibrium data

When a solid surface is exposed to a gas, the molecules of the gas strike the surface of the solid. Some of these striking molecules stick to the solid surface and become adsorbed, while some others rebound back. The rate of adsorption is large at the beginning and it continues to decrease as more and more of the solid surface becomes covered by the adsorbate molecules. The equilibrium state is reached when the rate of adsorption is equal to the rate of desorption.
In equilibrium state, the amount of adsorbate uptake per kg of adsorbent, W [kg/kg], is called adsorption equilibrium capacity or equilibrium uptake. W depends on the equilibrium pressure, P, the adsorbent temperature, T, and the nature of gas-solid system, thus it may be written as [5],

$$W = f\,(P, T, \textit{system type}) \quad (1)$$

The form of the Eq. (1) may be complex and f is usually determined experimentally. Adsorption equilibrium data of activated carbon (KOH-H_2 treated Maxsorb III)/ethanol pair as predicted by Dubinin Astakhov (D-A) equation with a basic adsorption cycle is shown in Fig. 2. In practical adsorption cooling applications, the maximum adsorption capacity of the adsorbent cannot be fully utilized because it takes a long time to reach the equilibrium state.

D. Adsorption Refrigeration Cycle using Dühring diagram

Fig. 3 shows the basic adsorption refrigeration cycle which is consists of two isosters, having constant adsorbed phase concentration and two isobars corresponding to condenser and evaporator pressure. Due to heating by some external source, temperature as well as pressure of the adsorber system increases (process b to c) till it reaches condenser pressure. Desorption takes place at condenser pressure; desorbed refrigerant gets condensed by rejecting heat to a sink (process c to d). The refrigerant liquid goes to evaporator via a pressure reducing valve. Cooled by some external fluid, pressure and temperature of the adsorber system decreases (process d to a) till it reaches evaporator pressure, saturation vapor pressure of the refrigerant at the evaporator temperature. Boiling of the refrigerant, latent heat being supplied by the cooling load, takes place with vapor uptake at the adsorber (process a to b), completing the cycle.

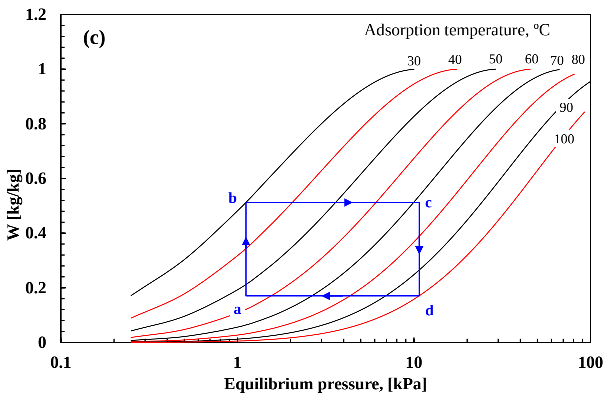

Fig. 2: Adsorption isotherms of KOH-H_2 treated Maxsorb III/ethanol pair as predicted by equilibrium isotherm equation [6].

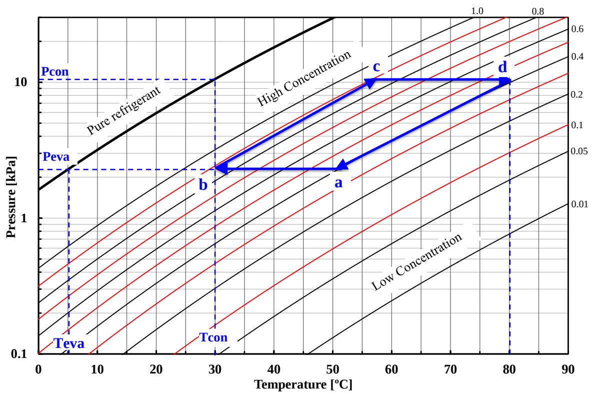

Fig. 3: Basic adsorption refrigeration cycle using conceptual Dühring diagram [6].

Fig. 4(a) shows the adsorption process where valve *V1* is opened and valve *V2* is closed, the pressure is kept constant at P_{eva}. The refrigerant vapor evaporates in the evaporator picking up its latent heat from the chilled water then, adsorbed by the adsorber via the valve *V1*. The refrigerant concentration in the adsorber increases from W_{min} to W_{max} (a→b in Fig. 3). In Pre-heating process, both the valves *V1* and *V2* are closed and the adsorber is heated at constant concentration using a high temperature heat source and hence the pressure increases from P_{eva} to P_{con} ($b \rightarrow c$ in Fig. 3).

Fig. 4(b) shows the desorption process where valve *V1* is closed and valve *V2* is opened the refrigerant regenerates and condenses on the condenser at pressure P_{con} via the valve *V2*

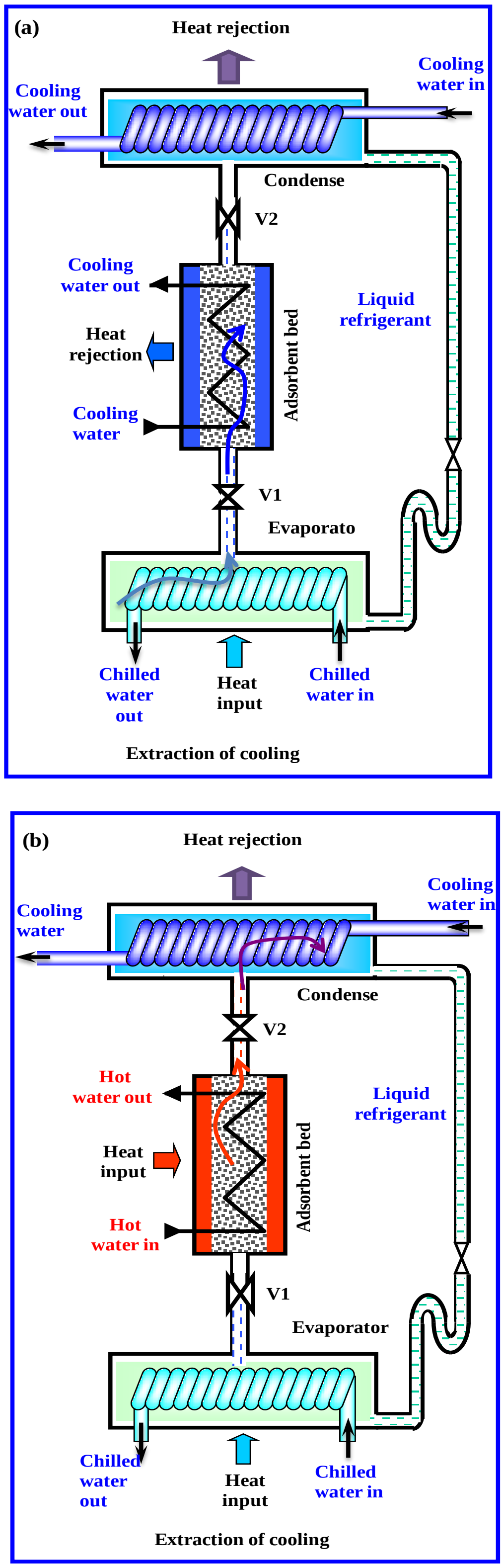

Fig. 4: (a) Adsorption and (b) desorption process with proper valve operation [7].

($c \rightarrow d$ in Fig. 3). The refrigerant concentration on the desorber decreases from W_{max} to W_{min}. In pre-cooling process ($d \rightarrow a$ in Fig. 3), the adsorbent bed is cooled at constant concentration which makes the pressure decrease from P_{con} to P_{eva}.

The model described here is a thermodynamically equilibrium model. This means, all the thermal contributions are calculated based on heat and mass balance provided by the (P-T-W) diagrams. The system performance (SCE-specific cooling effect, COP-coefficient of performance) is predicted using the following equations

$$SCE = (W_{\max} - W_{\min})\left[\Delta h_{eva} - \int_{T_{eva}}^{T_{con}} C_{p,ref}\, dT\right] \qquad (2)$$

$$COP = M_s \frac{SCE}{Q_d + Q_{sh}} \qquad (3)$$

The other relevant equations can be found in elsewhere [5]

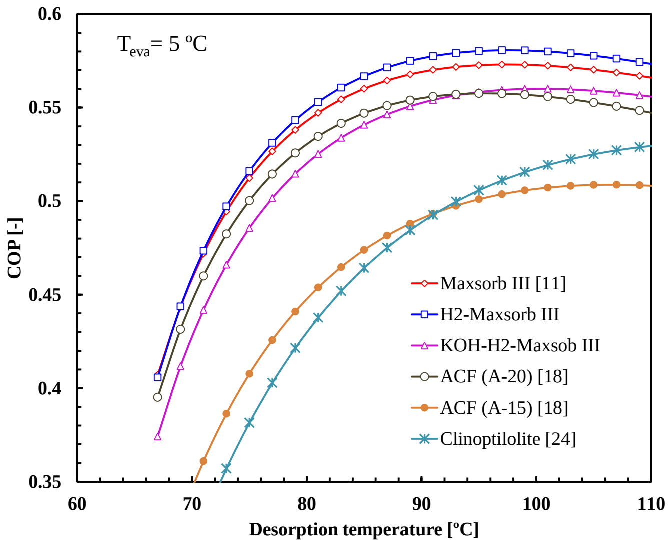

Fig. 5: Effect of desorption temperature on COP [6].

Fig. 5 shows the variation of coefficient of performance with desorption temperature for five different adsorbents/ethanol pairs at evaporation temperature 5°C. As the system driven by heat, here the performance of the system is shown with respect to available waste heat temperature. The value of *COP* increases linearly with the increase of desorption temperature. This is due to the concentration difference at different regeneration temperature. It is found that about 70°C regeneration temperature can drive the current system. With changing adsorbent-refrigerant pair, the regeneration temperature can be reduced.

IV. CONCLUSION

Basic cycle is simple and reliable; however it suffers from the problem of low efficiency; for single bed basic cycle, cold production is also intermittent. The bulkiness due to the limitation of sorption capacity of adsorbent material and low heat transfer rate inside the bed is the hindrance to spread the technology. So the different modified cycles are being tried to improve the efficiency and practicability of the basic cycle [8, 9]. These include multi stage cycle, heat recovery cycle, heat and mass recovery cycle, thermal wave cycle, forced convective thermal wave cycle, cascade cycle and multi-bed cycle etc. To maintain high vacuum, the large volume and weight relative to traditional refrigeration systems limits the extensive application of this technology.

Some newly develop adsorbents have promising adsorption characteristics with refrigerant that may lead to the development of next generation of adsorption chillers [10].

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Enhanced Audio-Visual Warnings for Reducing Bird Fatalities at Wind Turbines

Shahriar Khan, Md. Ikramul Haque
Department of Electrical and Electronic Engineering
Independent University, Bangladesh
Bashundhara R/A, Dhaka - 1223, Bangladesh.
Email: khandhaka@gmail.com

***Abstract*-- Bird and bat fatalities by wind turbines has slowed the installation of new turbines, and even prompted the dismantling of existing turbines. Other animals can coexist in artificially created dangerous environments, like dogs maneuvering among cars in busy streets. Based on this concept, a previous paper has proposed that bird and bat mortality can be reduced by audio visual warnings in the proximity of wind turbines. This paper proposes further details of audio visual warnings, including directional lights, which will enhance the learning process and act as warnings. The leading edges and the peripheral regions of the blades are most likely to strike birds and bats, which may be trained to keep away by the colors, lighting and sounds of leading edges. Lights and sounds need only have a range of a few tens of meters and directionality towards the danger zone, meaning the lights and sounds will be imperceptible to humans in the vicinity. So that the globally mobile birds do not have to relearn the warning signals, countries can converge towards common standards for the warning colors, lights and sounds on wind turbines.**

***Keywords*-- Bird, bats, wind turbine, lights, warning.**

I. Introduction

Every year, thousands of bats and birds are killed by wind turbine blades, evident from the dead and dismembered bodies lying around. The problem is of great urgency, as birds across the food chain have shown a sharp decline globally in the last few decades. Bird and bat mortality is a major reason for the slowing of installation of new turbines, or even the dismantling of turbines with high casualty records.

Figure 1. A dead kite at a wind farm in the UK. (Courtesy: telegraph.co.uk)

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Birds killed include those at the bottom of the food chain, to those at the top, such as eagles hawks, owls, etc [1,2,3,4].At a wind farm in West Virginia, 1400 – 2000 bats were being killed each year [5,6].

A. Past Steps for Reducing Fatalities

Wind turbines have been dismantled when they were found to kill too many birds. With its 5400 wind turbines, the Altamont Pass wind farm in California is the largest wind farm in the world. About 130 turbines were dismantled by 2007 because of bird fatalities. So as to reduce bird fatalities, about half the turbines were shut during the winter months, when the bird density was the highest.

Turbines have been placed in areas least frequented by birds [7]. Unfortunately, areas of high winds favorable to turbines, such as hill ridges, often coincide with the flight path of birds.

Newer turbines have lower rotating speeds and are placed higher above the ground, away from the foraging areas of birds and bats [8]. This may be effective for birds lower in the food-chain, but less effective for predatory birds which fly at higher altitudes for preying on other birds.

At wind farms in Texas, radars detect approaching birds, so as to temporarily shut the turbines, allowing their safe passage [9,10,11]. This method requires detection technology, and the inconvenient shutting of turbines. Ultrasonic boomboxes were used in Austin Texas, to confuse echolocation system of bats, and reduce bat fatalities [12].

B. Approach of this paper

Wind turbines are a looming sight, audible and visible over distances. Ironically, these very sights and sounds may have a role in training birds and animals of the mortal danger of the blades. Additional sights and sounds have been proposed to further warn birds and bats [13,14]. This paper provides details on colors, lights, and sounds placed strategically to better alert birds to mortal danger.

In the search for a comprehensive warning system to birds and bats, this paper assesses the needs of birds for movement and foraging. The sources of danger from the blades, and existing warning stimuli given to birds and bats are examined. Based on the findings, this paper proposes added visual stimuli in the form of strategically placed lights and sounds.

II. Animals in Dangerous Artificial Environments

It may be very instructive to see the existence of animals in dangerous artificial environments. Stray dogs and cats learn to live on streets maneuvering between cars without being run over. Decades ago, birds would run into glass buildings, power lines, and car windshields, but these incidents are rarely heard of nowadays [15]. All these point to a learning process in animals, consistent with Darwinian process of survival.

Figure 2. Stray dogs in a busy city have learned to live on streets among cars, quite unlike what they have adapted to over millions of years.

A. Birds Living or Moving among Wind Turbines

Birds and bats dwell in wind farms for the dual purposes of foraging for food, and for general movement and migration. Birds at the bottom of the food chain, forage for seeds, grains, and insects, and dwell relatively close to the ground often below the blades. Birds higher in the food chain or predatory birds, dwell at higher altitudes, so as to have a better vantage point for preying on rabbits, other birds, etc, Their higher flight paths coincide with the paths of the blades putting them at major risk.

The extreme options are to stop building wind turbines altogether, or to build them without any consideration for birds and bats. The solution lies somewhere in-between, where birds and wind turbines can coexist, with the least fatality to birds (figure below)..

Figure 3. Birds should be further warned to say away from wind turbines (courtesy: birdnote.org)

III. Sources of Danger and Location of Warnings

The blades with peripheral speeds as high as 114 mph, kill birds and bats upon impact, usually by the leading edges of the blades. Birds may not see or hear the approaching blades until it is too late. Birds and bats are also killed from pressure changes around the blade, which cause their heart and lungs to burst.

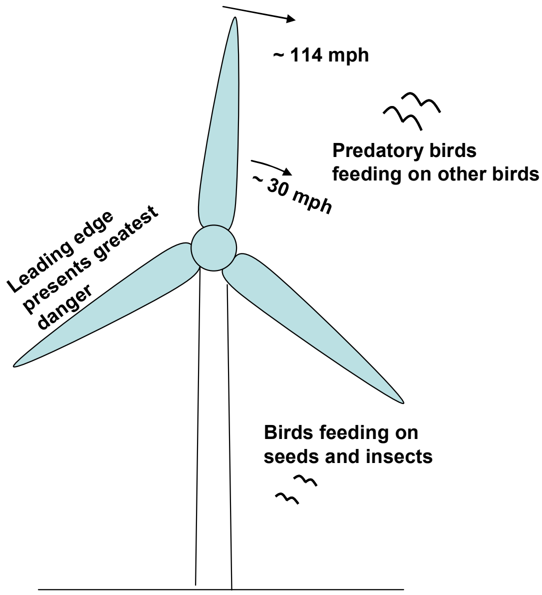

Figure 4. Birds are usually killed by the leading edges fo the blades at the peripheries. Birds lower in the food chain are killed at lower altitudes.

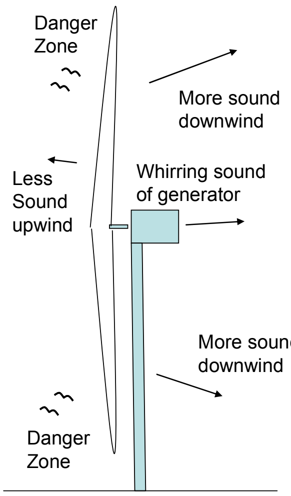

Figure 5. The Swoosh of the blades and whirring of the generator cog wheels are more intense downwind, while they are needed upwind to warn birds.

The speed of rotation for the generator is raised using gears, which produce a whirring sound. The sound from the blades and the generator are carried downwind, making the sound more intense downwind than upwind. In contrast, the danger to birds lies more in the upwind area, where they are more likely to fly into or be swept into the blades. The location of the generator behind contributes less to warning birds and bats as the greater danger lies in front.

A. Learning Process of Birds

Of much interest to us is the variation of casualty numbers in successive years at wind farms. The literature describes several hundred birds dying on the first day after installation of a wind turbine. The numbers of birds killed per year likely decline in successive years, although the publicly available data on this issue is rather sketchy.

There are two likely reasons for the decline. Firstly, past fatalities bring down bird populations, causing future fatalities to decline. Secondly birds and bats likely undergo a learning process, where they become trained to stay away. Within a few days of installation, birds "learn" to keep away from the blades. The learning process has to do with evolutionary forces, that birds which do not recognize the risk of the turbine blades are eliminated. Over time, the sights and sounds of turbines may be rightfully interpreted by birds and bats to be a source of danger.

An approaching blade is a formidable sight rightfully capable of scaring a bird. Wind turbines emit sounds of varying intensity and frequency, some of which may be in the ultrasonic range. The high-speed blades traveling at about 114 mph emit the "swoosh" audible for hundreds of meters. If the wind turbine must be likened to a household appliance, the closest would be a washing machine.

The low frequency sounds and the swoosh sounds can be heard for hundreds of meters around a wind farm and birds and bats may be aware of the whole general area.

The fact that some birds are still killed every year is testimony that the learning process in the birds remains incomplete. They need further stimuli as a warning, and training to stay away from the blades.

B. Learning from Close Encounters

We recall the Pavlovian response that a scary and painful but non-injurious encounter with a blade will teach a bird to stay away from turbine blades. For every fatal encounter, there will be a number of painful or mildly injurious close encounters, which will teach birds to stay away.

Will a fatal encounter of one bird or bat teach remaining birds to stay away? According to similar examples in the animal kingdom, the answer is mostly "yes". In city areas, crows will make a commotion upon seeing an air gun. Crows will move away, when the barrel is pointed at them. This is further evidence that remaining crows learn from the fatal mistake made by earlier crows sitting in the line of fire.

Since antiquity, the scarecrow has been used as an attempt to scare birds away from crops Birds learn to ignore the scarecrow, as soon as they find it does not pose any real danger.

C. Vision and Hearing of Birds

Birds have well developed sight and hearing, of which sight is more important [16,17,18]. The size of the eye, relative to the rest of the body is the largest in birds. In addition to the colors usually visible to humans, birds are often sensitive to ultraviolet light.

The eyesight and hearing of birds are not designed to warn against a turbine blade approaching at 100 mph. As poor visibility in adverse weather has been identified as a factor in bird deaths, blades should be easily spotted in poor weather.

The warning colors may be placed in the leading edges of the blades especially in the periphery where the velocity is the highest.

IV. PROPOSED VISUAL WARNINGS

Turbines are usually painted white or grey from aesthetic considerations. These light colors are thought to be visually less obstrusive, least cluttering the natural landscape. The mild and neutral colors of turbines may not be sufficient warning to birds. Instead, they may even attract insects at night, which in turn attract the birds [19,20]. Turbine colors are unlikely to affect bats, which are mostly blind.

More visual and auditory stimuli may better catch the attention of birds and bats. The heightened sensory stimuli might allow the birds to further associate the sight and sound of wind turbines with mortal danger.

A. Colors

In nature, bright colors are designed to get attention, either attracting or warning to stay away. Brightly colored flowers attract insects and birds to nectar and bright colors in frogs warn predators they are toxic and poisonous.

The following questions may be raised about their properties of the warning colors: (a) what colors (b) placement (c) design.

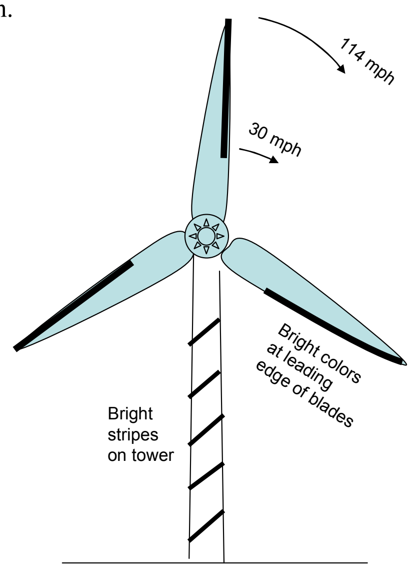

Figure 6. The leading edges of turbine blades may be colored brightly, so as to get the attention of birds. The tower may also have bright stripes.

Ultraviolet paint may be visible to birds, but least likely to bother human vision. As bird deaths rise during poor visibility, brightly colored blade edges would be easily spotted during poor weather.

The patterns of color on a flower guide birds and insects to the source of the nectar. Similarly, patterns of colors may be set so as to warn birds of the leading edges of the blades.

Warning colors on the leading edges of the turbine blades can be thin stripes only visible to birds at close range. The combination should remain dull and unobstrusive when viewed from a distance.

B. Proposed Warning Lights

Lights are more likely to get the attention of birds than just plain color. The question arises about the lights as to (a) whether flashing and for what durations (b) color (c) intensity (d) placement (e) directionality. At this time, the properties and placements of the warning lights may be for what would best catch the attention of a human being. As the findings progress and more data is accumulated, the following properties of the lights may be adjusted for what is best suited to warning birds.

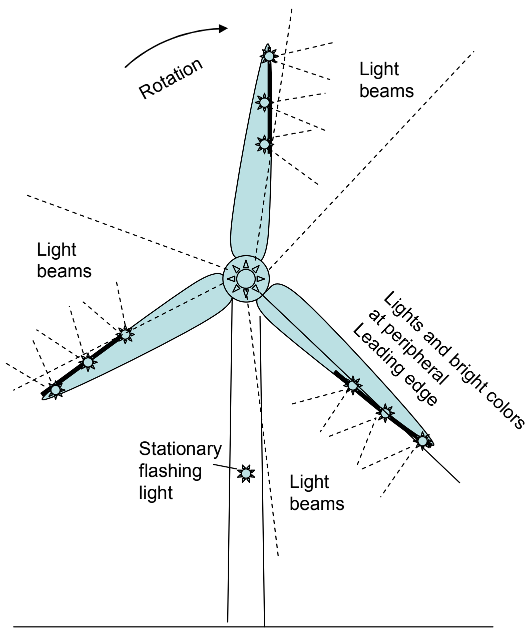

Figure7. Light on the leading edges of the blades will warn birds in their path. A rotating light in the center will warn birds just ahead of the blades.

An intermittent or flashing light is more likely to catch the attention of birds, rather than a steady light.

C. Intensity

The intensity should be limited such that the birds are only alarmed when they are in danger from proximity to the blades. The lights need be a distant reminder when the birds are far away, say more than a few tens of meters.

To improve visibility during the daytime, the lights may be intensified in the daytime. As bird mortality increases during poor weather, the light intensity may be raised during rainy or foggy weather

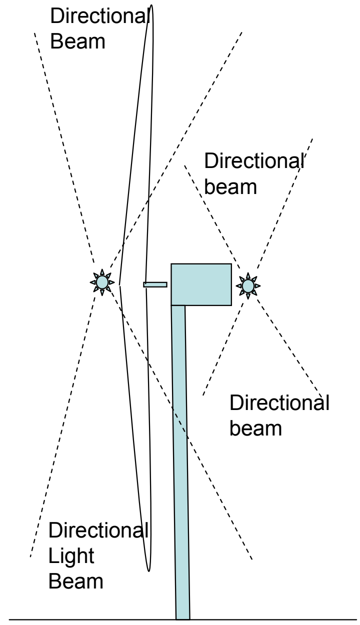

Figure 8. A rotating flashing light (like police car) may warn birds along the plane of the turbine. This will least bother human vision.

D. Color

The color should be different from the white lights used everywhere for illumination. An excellent candidate may be the newly invented colored LED lights which birds are not used to. Ultra-violet lights have the advantage of being often visible to birds but not to humans.

E. Placement and Directionality.

As wind turbines are large structures, it is better to use a number of strategically placed low-intensity lights near danger zones, rather than only one or two lights of high intensity.

The lights may be placed at the leading edges in the direction of rotation, which is also of the greatest danger to birds and bats. The rapidly approaching lights on a blade will be an added warning to a bird in its path.

At the point central to the three blades, there may be a flashing light, like on a police car. The light may move with the turbine, and light the danger area just ahead of the moving blades.

The number of beams will equal the number of blades; three beams for a three-bladed turbine and two beams for a two-bladed turbine. The beams will be directed mostly along the plane of rotation, and ahead of the rotational direction of the blades.

Flashing lights can also be placed on stationary locations such as on the tower and on the generator.

V. Proposed Warning Sounds

In spite of the far-reaching sounds of turbines, more sights and sounds are needed in the immediate vicinity. Warning sounds have the advantage over visual warnings, that they will alert the birds, regardless of the direction they are looking at. In general, warning sounds should be

(a) unpleasant to birds, just as some sounds are unpleasant to humans. Humans particularly dislike screeching, screaming, and gunshots.

(b) distress calls of birds of the species we are trying to warn. Caution should be used as the distress calls of a bird lower in the food chain may attract birds higher in the food chain.

As the sounds are to be present all the time, the disturbing sounds should not be too disorienting to birds.

The question arises as to the following properties of the speakers or sound sources. (a) placement and directionality. (b) whether intermittent and with what on-off durations (c) frequency (d) intensity The properties of the sound can be adjusted to what draws the attention of humans. Based on further research and additional data, the sounds can be adjusted to what is better suited for resident birds and bats.

A. Powered speakers vs. Passive Whistles

The question arises as to whether the sound sources should be passive (whistles) or active (speakers). For existing turbines, whistles may be easily placed on the moving blades powered by the high speed movement of the air. A whistle will be affected by the accumulation of dust, that will require periodic cleaning.. The frequency of the sound will be affected by wind speeds, and cannot be changed after installation.

Speakers are easily placed on the ground, the tower, and the generator. Unlike whistles, speakers can better control the generated sounds. Powered speakers on the moving blades are more problematic, as they require slip rings on the shaft, and cannot be installed on existing sources.

Stationary sound sources may be useful, but sound sources are more appropriate on the leading edges of the blades, which are the real source of danger. As an animal is more likely to drift with the wind, the sound sources can face slightly towards the front, or in the direction of the incoming wind.

The directionality of the sound should also point towards the leading edges of the blades, or the zone of greatest danger to the birds. The directionality of the sound will have the added advantage of creating less disturbance to humans in the vicinity.

B. Placement and Directionality of sources

The question arises as to locations, numbers and directionality of the speakers (or whistles). As the wind turbine is a large structure, one or two centrally placed high-intensity sources will not be able to adequately associate the danger zones with the sounds. A number of low-intensity sound sources near or at the danger zones, would better associate the danger with the sounds.

C. Intermittent Sounds

An intermittent sound is more likely to get the attention of birds and bats than a continuous sound. A major advantage of an intermittent sound is that the on and off periods will increase according to the Doppler shift, for an approaching blade. This will imply urgency and provide an added warning.

The initial on-off periods can be adjusted according to what gets the attention of humans. The on-off durations can be later adjusted according to further data on the responses of the birds.

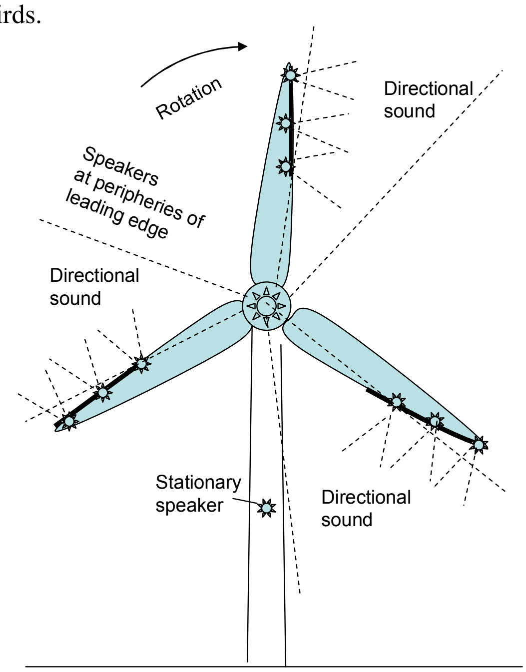

Figure 9. Patterns of ultra-violet may catch the attention of birds, but will be barely visible to humans. Chirping speakers near the ends of the blades will act as warning to birds

D. Frequency of Sounds

The sensitivity of birds to sound is not very different from humans. Ultrasonic clicks may be the only way to get the attention of bats which use high frequencies for echolocation. Sound may be the only way to get the attention of bats. Ultrasonic sounds have the advantage of being inaudible to humans in the vicinity.

Higher frequencies have the property of higher attenuation, and would attenuate in the immediate vicinity of the wind turbine. High frequencies will be carried less to distant locations, such as to human residents. Because of the shorter range of high frequencies, they can better associate danger zones with the sources of the sound.

A major advantage of sound over sights is that the Doppler shifted higher-frequency of approaching blades will be an excellent warning to birds and bats.

E. Intensity and Range of the Sounds

The intensity of generated sounds will determine the range around the turbines where the birds and bats are alerted, and how much the sounds are a disturbance to surrounding animals and humans. Lower intensity sounds would have limited range, and thus not draw the attention of birds outside of immediate danger, and humans living in the vicinity.

The sounds need not have a range of more than a few tens of meters, the danger zone of birds, meaning humans outside of this range will not be disturbed.

CONCLUSION

Bird fatalities have slowed the construction of wind turbines, or even led to the dismantling of turbines with high fatalities. The very sight and sound of wind turbines, while disturbing to humans, may also have become warnings, training birds and bats to stay away from the blades. This paper explores how to create added visual and auditory stimuli that will further repel the animals. Visual and audio signals complement each other in warning birds and bats. The leading edges and peripheral regions of the blades may be painted in bright colored stripes or ultra-violet paint to reinforce the warning process. The leading edges of the blades may have colored warning directional lights and directional sound to warn birds and bats.

The proposed steps may be implemented immediately at existing wind farms. Whistles utilizing the high speeds of the blades may be installed on existing blades. Powered speakers which require slip rings on the shaft. Speakers may be easily placed on stationary locations such as the ground, on the tower and on the generator. Ultrasonic frequencies are likely to better warn bats.

Numerous low intensity lights and sounds will ensure that the warnings are not an environmental nuisance to animals and humans.

Light and sound warnings to birds and bats only need to have a range of a few tens of meters, within the danger zones. Also the lights and sounds can be directional, pointing only towards the leading edges of the blades. The sounds and sights can be limited largely to the path of approaching blades. Also the sights and sounds can be largely limited to the plane of rotating blades. These factors ensure that the lights and sounds are too weak to become audible to humans in the vicinity. At least the noise will be drowned out by the washing-machine like long-range sound of wind turbines.

Birds are globally mobile as they may move across regions countries, or continents. With different audiovisual warnings from wind farm to wind farm, birds and bats may have to re-learn the different systems of warnings. Warning painting patterns should be similar across regions, countries, and continents, so that the birds do not have to relearn the danger for different turbines and different areas. Learning the danger at one turbine will be like learning the danger at all turbines. There can be some agreement towards a global agreement on warning sounds, lights, and colors to be used for wind turbines over the world. Data on the deterrence and warning value of sights and sounds should be made available to researchers worldwide.

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Design and Performance Analysis of a Directly-Coupled Solar Photovoltaic Irrigation Pump System at Gaibandha, Bangladesh

S. M. Shamim Reza
International Training Network Centre
Bangladesh University of Engineering & Technology
Dhaka, Bangladesh
Email: shamim01716@gmail.com

Md. Nazmul Islam Sarkar
Institute of Energy
University of Dhaka
Dhaka, Bangladesh
Email: sarkarmni@gmail.com

***Abstract*—Due to climate change and high price of fossil fuel, demand of electricity for irrigation need is increasing. Harnessing solar power to meet this increasing demand can be a good solution. In this paper, we have shown the design and performance analysis of a directly coupled solar photovoltaic (PV) motor-pump system operating at Gaibandha, Bangladesh. Three 1kW DC series motor coupled with pumps were powered by photovoltaic panels of 2kWp. The motor pumps were directly connected without any converter. All of the components of the system were available and bought from the local market. With average insolation, the system can lift 1,20,000 to 1,72,000 lit/day. We have calculated the efficiency of the motor-pumps at different time of the day. Finally, we have calculated the simple payback period of the system. We found the system to be viable technically and economically.**

***Keywords*—Solar irrigation; Green farming; Photovoltaic pumping; Solar for agriculture formatting; Green energy.**

I. Introduction

Application of solar photovoltaic (PV) energy for water pumping gained popularity recent years because of drastic decrease of PV panel's price. Also direct coupling of PV panels with the pump system has shown great potential with low cost for water pumping applications. Direct coupling of mechanical load with PV array requires a systematic study of load which might be cumbersome but eventually leads to a very simple and reliable design [1]. Usually, the output of the PV array is time-dependent and also non-linear in nature which directly varies with solar insolation level and cell temperature [2]. The proper matching of components is greatly essential in a direct coupling Pump-motor system.

M. A. Hossain, M. S. Hassan, and M. A. Mottalib [11] have done a feasibility study on solar irrigation in Bangladesh in which they have shown solar irrigation as profitable and environment friendly. S. I. Khan, M. M. R. Sarkar, and M. Q. Islam [12] of Bangladesh University of Engineering & Technology have done a design and analysis of a low cost solar water pump for irrigation in rural Bangladesh. The prospect of hybrid solar irrigation system in Bangladesh was also studied by M. A. Hasnat, M. N. Hasan, and N. Hoque [13]. After these fantastic initial assessments and analysis by the researchers we have implemented the idea of solar irrigation in real practice.

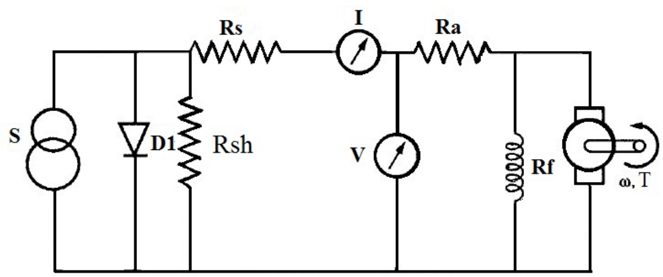

Fig. 1. Circuit diagram of a directly coupled solar photovoltaic water pump.

II. Theoretical study

A. Circuit diagram of photovoltaic solar pump

In this work, we have designed and studied an off-grid directly coupled solar PV powered water pumping system situated at Gaibandha, Bangladesh. We have used DC series motor in this design. Koner [3] has given a circuit diagram of a directly coupled series DC pump-motor system which is illustrated in fig.1.

B. Motor-Pump characteristics

The Koner [3] has given the following formula to calculate the working water head of the pump:

$$h = K_1(w^p)^2 - K_2(w_0 - w^p)^2 \quad (1)$$

where,
h: working water head, (m), w_p: pumping speed $(rads^{-1})$
K_1: voltage dependent water head constant, $m(rads^{-1})^{-2}$
K_2: flow rate dependent water head constant, $m(rads^{-1})^{-2}$
w_0: the speed of motor-pump system at no-flow condition, $(rads^{-1})$

Braunstein and Kornfield [4] have given the relation of water discharge to water head of the pump as:

$$Q = K_3(h_0 - h)^{1/2} = K_3K_2^{0.5}(w_0 - w^p) \quad (2)$$

where,
Q: flow rate of a pump (ls^{-1}),
h_0: water head of a pump at no-flow condition, (m),
K_3: flow speed constant, $(ls^{-1}m^{-0.5})$
The speed-torque relationship is given as:

$$T^p = K_4(w^p)^2 \quad (3)$$

where,
T^p: pump torque, (Nm), K_4: flow-water head constant of a pump, $(ls^{-1}m^{-1/2})$
Hsiao and Blevins [5] deduced the equations for DC series motor as follows:

$$V^m = MI^m w^m + I^m R_t \quad (4)$$

$$T^m = M(I^m)^2 \quad (5)$$

$$M = M_0(w^m/(w_0^m)) \quad (6)$$

where,
V^m: motor terminal voltage, (V),
M_0: motor constant, (NmA^{-2})
I^m: armature current of a motor, (A)
w^m: motor shaft speed, $(rads^{-1})$
R_t: Field coil and armature resistances of motor, (ω)
Finally, the efficiency of the motor pump is given by Kolhe, Joshi, and Kothari [2] as:

$$\eta_{mp} = \frac{\rho g Q H}{VI} \quad (7)$$

and the overall efficiency as:

$$\eta = \eta_e \eta_{mp} \quad (8)$$

where,
η_e: PV array efficiency, Q: flow rate, $(m^3 s^{-1})$
H: head of water, (m), g: constant of gravity $(9.81ms^{-2})$
ρ: density of water, (kgm^{-3})

C. Solar Radiation and PV feasibility of Bangladesh

The effectiveness of solar irrigation pump largely depends on the solar insolation availability. As a tropical country Bangladesh receives sufficient amount of solar radiation to run irrigation pumps. The 22 years (1983-2005) average of solar radiation data of Dhaka, Bangladesh along with clearness index is shown in fig. 2 [6].

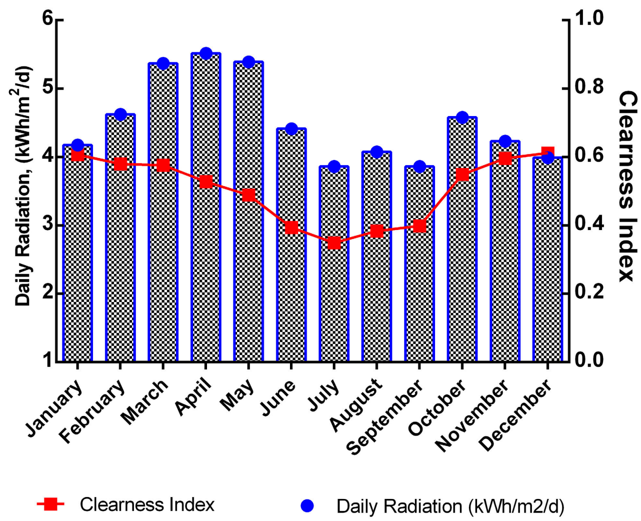

Fig. 2. Monthly averaged daily solar radiation with superimposed clearness index of Dhaka, Bangladesh.

TABLE I
SUMMARY OF EXPERIMENTAL SETUP

Parameter	Value
No. of Pumps	3
Pump rated power	1 kW
Pump motor type	DC series motor
Total Power of Solar Panel	2 kWp (2000 Wp)
System Voltage	48 60 V (DC)
Type of Panel	Mono Crystalline
No. of Cells per panel	72
Bore hole / Housing Dia	Shallow, 6 inch pipe, 120 feet depth
Static water level	Max. 30 feet
Suction Pipe size	1.5 inch, 2 inch & 3 inch
Delivery Pipe	1.5 inch, 2 inch & 3 inch
Total Water Lifting	1,20,000lit-1,72,000 lit/ day

III. EXPERIMENTAL SETUP

There are three PV arrays, 3 DC series pump-motors and a control panel. Each unit of solar array contains four panels of 12V each and capacity of total array is 2 kWp. Three pipes are connected to the 6” main bore well which has a depth of 120 feet and the static water level is 20 to 25 feet. The project was carried out at Gaibandha, Bangladesh. This design was committed to contribute to sustainable agriculture development, where the use of fossil fuels can be reduced by using solar energy systems. There was also a storage tank to enable us to preserve and use the irrigation water during periods when the sun radiation is not received sufficiently or during hours of darkness at night. The summary of the experimental setup is given in Table 1.

The three motors will start to work at minimum 24V. From 7am-12 pm, at the starting of the day with low insolation at least one motor with small boring will start to run. From 12pm-3pm, at the middle of the day two motors can run equally. With the availability of sufficient insolation 3 motors can operate simultaneously. The excess water can then be stored in the storage tank for later use. The schematic diagram of the design is shown in fig 3.

The motors are adjusted to a boring system. The lifting three pipes are connected to 6 bore well system. The length of bore is 120 ft. and the static water level is 20 to 30 feet. The diagram of irrigation pump boring sizes are shown in fig. 4.

IV. IRRIGATION WATER REQUIREMENT

Changes in irrigation demand has grown very rapidly due to the increasing demand of the food requirement. Boro rice is the main crop product during dry season when water is very

(a) Solar panels at Gaibandha

(b) Pumps at operation

Fig. 5. Operation of solar irrigation pump at Gaibandha, Bangladesh

TABLE II
RPM AND FLOW RATES OF THE THREE MOTOR-PUMPS

	Motor 1		Motor 2		Motor 3	
Time	Voltage, (V)	Current, I (A)	Voltage, (V)	Current, I (A)	Voltage, (V)	Current, I (A)
9:00	24.0	14.8	33.8	16.0	31.6	14.0
9:15	22.8	13.0	35.8	20.3	31.6	15.0
9:30	24.4	14.3	31.8	16.9	33.1	15.1
9:45	21.9	13.4	31.8	15.2	33.0	14.2
10:00	24.2	15.0	32.8	18.4	34.1	16.2
10:30	24.3	13.2	24.0	15.3	27.5	12.9
11:00	24.5	15.5	26.0	14.9	28.3	14.1
11:15	23.8	13.1	26.3	14.6	29.3	13.8
12:00	20.7	12.3	26.9	15.3	30.6	15.9
12:15			25.3	14.8	28.6	13.5
1:00			25.9	12.7	29.0	11.7
1:30			25.8	16.2	29.2	15.1
2:00			25.2	16.1	28.6	14.5
2:30			24.3	14.1	27.8	13.3
3:00			18.7	10.6	22.8	10.5
3:15			24.7	13.8	30.3	14.4
3:30			14.6	8.4	19.2	12.2
3:45					27.0	13.4
4:00					19.4	8.8

scarce due to scanty rainfall. Let us find the water requirement of Boro rice per hectare area of land. The formula to find required water for irrigation [10] is given as follows:

$$Required\,Water\,Volume\ = (Required\ water\ height) \times (Area) \times (No.\ of\ \ irrigation)$$

The required average water height for Boro rice is 8.5 cm and area of the land is assumed to be 1 hectare (10000 m^2) and approximate number of irrigation required is 25 times [7]. So, we can now calculate the water requirement per hectare as:

$$Total\,Water\,required\,for\,one\,hectare\,of\,\,Boro\,irrigation\ = (8.5/100)m \times 10000m^2 \times 25 = 21250m^3/h$$

As the total time required for Boro production is 75 days [7] and as $1m^3 = 1000l$:
$Total\ \ average\ \ water\ \ required\ \ per\ \ day\ \ per\ \ hectare\ = (21250m^3/h \times 1000l)/75days = 2,83,333l/h/day.$
We can see that our pumps can irrigate approximately half hectare land each day.

V. MOTOR-PUMP PERFORMANCE ANALYSIS

The performance of the PV powered motor-pump system is studied. Data for rpm and flow rate is taken at 15 minutes interval. Table 2 shows the rpm and flow rates of three motor-pumps. Pump 1 has a smaller bore hole than other two pumps. So with lower amount of insolation at the morning or at the evening pump 1 can operate. The other two pumps start operating when there is sufficient amount of insolation usually at mid day. When pump 2 and pump 3 starts operating at rated load then pump 1 is switched off. So actually at a time maximum 2 kW rated load are operating and thus 2 kWp solar panel is sufficient for operation.

The voltage and current curves of the three motor-pumps are shown in fig. 6 and the power curves are shown in fig. 7. We can see that at the morning from 9:00 to 10:00 am the pumps have maximum power as the insolation is high at that time. But interestingly, from fig. 8 we can see that all the pumps flow rate remain approximately constant without drastic change with the change in insolation. This indicates that the system is stable and will operate properly even there is minor fluctuation in solar radiation level.

TABLE III
COST OF SOLAR IRRIGATION PUMP SYSTEM

Name of the Equipment / Setup	Unit Price (USD)	Quantity	Cost (USD)
Solar Panel total 2 kWp	1 / Wp	2000	2,000
Motor - 1000 W	125	3	375
Pump	62.5	3	187.5
Boring Well	-	-	1,250
Panel Structure	-	-	500
Electrical Wiring and Misc. Cost	-	-	625
Installation charge	-	-	125
		Total in USD =	**5,062.5**
	(1 USD = 80 BDT approx.)	Total in BDT =	**4,05,000**

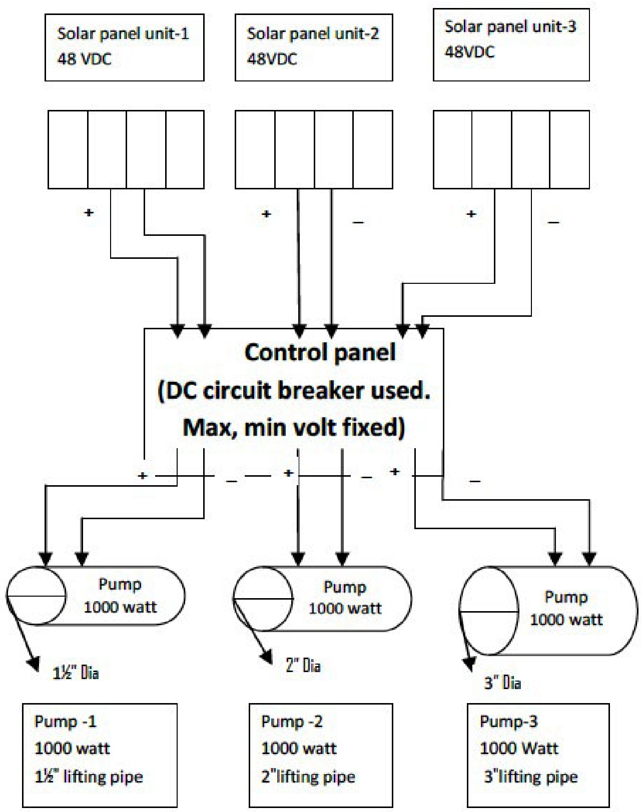

Fig. 3. Schematic diagram of solar irrigation pump

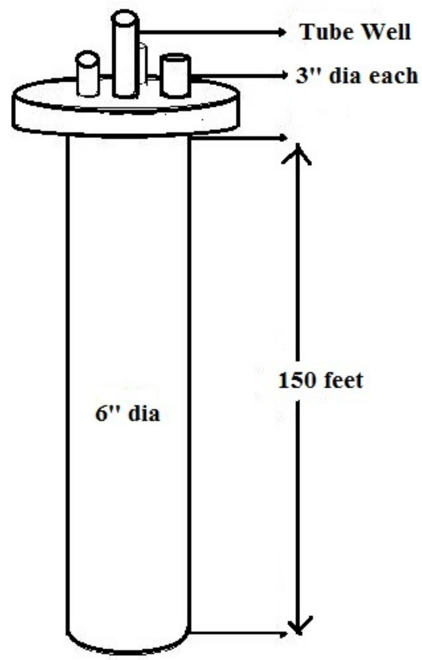

Fig. 4. Irrigation pump boring sizes.

TABLE IV
COST OF IRRIGATION PER HECTARE OF DIFFERENT AREA

Place	Cost per hectare (BDT)	Cost (USD)
Netrokona	18,500	231.25
Gopalgonj	21,800	272.50
Sherpur	18,700	233.75
Moulovi Bazar	20,500	256.25
Habigonj	19,700	246.25
Average	19,840	248.00

The efficiency of the three motor-pumps are calculated using equation (7) and shown in fig. 9. It was seen that motor-pump 3 has the maximum efficiency among the three pumps.

While performing the experiment it was also found that with a fixed rpm of the motor, the discharge will remain the same but rpm of the motor do not remain same due to mechanical loss due to friction and electrical loss. So, even the rpm is increased but correspondingly discharge did not increase due to above reason. During low insolation in the morning only motor -1 was operating due to the smaller size of the discharge pipe but when insolation increased, both motor-2 & 3 could operate simultaneously. In this study it is observed that operators judgment to extract maximum yield, is very important. Also there is a high fraction of excess electricity produced in non-irrigation seasons. This excess electricity can be supplied to drive other farming load like weed cutter, crop harvester etc. The excess electricity can also be supplied to nearby village to power solar home systems (SHS).

TABLE V
YEARLY CASH INFLOW CALCULATION OF THE PROJECT

Season	Type	Amount of irrigated land	Cash Inflow (BDT)	Cash Inflow (USD)
Mid January - Late April	(Boro Season)	1/2 hectare	19,840/2 = 9,920	124
April - June	(Supplementary irrigation for any crop)	1/4 hectare	19,840/4 = 4,960	62
July - August	(Rainy season)	No irrigation required	-	-
September - November	(Supplementary irrigation for any crop)	1/4 hectare	19,840/4 = 4,960	62
November - March	(Wheat & Mustard irrigation)	1/2 hectare	19,840/2 = 9,920	124
Total	-	$1\frac{1}{2}$hectare	29,760	372

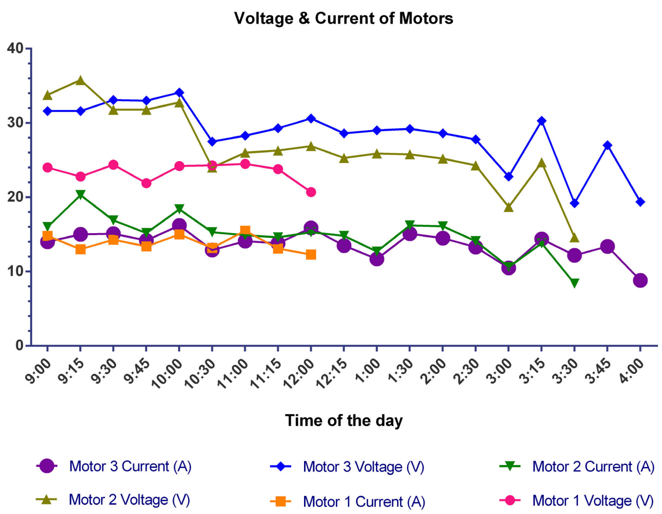

Fig. 6. Voltage and Current curves of three motor-pumps.

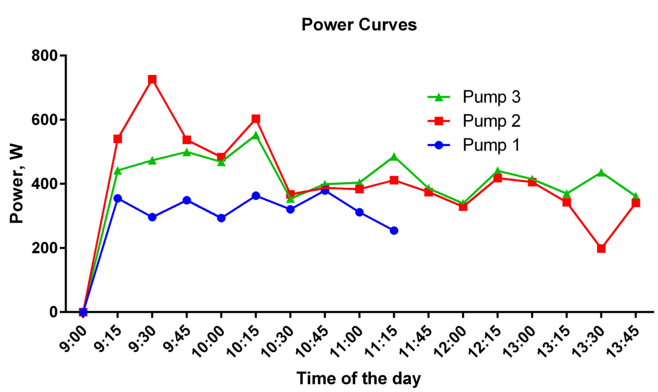

Fig. 7. Power curves for three motors

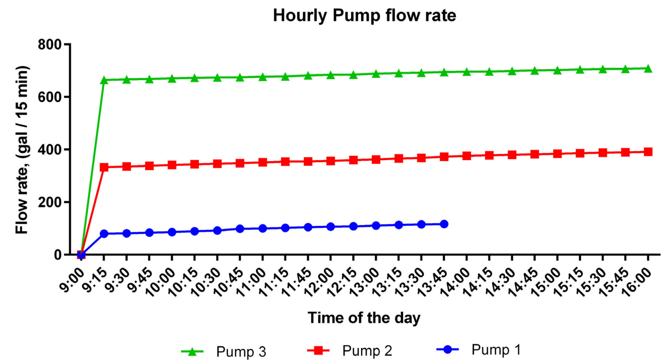

Fig. 8. Hourly pump flow rate.

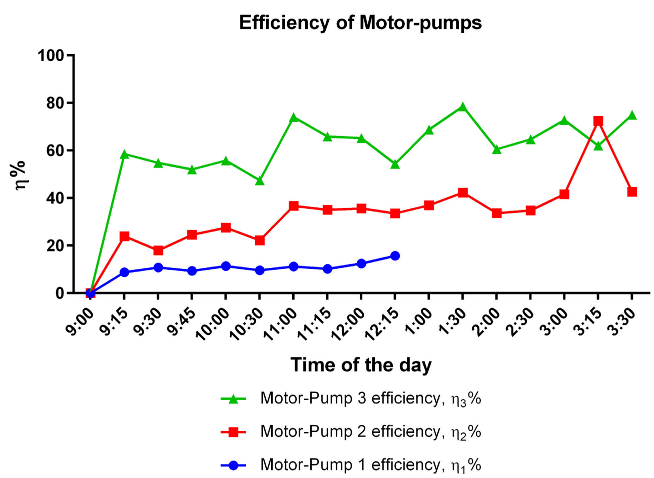

Fig. 9. Efficiency of the Motor-pumps.

VI. COST OF PV IRRIGATION PUMP SYSTEM

IDCOL (Infrastructure Development Company) Bangladesh and donor agencies give 40% of total cost as grant to encourage solar irrigation [8]. So, setting up a solar irrigation system would cost less than the costing shown here for this project. Table 3 shows the related cost for the set up in BDT and the total amount is 4, 05,000 BDT.

VII. CALCULATING SIMPLE PAYBACK PERIOD

To calculate simple payback period we need to know the cost of irrigation per area of land to calculate yearly cash inflow of the project. The irrigation cost per hectare of different areas of Bangladesh is given in Table 4 [9].

From the above Table 4, we have calculated average cost of irrigation per hectare of land. In Table 5, we have shown the yearly total amount of irrigated land by the project and total cash inflow of the project. Now we have calculated the payback period as follows:

$Simple\ payback\ period = (Initial\ Investement)/(Yearly\ Cash\ inflow) = (4,05,000(BDT))/(29,760(BDT/year)) = 13.6 years$

It is worth mentioning here that the solar panels usually have a lifetime of 30 years and the pumps can operate 20 years with little maintenance easily. So the project has a positive cash flow in its lifetime.

VIII. Results & Conclusion

The performance of the motor-pump system is illustrated in fig. 6-9 and we have also calculated the simple payback period which is only 13.6 years without any grant from government or donor agency. So project is lucrative in technical point of view as well as in economical point of view. Excees electricity produced during non-irrigating seasons can be used in Solar Home Systems or to drive other farming load. Also the advantage of the solar power is that it is non-polluting. The GHG emission of diesel is very high. The emission can be reduced by implementing solar powered pump as it emits no GHG. So the environmental benefit is also very high.

Acknowledgment

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Design of Blades for a Low-Speed 400W Wind Turbine Suitable for Coastal Area of Bangladesh

Mahtab Murshed[1], Md. Yeasin Arafat[2], M. Abdur Razzak[3]
Department of Electrical and Electronic Engineering
Independent University, Bangladesh
Plot-16, Block-B, Bashundhara, Dhaka-1230, Bangladesh

E-mail: [1]Mahtab_murshed@hotmail.com, [2]nealmagik@gmail.com, [3]razzak@iub.edu.bd

Abstract—**Implementation of wind turbines has been increased significantly because of its availability, easy and low cost generation around the world. Meanwhile in Bangladesh wind energy conversion is a very recent concept compared to other renewable energy conversion techniques and yet in many places research is going on to measure and analysis the wind velocity. The primary target of this research is to determine the wind prospects of Teknaf coastal area in Bangladesh by developing a statistical analysis of wind velocity at that region and to propose the design of blades for a low-speed wind turbine using theoretical analysis of power availability and wind velocity at different heights. The design approach can be applied successfully to develop a low-speed wind turbine's pole and blade construction.**

Keywords—Wind Turbine; Bangladesh; Teknaf Coastal area; Blade design; Wind power

I. Introduction

The proper utilization of energy indicates the proper social development along with the country's economic growth. According to the global energy report, the major portion of the world's energy requirement has been supplied by renewable energy sources. The conventional non-renewable energy sources and conversion techniques are causing serious negative impacts on our environment such as global warming, acid rain, ozone layer depletion etc. In order to develop a clean energy source there is no alternate of renewable energy because renewable energy sources are very clean, environment friendly and free. Wind energy plays one of the vital roles among the renewable energy sources. Wind energy is been used earlier for many centuries to propel ships, pump water, irrigations, windmills etc. In order to generate electricity from the kinetic energy of wind requires a minimum average wind speed of 6 m/s. In Bangladesh the average wind velocity is very low (Less than 2.5m/s) to develop large scale wind turbines. Generation of electricity using the wind turbines is a newer technology in the country compared to other usage of the energy mainly because of the low-speed wind turbine holds less possibility for commercial usage. However, various researches have been performed and many of them are currently under process to analyze the wind characteristics of the coastal areas in Bangladesh [1-3]. Most of them concluded with a state that Bangladesh has fairly wind energy potential at Coastal areas and some hilly areas [1].

A small, low-speed and off grid wind turbine can be a great energy solution for the people of remote coastal areas in Bangladesh targeting wind turbines driven pumps for drinking water and irrigation, industries along the bay of Bengal coastline likeice making, shrimp/fish farming, fish processing and salt production industries, hatcheries etc., Many industries in those areas are off grid, currently using diesel generators. Although the development of small off grid wind turbine at that region is also quite low due to some limitations such as lack of sufficient and reliable data, lack of interest by the government and non-government organization due to the lower efficiency because of low wind speed [1, 2].

With those in mind, the preliminary aim of this research is set to determine the wind prospects of Teknaf coastal area in Bangladesh by developing a statistical analysis of wind velocity at that region at different heights above the ground, theoretical analysis of wind power availability and finally, the design of blades for a 400W low-speed wind turbine has been performed using Qblade software, an open source blade designing software by Hermann Föttinger Institute of TU Berlin. The design approach can be applied successfully to develop a low-speed wind turbine's pole and blade construction, which is suitable for the coastal areas of Bangladesh.

II. Wind Prospects in Bangladesh

The geographical location of Bangladesh is in the latitude between 20°34'- 26°38'N and the longitude between 88°01-92°4E. There are many hilly and coastal areas of Bangladesh which have potentials for small scale wind energy generation as shown in Fig.1 The southern part of the country has a 724 km long V-shaped coastal line along with more than 200 km long hilly coastline areas and more than 50 islands situated in the Bay of Bengal, where strong wind flows during the monsoon period [2]. In the coastal area of Bangladesh, the annual average wind velocity at 30m height is been recorded as more than 5 m/s, which holds tremendous amount of energy [3]. Wind velocity in some north-eastern parts in Bangladesh recorded more than 4.5 m/s [3, 4]. The wind velocity gets significantly enhanced when it enters the coastal line of the southern part of the country. Studies done by local government engineering department, meteorological department, and Bangladesh University of Engineering and Technology indicates the wind velocity for power generation in Bangladesh

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is available during the pre-monsoon to post monsoon season (from March to October) and the windy months with maximum wind velocities are pointed as June-August. Various coastal areas of the country such as Teknaf, Kutubdia and Cox's Bazar (as shown in Fig.1) have immense potential of wind energy to generate electricity. One year data from the research performed by Bangladesh Centre for Advanced Studies shows that at 50 meter height in these areas the wind speed varies from 4.1 to 5.8 m/s with a power density of 100-250W/m^2 [6]. Teknaf is a sub-district of Cox's Bazar district located at 20.8667°N 92.3000°E, as shown in Fig.1, where the average wind velocity recorded as 2.16m/s at 5m at the reference height [1, 7].

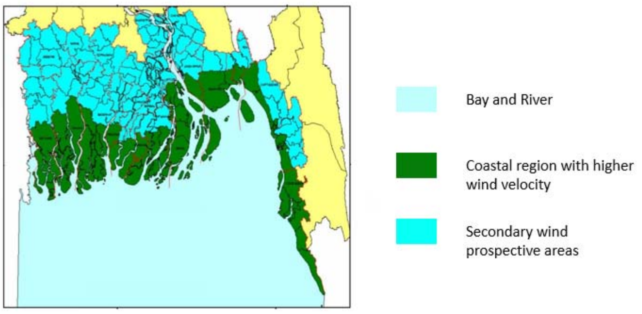

Fig. 1. Coastal areas of Bangladesh

III. 400W Wind Turbine for Teknaf Coastal Area

A. *Wind Data*

The primary objective for studying the wind data is to analyze the maximum, minimum and the average wind velocity in Teknaf coastal region of Bangladesh during the pre-monsoon to post-monsoon period, as previous studies described the effective wind velocity for power conversion recorded at that region were only during the monsoon period [1, 7, 8]. Wind data of Teknaf coastal area in Bangladesh from March to October have been considered. The wind data have been measured using an anemometer at 10feet (3.048m) above the ground for this research work as depicted in Fig.2.

From the analysis of the average wind velocity of the region at 3.048m above the ground we get a maximum wind velocity of 3.5m/s and the average of wind velocity of the effective time period (from March to October) is measured as 3.2m/s which holds a below-average wind prospect in this region.

B. *Height Calculation for a Low-Speed Wind Turbine*

The wind velocity, v at reference point, can be calculated by using wind power law [9, 10] as,

$$\mathrm{v} = v_0 \left(\frac{h}{h_0}\right)^{\alpha} \qquad (1)$$

where, v_0= wind velocity, h = measured height and h_0= reference height. The coefficient α varies depending on the stability of the atmosphere. For a stable atmosphere like coastal areas it remains as $\alpha = \frac{1}{7} = 0.143$. A theoretical wind velocity calculated for different height above the ground using eq.(1) are listed in Table I. The wind velocity for the wind power system at the proposed height of 20m is found to be,

$$\mathrm{v} = v_0 \left(\frac{h}{h_0}\right)^{\alpha} = 3.2375 \left(\frac{20}{3.05}\right)^{0.143} = 4.24 ms^{-1}.$$

Table I. Measured height vs. wind velocity

Height from ground (m)	Wind Velocity (ms^{-1})
3.04	3.234
6.09	3.5709
9.14	3.7841
12.19	3.943
15.24	4.0709
18.28	4.1784
21.33	4.2715

C. *Air Density*

The air density at different temperature is shown in Table II [11]. The average temperature (°C) at Teknaf coastal areas is about 30°C at which the average air density is found to be 1.164kg/m^3.

Table II. Air density

Temperature(°C)	Air Density (Kg/m^3)
35	1.145
30	1.164
25	1.183
20	1.204
15	1.225
10	1.246
5	1.269
0	1.292
-5	1.316

D. *Maximum Available Power Calculation*

According to the Betz Law a wind turbine cannot convert more than 59.3% of the kinetic energy of the wind into mechanical energy turning a rotor. The value of Betz's coefficient, C_p determines the maximum available output power [8] given by

$$P_{available} = \frac{1}{2}\rho A v^3 C_P \qquad (2)$$

where $A(=\pi r^2)$is the swept area of the rotor blade and C_p(=0.59) is the Betz limit. Now consider the desired output power of the turbine as $P_{available} = 400W$, pole height = 20m, number of blades = 3, blade's radius, r = 2.5m, and blade area, $A = \pi r^2 = 19.63\text{m}^2$. For the wind speed, v = 4.24m/s (calculated in section III.B), air density, ρ =1.164kg/m^3 (found from Table II), blade radius, r = 2.5m, and Betz limit, C_p=0.59, the maximum theoretical available power for a 400W (desired output power) wind turbine can be calculated using eq. (2) as

$$P_{available} = \frac{1}{2}\rho A v^3 C_P = \frac{1}{2} \times 1.164 \times 19.63 \times 4.24^3 \times 0.59$$
$$\approx 514W \text{ (theoretical)}$$

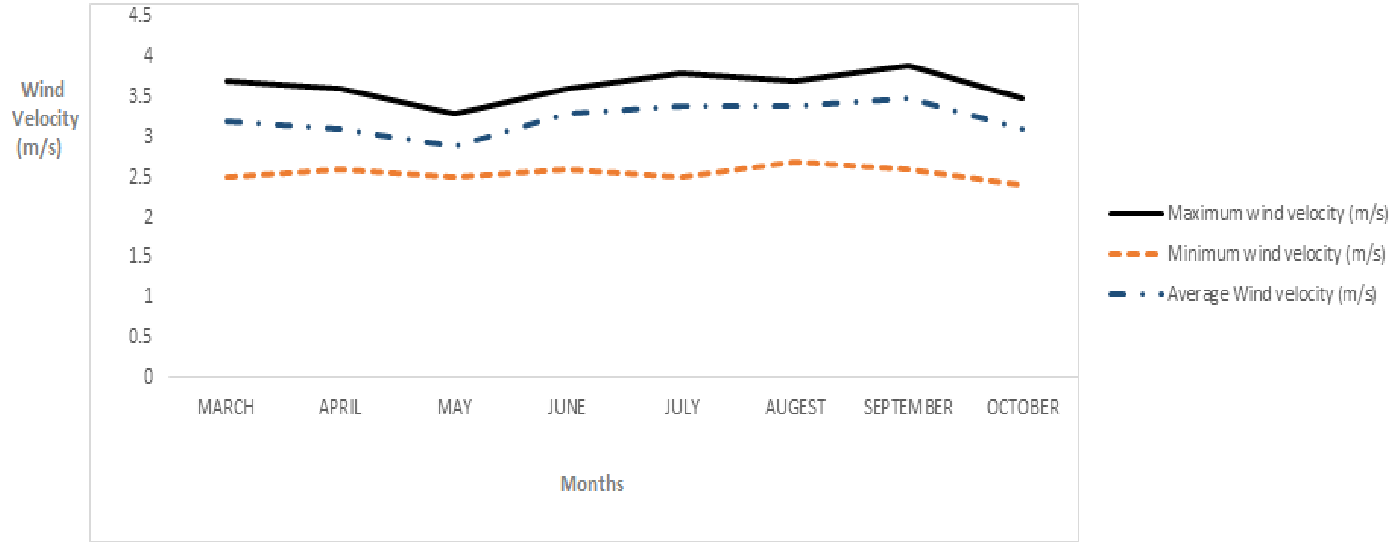

Fig. 2. Measured wind velocity curve during the pre-monsoon to post-monsoon period in the Teknaf coastal area in Bangladesh

Fig. 3. Root Foil (Circular) NACA 23012, Root Foil NACA 0018, Tip Foil NACA 23012 selection

IV. Design of Blades for a 400W Wind Turbine

A. *Calculation of Blade Radius*

Considering the pole height = 20m, number of blades = 3, wind speed = 4.24 m/s, input power = 520W, Betz limit, C_p = 0.40, the blade radius, *r* can be determined using eq.(2) as

$$r = \sqrt{\frac{2P_{available}}{\rho v^3 C p \pi}} \approx 3\text{m}$$

B. *Calculation of Power Extraction Effeciency*

Considering the extracted power by blades=400W and the available power calculated for the swept area by blades ≈ 514W. Power extraction efficiency by blades can be determined as

$$Efficiency = \frac{Extracted\ power}{Maximum\ input\ power} \times 100\% \approx 77\%$$

C. *Foil Selection*

Research shows that NACA 23012 is the most durable, shapeable air foil for low-speed horizontal axis wind turbine (HAWT), which has been selected as the tip foil for the research, on the other hand NACA 0018 air foil is one of the efficient considering its commercial availability and durability which has been selected as the root foil for this research [12, 13]. The air foil selection with the measurements is shown in Fig. 3. The core analysis of root foil NACA 23012, tip foil NACA 0018 is shown in Figs. 4 and 5, where,*D*= drag, *L*= lift; α = incidence angle, C_l = lift coefficient, C_d = drag coefficient, C_m= pitching moment coefficient.

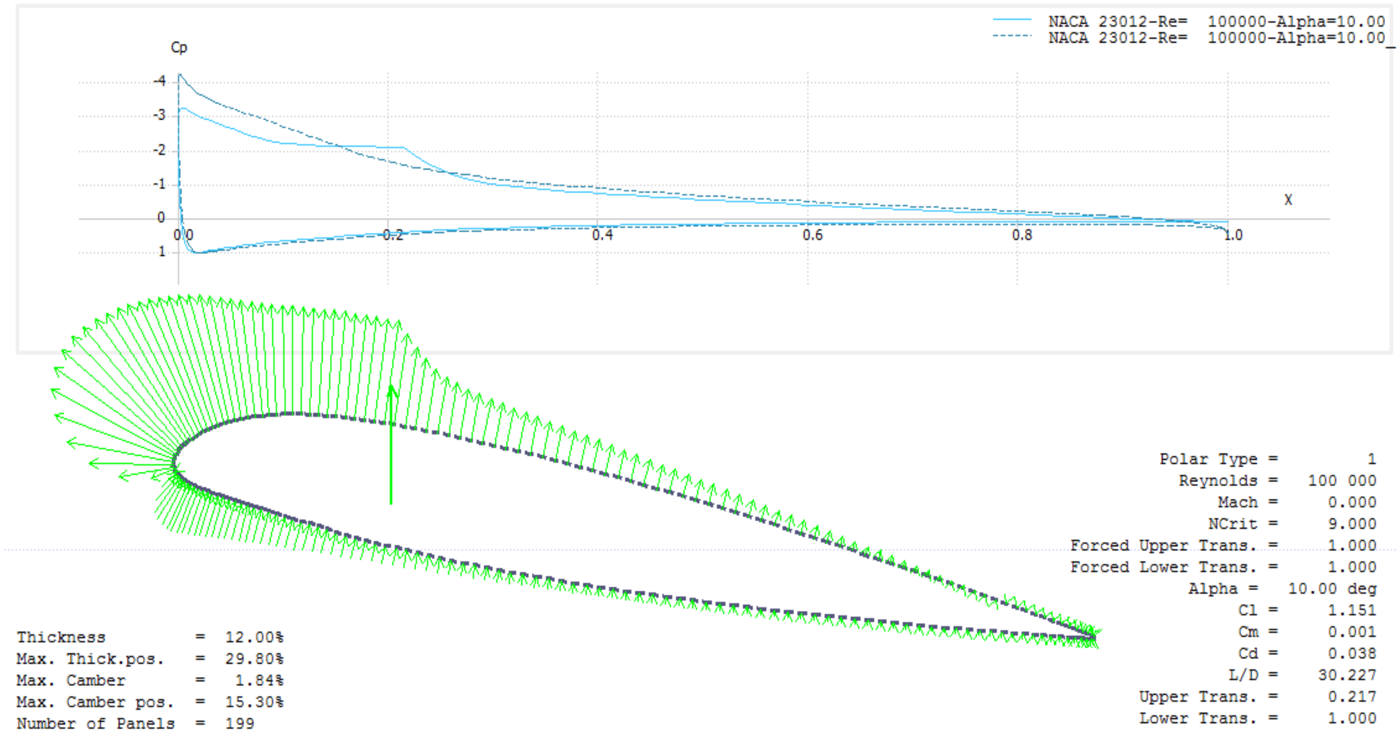

Fig. 4. Tip foilNACA 23012 core analysis (Operational point view)

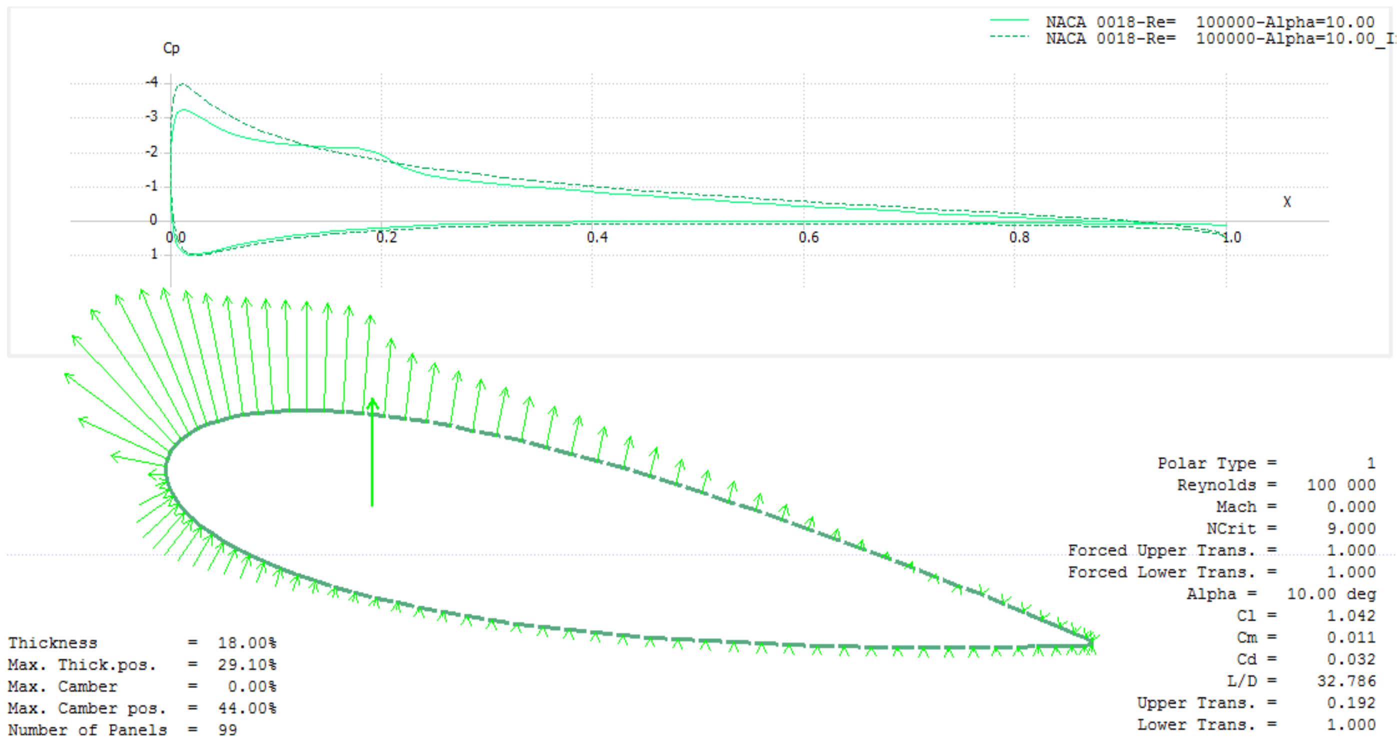

Fig. 5. Root foilNACA 0018 core analysis (Operational point view)

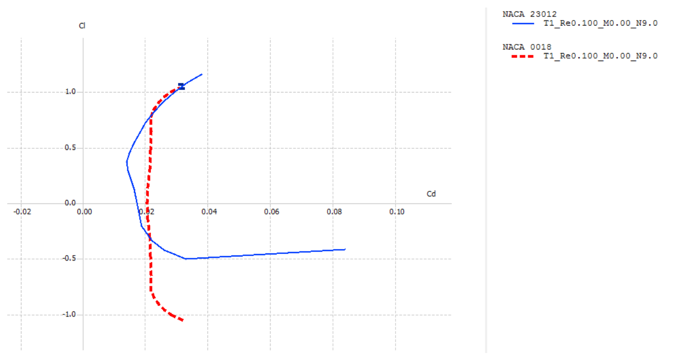

Fig 6. Tip foilNACA 23012 and root foil NACA 0018 analysis (Lift coefficient, C_l vs. drag coefficient, C_d)

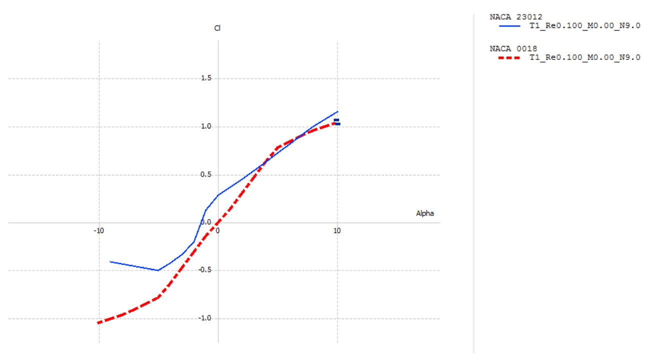

Fig. 7. Tip foil NACA 23012 and root foil NACA 0018 (Lift coefficient, C_l vs. Pitching moment coefficient, α)

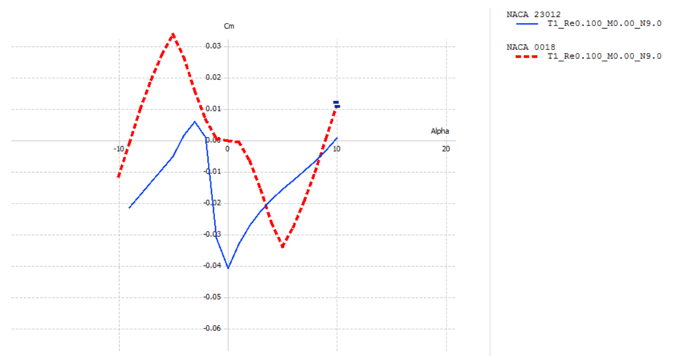

Fig. 8. Tip foil NACA 23012 and root foil NACA 0018 (incidence angle, α ; vs. pitching moment coefficient, C_m)

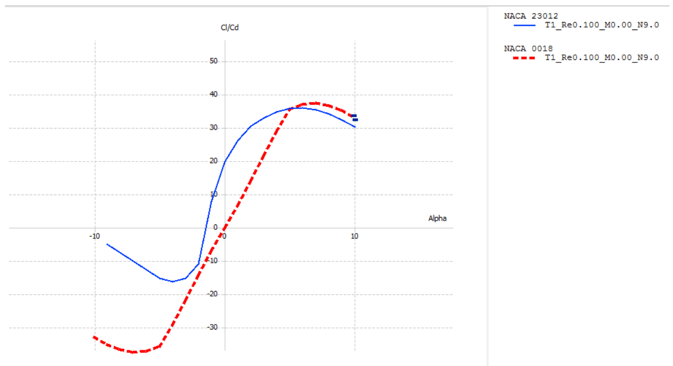

Fig. 9. Tip foil NACA 23012 and root foil NACA 0018 (Glide ratio C_l / C_d vs. Incidence angle, Alpha)

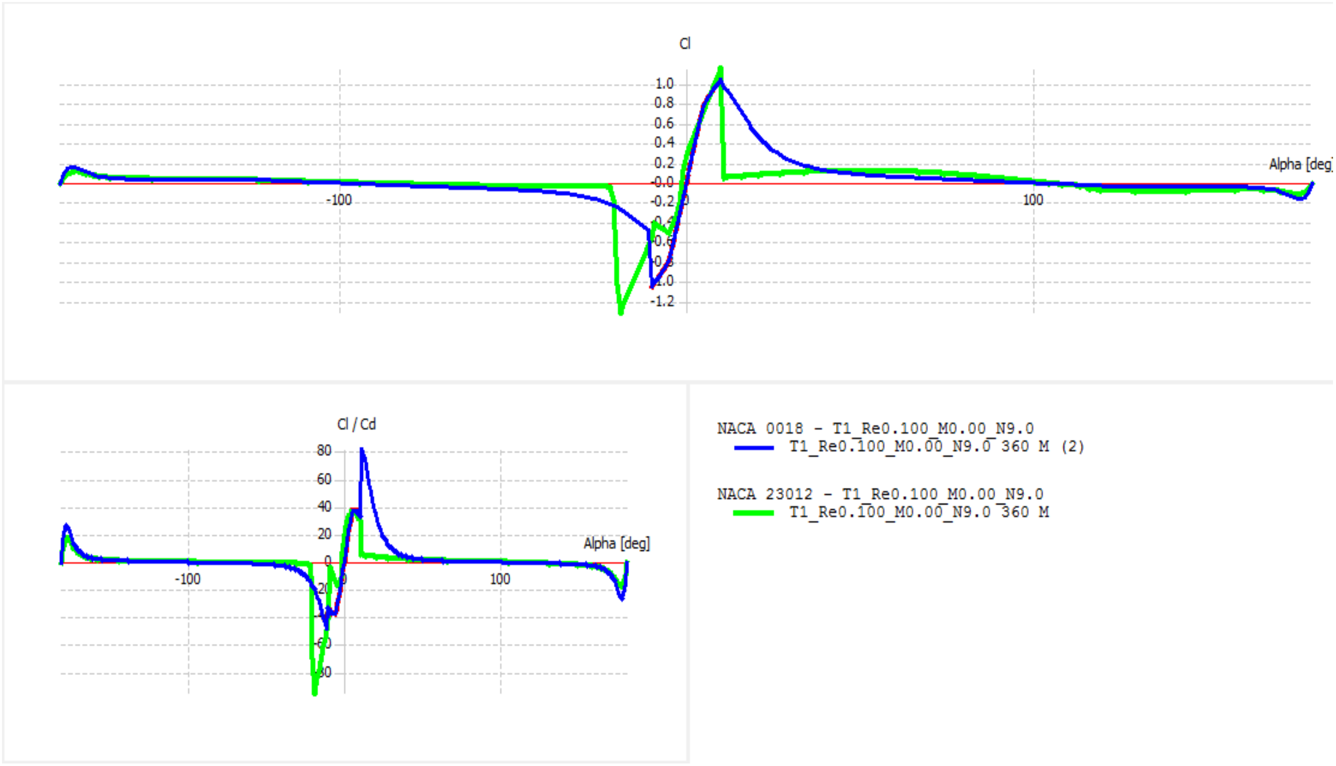

Fig. 6. Tip foilNACA 23012 and root foil NACA 0018 polar extrapolation

Airfoil simulation from the blade analysis is limited to a small inflow angles (taken from -10° to +10°) for this research work. But the blades of horizontal axis wind turbine operate in higher inflow angles. In order to converge and produce near accurate theoretical results it is necessary to extrapolate the airfoil performance in polar form for the wind flow. The polar extrapolation for tip foil NACA 23012 and root foil NACA 0018 is shown in Fig. 6, where, α =incidence angle, C_l= lift coefficient, C_d= drag coefficient, C_m= pitching moment coefficient.

In simulation, both the blade foils and the foil properties such as drags, lifts, incidence angles, lift coefficients, drag coefficient, pitching moment coefficients, have been analyzed to satisfy blade element momentum theorem BEM. Figs. 7-10 shows various blade properties for root foil NACA 0018 and tip foil NACA 23012, where, where, α =incidence angle, C_l= lift coefficient, C_d= drag coefficient, C_m= pitching moment coefficient. The designed blade for single view and rotor view with placement of foils at different section of blades are shown in Figs. 11 and 12, respectively, which can be considered for low-speed 400W wind turbine.

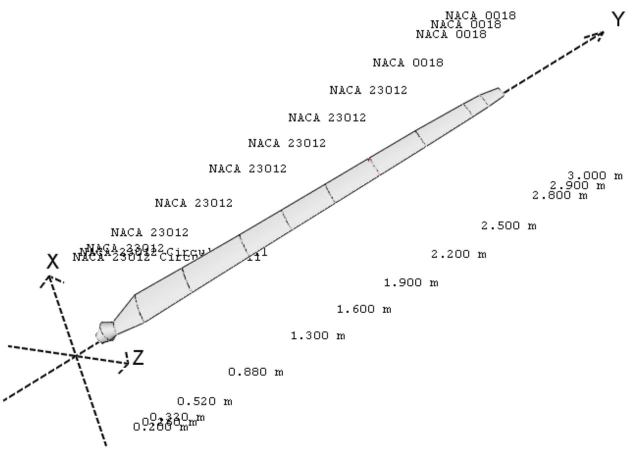

Fig. 11. Blade design (single blade view)

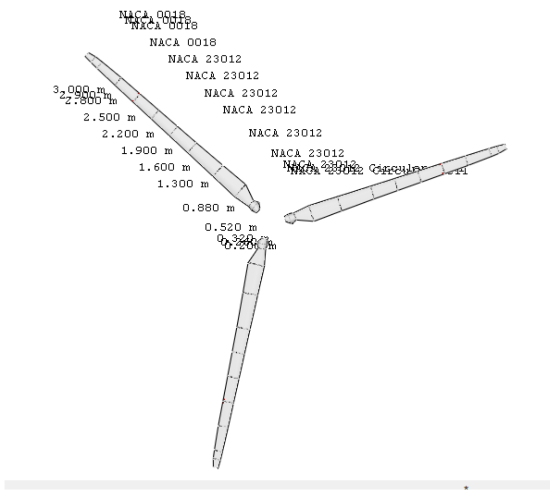

Fig. 12. Blade design (rotor view)

V. CONLUSION

In this research, the statistical wind velocities at different height above the ground in the Teknaf coastal areas of Bangladesh, the energy availability over the region, finding the height for a 400W wind turbine and the design of blades for the low-speed wind turbine has been studied. The wind velocity data of Teknaf coastal areas measured using anemometer shows a great prospect for wind power generation in the region for most of the time in a year. Considering the fact that with a good amount of energy available for low-speed wind turbines in the region, the blades of 3m (radius) for a low-speed 400W wind turbine is designed after selecting the air foils. This design approach can be helpful for developing a small scale low-speed wind turbine with the statistical analysis of wind velocity at Teknaf coastal area of Bangladesh.

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Empowering Remote Area of Bangladesh Using Pedal Generator

Alimul Haque Khan, Md. Moniruzzaman, Md. Muhibbullah
Mehedi Hasan & Niaz Morshed
Electrical & Electronic Engineering
Bangladesh University
Dhaka-1207, Bangladesh.
Email: alimul_buet@yahoo.com

***Abstract*—Now-a-days, Bangladesh is facing a problem with shortage of natural resources especially in gas sector.A large number of population in Bangladesh do not have the facilities of electricity. Besides that the people of remote area are normally far from modern facilities such education, health, online services etc. In general, they use kerosene as fuel for lighting purpose and it is hard for them to access modern technologies such as mobile, computer, internet, e-health. Pedal generator, a flywheel driven by human and coupled with an electric generator. may be an alternative solution in these situations. The efficiency and the performance was good. It can be operated in a standalone mode or may be used with PV module as a hybrid system. Though, the research has been done with respect to Bangladesh, this can be applicable everywhere. This will provide an easy, cheap, handy and pollution free source of energy by means of pedal generator.**

***Keywords*—pedal Generator, rotational energy, secondary energy.**

I. Introduction

Electricity is a secondary type of energy. Primary energy is defines as the energy that is available enough in nature such as energy is reserved in gas, coal etc as comical energy. On the other hand secondary energy is the energy that is derived from primary energy such as electricity can be derived from gas by means of mechanical rotation or from light by means of Photo Voltaic panel. Human power is basically as old as mankind. As long as people are used their muscles to pick up, carry and handle things. Human began making small tools which are the first examples of Human powered products. The first human powered product to convert human work into electricity was the Philips dynamo torch [1]. The pedal power [2] transfers the energy from a human source through the use of a foot pedal and crank system. This technology is most commonly used for transportation [3]and has been used to propel bicycles [4], [5] for over a hundred years. Less commonly pedal power is used to power agricultural citedavid and hand tools [6] and even to generate electricity [7], [8]. Some applications include pedal powered mobiles [9], pedal powered grinders [10]and pedal powered water wells [11].

Most of the power plant in Bangladesh uses gas as fuels. Few of the power plants are High Speed Diesel (HSD) based and few are renewable energy based. However, only around 40% of people in Bangladesh have the facilities of electricity. Rest of the population does not have electricity. Besides that the people of remote area are normally far from modern facilities such education, health, online services etc. Normally they use kerosene as fuel for lighting purpose and it is hard for them to access modern technologies such as mobile, computer, internet, e-health. Somewhere people use Solar Photo Voltaic (PV) module to meet the purpose. However, it is quite costly and some times and somewhere sunlight is not available and has some bad effect on environment due to cutting long trees. Pedal generator may be an alternative solution in these situations. We have shown in this research works that the pedal system power generation is suitable for the remote area of Bangladesh. It can be operate in a standalone mode or may be used with PV module as a hybrid system. Specific objective of this research project is to have an easy, cheap, and handy and pollution free source of energy by means of pedal generator.

II. Energy and Efficiency

Electricity can be generated by several types of converter with single or multi-stage conversion. Most common type of generation is obtained from mechanical energy. Mechanical energy is also some times, secondary types of energy. The rotational energy or angular kinetic energy is the kinetic energy due to the rotation of an object and is part of its total kinetic energy [12]. Rotational energy of any object around an object's axis of rotation me be represent as:

$$E_r = \frac{1}{2} \times I\omega^2 \tag{1}$$

Where, ω is the angular velocity, I is the moment of inertia around the axis of rotation, E_r is the kinetic energy.

The mechanical work required for / applied during rotation is the torque times the rotation angle. The instantaneous power of an angular accelerating body is the torque times the angular velocity. For free-floating (unattached) objects, the axis of rotation is commonly around its center of mass. The close relationship between the result for rotational energy and the energy held by linear [12] (or translational) motion:

$$E_t = \frac{1}{2} \times mv^2 \tag{2}$$

The electric energy is defined as the total work done or energy supplied by the source of e.m.f. in maintaining the current in an electric circuit for a given time [13]:

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$$Electric\ Energy = electric\ power \times time = Pt \quad (3)$$

$$Electric\ Power = Voltage \times Current = Vi \quad (4)$$

Thus the formula for electric energy is given by:

$$Electric\ Energy = P \times t = V \times i \times t$$
$$= i^2 \times R \times t = \frac{V^2 t}{R} \quad (5)$$

The S.I. unit of electric energy is joule (denoted by J) where,

$$1joule = 1watt \times 1second = 1volt \times 1ampere \times 1second$$

The commercial unit of electric energy is kilowatt-hour (kWh) where,

$$1kWh = 1000Wh = 3.6 \times 10^6 J$$
$$= One\ unit\ of\ electricity\ consumed.$$

The number of units of electricity consumed is

$$n = \frac{total\ wattage \times time\ in\ hour}{1000}$$

The cost of electricity consumption in a house

$$= No.\ of\ units\ consumed \times per\ unit\ cost\ of\ electricity.$$

In electricity generation, an electric generator is a device that converts mechanical energy to electrical energy [14]. A generator forces electric current to flow through an external circuit. The source of mechanical energy may be a reciprocating or turbine steam engine, water falling through a turbine or waterwheel, an internal combustion engine, a wind turbine, a hand crank, compressed air, or any other source of mechanical energy. Generators provide nearly all of the power for grids. The reverse conversion of electrical energy into mechanical energy is done by an electric motor, and motors and generators have many similarities. Many motors can be mechanically driven to generate electricity and frequently make acceptable generators [14].

Mechanical efficiency measures the effectiveness of a machine in transforming the energy and power that is input to the device into an output force and movement. Efficiency is measured as a ratio of the measured performance to the performance of an ideal machine.

$$Efficiency = \frac{Measured\ Preformance}{Ideal\ Performance}$$

The flywheel produces electric power by losing its rotational energy. The losing energy is mainly supplied by the paddler. The power of the paddler could be measured by the energy equation of the fly wheel every second. Although, the unit of flywheel energy is $Joule$, the power of the paddler is calculated from the energy supplied to the flywheel every second by the paddler.

$$Efficiency, \eta = \frac{Vi\ Watt}{\frac{1}{2} I \omega^2\ Joule/sec} \quad (6)$$

III. Pedal Power Generator

The pedal power generator consists of an iron frame. The pedal is mounted securely to this frame and the rear tire position to turn that has been custom fit over the generator shaft. The amount of electrical power that can be generated by the pedal power generator is determined by the energy available from pedaling. The stronger the user, the higher the production of electrical power. It is not essential but wonderful is that the pedal power generator output may be directly connected with a load such as water pump, light and 12V battery for charging etc.

A. Structure For Energy Conversion

It has 2.5 feet of iron (1.5 inches angle structure) and 20 inches shaft made by iron stick and fixed with each other as fall a general frame. After that, shaft are re-size from work shop and attached with 2 pieces bearing and balance wheel and 14 inches pulley (around the flywheel) fixed with shaft. A gear box attached is on the right side of pedal frame and a stand is attached with the gearbox. Then 2 inches pulley attached with alternator shaft. Now pedal machine pulley and alternator pulley attached by 88 inch belt. Then the pedal generator is installing by done pedaling and fixed load box from alternator output.

Regular rpm of the generator is about 1800. The generator was aimed to have a rated rpm of 1800 for production of electricity having 50 Hz line frequency. However, a generator of 3000 rpm was used. Both AC and DC generator has been coupled with the structure an the performance has been checked. These are shown in Fig. 2 and Fig. 1.

Fig. 1: Complete setup of the Pedal Generator system with DC generator, Storage and Light bulb

B. Debug And Finalize Of The Design

Several types of structure have been thought such as the pedal based knife sharpener, pedal based paddy separator machine, the oil extractor pulled by animal. Finally a similar structure close to the paddy separator machine is chosen as more acceptable. Then paddy separator machine was build in work shop. However, most of them were professional and they need exact design. Before finalizing the complete design, the process went through a lot of trial and error method. It was done in a remote area of Pabna, a district of Bangladesh where cost was lower and it was easier to be involved in the

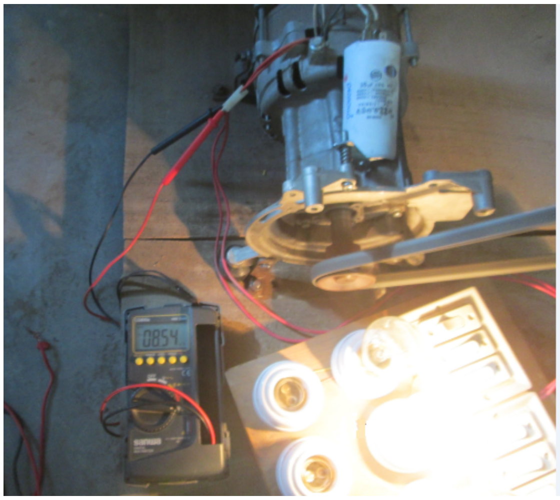

Fig. 2: Complete setup of the Pedal Generator system with AC generator and light bulb running directly

workshop. Then it was carried to Dhaka city. This structure was modified for several times. Major portion of the expense was in this field.

C. Generator Coupling

The coupling generator with the prime mover was another challenge. The structure was finally fitted on a wooden board. Necessary equipment for the project has been revised, the most needed equipment were an AC generator at least of 600 W, a 2 feet x 4.5 feet wooden board and some types of ranches. The necessary materials were collected from different places in Dhaka within two or three weeks. The AC generator was an one horse power with two stroke petrol engine. The petrol engine and the generator were separated with care. Then it was brought to a workshop at Gabtoli, Dhaka to attach the shaft with pulley and it was done. Next step was to send it to a workshop to set up the generator and iron structure (modified paddy separator) to wooden board. This machine and generator were connected to strong bolt with the wooden board.

D. Producing Electricity

The most challenging part was to generate electricity. Several markets and workshop were searched to manage a suitable generator as per the design. A generator was chosen with 3000 rpm whereas the design was 1800 rpm. The rpm varied 1000 to 2100 which mainly depends on the man working behind the pedal, whereas, the speed of the prime mover was around 180 rpm to 385 rpm. Two person, pedaling continuously, were able to keep the rpm just over 1800. Several design was tried to increase the rpm of the structure by changing the size of pulleys. For an rpm of 1800 of the generator pulley, the the rotation of the fly wheel was 330 rpm. All of the calculations shown here are based on a generator speed of 1800 rpm and prime mover speed of 330 rpm. However, the rpm used to change rapidly. At the lower rpm the output was not enough to provide electricity to a small bulb. Finally capacitor and other internal structure were changed. Thus, the produced electricity was enough to lighten up a 200W AC bulb with a 100W and a 60W bulb more. However, voltage was very low. A capacitor with higher value was also tested. It was quite better. This same experiment was also done by a DC generator and its experience is better than AC generator. In both cases, charged battery and UPS was connected to the system to run computer and other equipment.

IV. Calculation Of Prime Mover Design

The pedal generator is installing by done pedaling and fixed load box from alternator output. The summary of the calculation is provided bellow.

Here,

$\rho = 6.98\ gcm^{-3} = 6.98 \times 10^3\ kgm^{-3}$

$r_1 = 1.5\ cm = 0.015\ m$

$r_2 = 15.25\ cm = 0.1525\ m$

$r_3 = 17.5\ cm = 0.175\ m$

$r_4 = 11.5\ cm = 0.115\ m$

$r_5 = 3.75\ cm = 0.0375\ m$

$t_1 = 49\ cm = 0.49\ m$

$t_2 = 1.75\ cm = 0.175\ m$

$t_3 = 5\ cm = 0.05\ m$

A. Determination of Moment of Inertia

All the dimensions mentioned above are shown in Fig. 3 to Fig. 7. These Figures contain a common straight line (having sloop around 35^0 which is the axis of rotation for each measurement. The radius of the pulley which was connected with the generator is (not shown in the illustration).

$r_{generatorpulley} = 3.2\ cm = 0.032\ m$

Figure 3 is showing calculation of I_1 can be found by

$I_1 = \frac{1}{2} t_1 \rho \pi {r_1}^4$

$I_1 = 2.7198 \times 10^{-4} kgm^2$

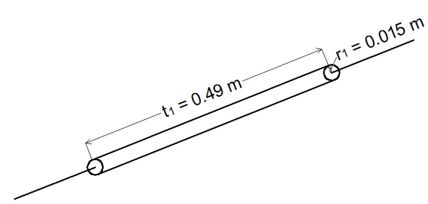

Fig. 3: Illustration for calculation of I_1

Figure 4 is showing calculation of I_2 can be found by

$I_2 = \frac{1}{2} \times \rho\pi \times t_2({r_2}^4 - {r_1}^4)$

$= \frac{1}{2} \times 6.98 \times 10^3 \times 3.1416 \times 0.175 \times (5.4085 \times 10^{-4} - 5.0625 \times 10^{-8})$

$= 0.1037653\ kgm^2$

Figure 5 is showing calculation of I_3 can be found by

$I_3 = \frac{1}{2} \times \rho\pi \times t_3({r_3}^4 - {r_2}^4)$

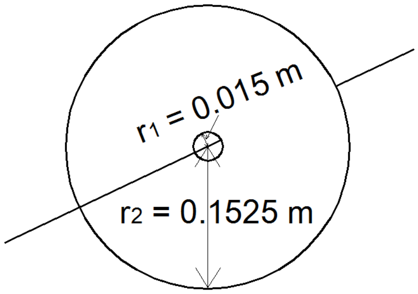

Fig. 4: Illustration for calculation of I_2

$= \frac{1}{2}6.98 \times 10^3 \times 3.1416 \times 0.05 \times (9.3789 \times 10^{-4} - 5.4085 \times 10^{-4})$

$= 0.2176591\ kgm^2$

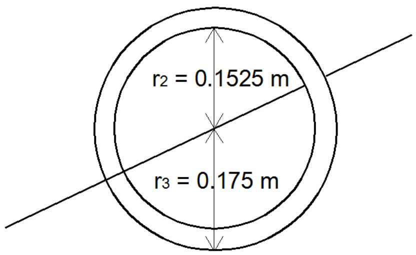

Fig. 5: Illustration for calculation of I_3

Figure 6 is showing calculation of I_4 can be found by

$I_4 = 3 \times (\rho \pi {r_5}^2 \times t_2 {r_4}^2 + \frac{1}{2} \rho \pi {r_5}^4 \times t_2)$

$= 3(6.98 \times 10^3 \times \pi \times 1.406 \times 10^{-3} \times 0.175 \times 0.01322) + (\frac{1}{2} \times 6.98 \times 10^3 \times \pi \times 1.9775 \times 10^{-6} \times 0.175)$

$= 0.0225486\ kgm^2$

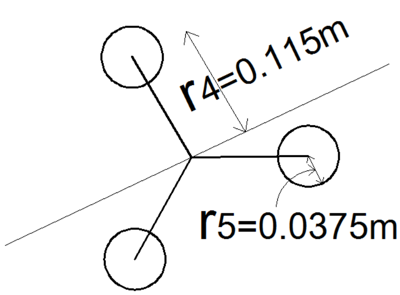

Fig. 6: Illustration calculation of I_4

Figure 7 is showing calculation of I can be found by

$I = I_1 + I_2 + I_3 - I_4 = 0.2991477\ kgm^2$

B. The Angular Velocity and the Kinetic Energy

The angular velocity ω is found as

$\omega = 2\pi \frac{rpm}{60}\ rad/sec$

$\omega = 2\pi \frac{330}{60}\ rad/sec = 34.5575\ rad/sec$

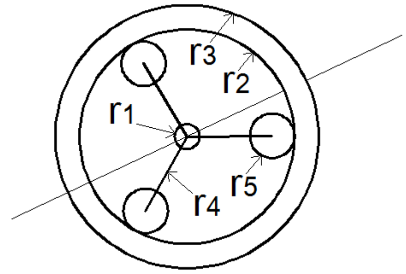

Fig. 7: Illustration for calculation of I

Now, $E_k = \frac{1}{2} I \omega^2$

$= \frac{1}{2} \times 0.2991477 \times 34.5575^2 = 178.62442\ Joule$

C. Efficiency

Output of the system is varied rapidly as the speed was changing quickly. However, the measurement was taken when the speed of the prime mover was around 330 rpm. The voltage and current with a load of 360 W (1 x 200W + 1 x 100W +1 x 60W) tungsten light bulb varied around 118 Volt and 854 mili Ampere. The output power thus, was measured to be around 100 W. It is true that the output fluctuated very much and thus only approximate measurement of voltage, current and speed was possible. Hence, the efficiency could be measured by equation 6.

$Efficiency, \eta = \frac{100\ Watt}{178\ Joule/sec}$

$Efficiency, \eta = 56.18\%$

The losses were incorporated mainly with the huge friction at the bearings of the prime mover. The sound loss was also significant. Finally, the loss of the generator due to under frequency operation decreased the efficiency.

V. Conclusions

This is a useful machine at places where many people gather and stay together (meetings, residential schools). It is easy to maintain and make. This project was extremely challenging, consuming huge amounts of time, energy and resources. However, the knowledge and experience obtained was tremendously valuable and has given confidence to work with more complicated electrical projects. The efficiency of the developed system is quite good. It would be more than the achieved value if the frictional loss of the rotary parts could be minimized. Installation of this machine in a remote area for where it was designed, is necessary to get field level data. This installation will also provide deep and clear information about the durability, reliability, feasibility, ease of use as well as farther modification of the system.

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Design and Analysis of an Outer Rotor Permanent Magnet Alternator for Low-Speed Wind Turbine

Md. Yeasin Arafat, Mahtab Murshed, M. Abdur Razzak
Department of Electrical and Electronic Engineering
Independent University, Bangladesh
Plot-16, Block-B, Aftabuddin Road, Bashundhara R/A, Dhaka-1229, Bangladesh
E-mails: nealmagik@gmail.com, mahtab_murshed@hotmail.com, razzak@iub.edu.bd

Abstract— **The outer rotor permanent magnet alternator (PMA) is superior for small wind turbine system due to its robust, little maintenance and low cost configuration. In this research, the design and performance analysis of a radial flux outer rotor type PMA used for gearless, extremely low-speed, and small capacity wind turbine system has been discussed. The design has been simulated to analyze this PMA. The elementary configuration like material types, magnet types and additional electrical and mechanical parameters are studied, and the performances parameters of PMA are improved by changing these elementary electrical and mechanical parameters or some other related factors such as reducing the cogging effect. Cogging torque has been reduced by employing fractional slot per pole, width of slot opening, mounting of the magnets. Also the slot shape has been custom-made to increase the efficiency. The slot fill factor was improved by using different wire diameter used as winding coil. This improvement has been played a great role to reduce copper losses thereby improving the thermal condition of the slot. Finite element analysis (FEA) method was used to analyze this PMA in order to test the real time performance simulation with loss and cogging torque calculation. By taking all these considerations into account, higher efficiency from the outer rotor arrangement with minimum losses has been achieved.**

Keywords—Outer rotor PMA; low-speed wind turbine system; finite elements analysis (FEA); cogging effect

I. INTRODUCTION

In recent time renewable based power system turn into more popular to minimize the pressure on conventional fossil fuel based power systems. One of the best attempt on this side is to apply small size solar system. This is very popular in recent trend. Wind based power system is another domain to increase the total percentage of renewable power generation.

Multiple pole permanent magnet alternator have become very attractive particularly for small ratings wind power system [1-3]. Small scale wind power system needed mechanically simple, stable, cost effective alternator design in order to become a dependable energy source. Instead of geared machines, the use of direct driven alternator are much popular, because it eliminates some quantity of drive components. This reduction of drive components offers the opportunity to cut prices and increases system efficiency and reliability [4].

For small-scale wind power plant Permanent magnet alternator (PMA) with multi pole is one of the best solution. Permanent magnet alternator with Low-speed multi-pole configuration are maintenance-free and used in several weather conditions. Also it has option to combine PM wind alternator for hybrid technologies like wind-diesel, wind-photovoltaic, etc. [5]. To transform wind energy into electric energy, numerous types of alternator concepts have been suggested and used [6]. The fundamental features of PMA structures are surface mounted permanent magnets with multi poles, fractional number of slots per pole, commercially used material for rotor and stator. Permanent magnet alternator has several advantages like high efficiency and reliability since the external excitations not needed. So conductor losses by external excitation are removed from the rotor [7, 8].

Recently most of the research are doing in this field on high speed PM machine (around 2000–4500 rpm) for hybrid electric vehicle (HEV) and low-speed PM machine (around 200–1500 rpm) for power generation specially wind power generation [9-13]. Also the Axial Flux PM machine is introduced for virtually zero cogging torque but has limited output power and voltage. That's why Radial Flux PMA with minimum cogging torque is still top of the research topic. Several researchers are introduced different types of method, algorithm and model to decrease the cogging torque and maximize the efficiency. But in extremely low-speed machine like 100 rpm the efficiency fall drastically, which is unexpected for a small scale power system. Also the percentage of cogging torque of the machine increases at low-speed due to higher interaction or line up among the rotor, permanent magnet and the stator slot. This torque produces noise and vibration while the machine is running. Arrangement of the magnetic field, slot opening and filling factor, number of slots per pole per phase, pole pitch and distribution of magnetic flux density are some of the main factors affecting the cogging torque [14].

Therefore, improving the cogging effect was one of the main goals to modify the design of this alternator. Different modification like fractional slot per pole, slot opening, customized slot shape, and modified winding coil wire diameter were applied to reduce this cogging torque to achieve the maximum efficiency at low-speed. All the losses like core loss, eddy current loss, frictional loss, and copper loss were taken into account for better analysis. The material uses in this alternator like steel material and magnetic material both are commonly used in commercial level to develop an efficient PMA. NdFeB type rare earth magnet were used for higher energy density.

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The outer-rotor type of machine is mostly popular in low-speed application like low-speed wind or hydro power generation system. In this research, a gearless, low-speed external rotor radial flux alternator model with permanent magnet excitation has been studied, and the electromagnetic field in air gap with improved cogging effect and maximum efficiency has been examined. The design equations are taken into consideration based on finite element analysis (FEA) and verified by ANSOFT Maxwell RMXPRT and ANSOFT Maxwell 2D.

II. MATHEMATICAL EXPRESSION

A. Basic Equation

From the basic equation of the rotating machine, frequency can be determined by fixing the number of poles and rated speed as [15],

$$N = \frac{120 \times f}{P} \tag{1}$$

where N = rated speed, P = pole number and f = frequency.

Also to produce greater energy a bigger magnetic field is essential for a given number of poles shown as [15]

$$\phi_g = B_{av} \times \left(\frac{\pi \times D \times L}{P}\right) \tag{2}$$

where ϕ_g = magnetic flux, B_{av} = average flux density, D = stator inner diameter, L = length of stator.

B. Cogging Torque

Permanent magnet alternator can easily be modeled by a permanent magnet and an exciting coil. The equivalent magnetic circuit equation of a permanent magnet and exciting coil, is given by [16],

$$W_c = \frac{1}{2} \times L \times i^2 + \frac{1}{2} \times (\Re + \Re_m) \times \phi_m^2 + N \times i \times \phi_m \tag{3}$$

where $\Re$ and $\Re_m$ are the reluctances seen by the magneto motive force and the magnetic field respectively; and ϕ_m= magnetic flux of the magnet linking the exciting coil. The first term correspond to the co-energies of the self-inductances, second term related to the permanent magnet, and the third term correspond the mutual flux [17]. Differentiating the total co-energy, W_c which is equal to magnetic field energy, W with respect to mechanical angle or rotor angular displacement θ, the electromagnetic torque T can be found as [16],

$$T = \frac{\partial W_c}{\partial \theta} \tag{4}$$

where i = exciting current = constant.

By substituting (3) into (4), the torque can then be calculated as

$$T = \frac{1}{2} \times i^2 \times \frac{dL}{d\theta} - \frac{1}{2} \times \phi_m^2 \times \frac{d\Re}{d\theta} + N \times i \times \frac{d\phi_m}{d\theta} \tag{5}$$

The second term in (5) is not a function of the polarity of the flux and proportional to the square of the magnetic flux, while the negative sign represents the inversely proportional relation between inductance and reluctance. Meanwhile the coil inductance is fixed, and independent of the rotor angular displacement, θ in case of lacking any exciting current, i = 0, simply the second term will be present in (5). Therefore cogging torque can be evaluate by aiming on the magnetic interaction as well as the reluctance variation between the exciting coil and magnet, which yields,

$$T_{cogg} = -\frac{1}{2} \times \phi_g^2 \times \frac{d\Re}{d\theta} \tag{6}$$

From (6) the cogging torque can be determined by variation of reluctance in the magnetic circuit with the rotor angular displacement and the magnetic flux ϕ_g=ϕ_m. It shows that, cogging torque appears when the magnetic flux travels through a changeable reluctance.

III. COGGING TORQUE MINIMIZATION

Cogging torque or cogging effect is expected in PMA but not desirable which is a periodic alternation torque, occurred due to interaction between permanent magnets of the rotor and slotted iron structure. The consequence of cogging torque is increased when the rotor speed is very low. The cogging torque of the alternator of a direct-drive wind turbine needs to be overcome before any suitable electric power is developed at the terminal at cut-in speed. This cogging torque creates unbalanced torque pulsation, which results extra and undesired vibration and noise during alternator operation [16]. Therefore, it is very important to reduce the cogging torque.

Cogging torque can be minimized simply by reducing the magnetic strength but it was not considered in this study, as weak magnet will also significantly reduce power/torque density of the PMA [18]. Another frequently used method to reduce cogging torque is by using fractional slot per pole which is used in the present research. Also two more techniques like mounting of the magnet and customized slot type were also applied in this proposed design to minimize cogging torque or effect.

Usually, there are two separate approaches to calculate cogging torque: the analytical and numerical ones. The analytical methods are suitable for comparatively simple geometry, but due to oversimplification inaccuracy may occurred. Nonetheless, analytical approaches deliver closed-form solutions that can simply insightful performance predictions with confidence. This method make them ideally suited for preliminary design. On the contrary, the numerical measures are normally realized by two-dimensional (2D) and three-dimensional (3D) FEA methods. Also, this technique offers more accurate calculations for complex geometry. Due to inclusion of numerous repetitive computations, FEA approaches are extremely time-consuming for optimization [19]. Here RMXPRT and MAXWELL 2D is used for numerical analysis.

IV. MATERIAL FEATURES

Two primary materials are focused e.g. permanent magnets for designing the magnetic pole and silicon steel sheets or electrical sheets for designing the rotor and stator. In the following subsections, the most commonly used and recent trend materials are discussed to find out the best and cost effective one.

A. Permanent Magnet Materials

For choosing a suitable permanent magnet material from several available magnetic materials, first concentrate on the performance and cost of the alternator. Permanent magnet material should have sufficient residual magnetism density, higher magnetic coercive force and maximum energy product which can give greater energy density. Also it must have good magnetic stability, thermal stability, chemical stability and time stability with better economy [20]. Generally alnico is preferred over the applications, where the alternator is exposed to extreme location. The flux densities of alnico magnets are equivalent to soft magnetic irons but due to lower values of coercive force they are simply demagnetized compared to ceramic magnets [21].

On the other hand, ceramic magnets have low maximum energy density because of lower values of retentivity with minimum cost. Rare earth magnetic materials such as samarium cobalt alloys have comparatively better magnetic properties, but these materials are too expensive for designing an alternator. The rare earth polymer bonded magnets, ferrites and cobalt based metallic magnets are cost effective but physically hard and brittle.

Recently, the use of NdFeB type rare earth magnets are increased due to its higher energy density and residual flux density amongst available permanent magnet resources [22-25]. The main parameters of NdFeB are listed in Table I. The parameters are defined the actual size of the permanent magnet includes pole arc coefficient, permanent magnet axial length, and the length of the magnetizing direction [20].

TABLE I. MAIN PARAMETERS OF NdFeB

Property	**Value**
Residual flux density	1.15 T
Coercive force	915 kA/m
Maximum energy density	263.1 kJ/m3
Relative recoil permeability	1.03

TABLE II. DATA TABLE FOR M19_26G SILICON STEEL SHEET

Property		**Value**
Material Grade		M19_26G or M350-50A
Thickness		0.50 mm
Minimum Magnetic Induction at 1 T, 50 Hz		1.45 W/kg
Minimum Magnetic Induction at 1.5 T, 50 Hz		3.33 W/kg
Minimum Lamination Factor		97%
Core loss at 1.0 T, 50 Hz		1.33 W/kg
Core loss at 1.5 T, 50 Hz		2.94 W/kg
Minimum Magnetic Induction at	H=2500 A/m	1.59 T
	H= 5000A/m	1.69 T
	H= 10000A/m	1.79 T

B. Rotor and Stator Materials

Currently electrical steel sheet or silicon based steel sheet is widely used to design any kind of electrical machines such as alternator, transformer applications due to their low volume and cost. In this designing procedure M19_26G or M350-50A silicon steel sheets is used. The magnetic properties of M19_26G are provided in Table II [26].

V. MACHINE FEATURES

In this section, the machine geometry and its modification from conventional one were discussed.

A. Outer Rotor Radial Flux PMA

The conventional rotor flux PMA (RFPMA) is categorized into inner-rotor and outer-rotor types. The inner-rotor type RFPMA has interior rotor positioned inside of the stator, thereby having a robust mechanical arrangement without standing mass-production capability. This type of alternator is basically suitable for the high-speed application like high-speed servomotor or conventional power generation or high-speed wind turbine with gear box.

In inner-rotor type, since the rotor is located at the inner side of the alternator where the permanent magnet is also attached, its diameter become comparatively smaller because of the structural limitation. This limitation causes trouble in obtaining a high output power due to its small cross-sectional area of the actual output as compared to the total volume. That's why an extra speed-increasing gear system is needed between the alternator and a blade because of the low voltage generated at a low-speed caused by the lack of a multi-pole structure. On the other hand, in the outer-rotor type RFPMA, the rotor is positioned externally thereby creating a larger effective output power cross-sectional area than that of the inner-rotor configuration. This is advantageous in terms of the output power, and power generation at low-speed is possible because of the presence of a multi-pole structure [27]. Also gear box can be removed in the proposed design considering the low-speed operation. Fig. 1 shows the 3D view of an outer-rotor PMA.

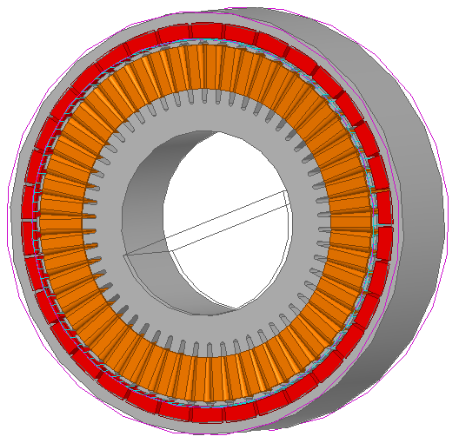

Fig. 1. 3D view of an outer rotor permanent magnet alternator

The external rotor configuration has several advantages like ease of installation, better cooling, and low maintenance with lower total cost. Therefore, the external rotor construction is more suitable to be applied in small scale low-speed wind energy systems. The design (electrical and dimensional) parameters of the PMA are listed in Table III.

TABLE III. ELECTRICAL AND DIMENTINAL PARAMETERS OF THE MACHINE

Property	Value
Rated power (Pout)	400 W
Reference speed (N)	100 rpm
Rated phase voltage (Va)	24 V
Thickness of PM (LPM)	7.0 mm
Number of stator slots (Q)	54
Number of poles (P)	34
Length of the air-gap (g)	1.0 mm
External diameter of the stator (Sout)	168 mm
Internal diameter of the stator (Sin)	85 mm
Length of the stator (L)	50 mm
External diameter of the rotor (Rout)	195 mm
Internal diameter of the stator (Rin)	170 mm

B. Fractional Slot

When the number of poles, and the number of phases are constant, the number of stator slots choices made by the number of slots per pole per phase. The number of slots per pole per phase has a bigger effect on the alternator. The number of slots per pole can be integer or a fraction. When the number of slots per pole is too large, the capacity of suppressing the higher harmonic will reduce. Therefore, the designed number of slots per pole per phase cannot be too big. The fractional slot is an effective and simple technique to weaken the cogging torque of the alternator. Also, fractional slot winding can significantly decrease the harmonic content to improve the electromotive force (EMF) waveform [28].

The pole-slot relation can be illustrated by slot number per pole and per phase as [15],

$$Q = \frac{Z}{P} = A + \frac{C}{D} \tag{7}$$

where Q is the number of slot per pole, Z is the number of stator slot and P is the number of rotor pole, A is an integer, C / D is an irreducible fraction.

C. Mounting of the Magnet

In the procedure of the permanent magnet alternator design the impact of mounting of the magnets has to be considered. There are several approach to mount the magnets on the rotor, but two common type mounting are mostly used for simple and robust rotor design. One is the surface mounting and another is the surface embedded mounting magnet design. The alternator with high power density have surface mounted radial magnetic pole shown in Fig.2. On the other hand the surface embedded mounting design is more suitable for high-speed applications. By comparing these two, the embedded design has greater torque ripple because of more interaction between stator slot and rotor.

In the present research, surface mounted magnet design is adopted with a value of pole embrace of 0.9 to get higher efficiency. The cogging torque was increased a little bit due to low air gap between magnetic pole and stator slots. The thickness of the magnetic pole is 7 mm.

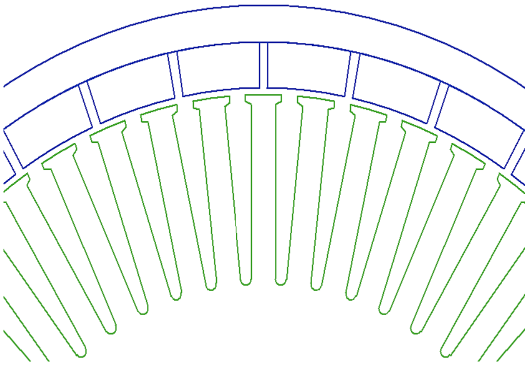

Fig. 2. Surface mounting permanent magnet pole design

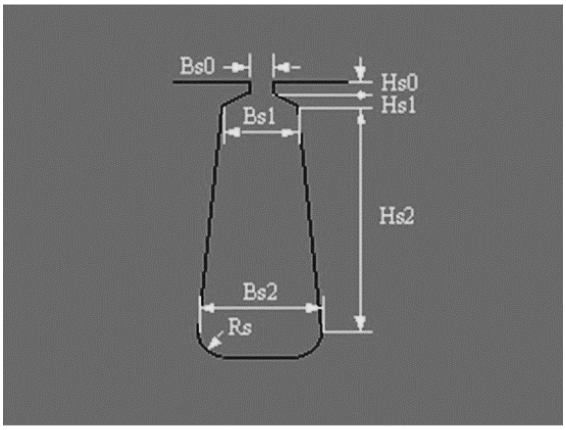

Fig. 3. Stator slot type

D. Stator Slot Shape

In the present design, the slot shape of the stator is modified to get higher slot fill factor. Increase of slot fill factor means more copper wire is fitted inside the stator slot, typically thicker conductors meaning a smaller amount of winding resistance which decreases the Copper losses (i^2R losses). This improvement will certainly increase the efficiency of the alternator. Also increasing the slot fill factor improves the thermal conductivity by replacing air (thermal insulator) with electrically conducting material like copper which is a good thermal conductor. So the total heat condition inside the slot is improved, which helps to achieve lower temperature in the conductors inside the slot. For this reason a good fill factor is fairly effective for designing a stator slot. In this machine the slot type was customized and achieved around 83% slot fill factor. A few years ago 50% to 65% slot fill factor was acceptable. Today, slot fills of 75% to 80% are fairly common and manufactured in mass capacity with a few production problems. In some cases slot fill factor up to 90% have been achieved. This can only be accomplished by optimizing the lamination design as well as the manufacturing process. The customized slot type has seven parameters where commonly used slot type has five parameters. In the current design, the stator slot has been customized with some parameters using trial and error method to get higher efficiency, like Bs1 > Bs2 with Rs = 0.7 mm as shown in Fig. 3.

E. Winding Coil Wire Modification

To get a thicker conductor American wire gauge (AWG) number 13 or 1.8 mm diameter wire is much more efficient with maximum fill factor for the proposed machine. The whole coil winding type is used in the present design with 24 conductors per slot where the coil half turn length is 58.5 mm as shown in Fig. 4.

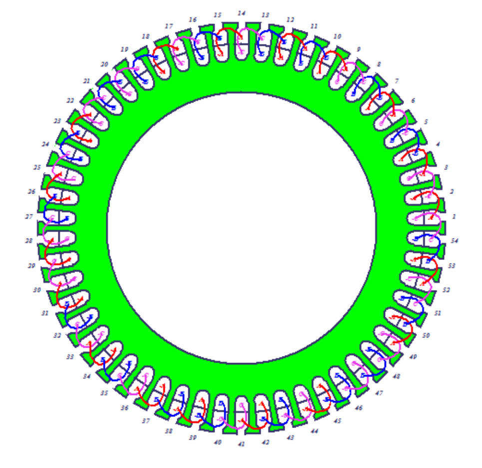

Fig. 4. Winding diagram of the alternator

VI. RESULTS AND ANALYSIS

The proposed alternator was examined in ANSOFT MAXWELL RMXPRT and MAXWELL 2D. For a given 0.1 second transient interval, the alternator was analyzed at each 0.001 second. Transient analysis is dependent on time with different initialization parameters. The simulation has been performed by setting all the parameters, and the results were observed over a full rotation of the alternator which are discussed in the following paragraphs.

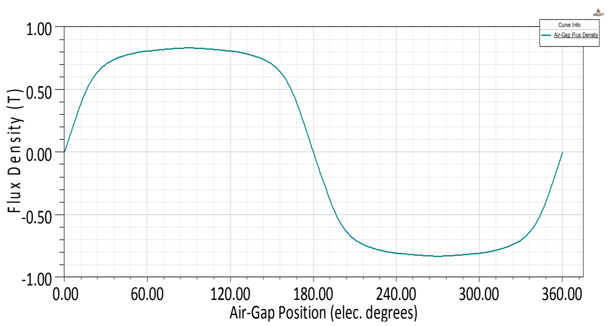

Fig. 5. Air gap flux density of outer rotor PMA (No load condition)

The length of air gap is limited as 1 mm. Maximum air gap flux density of this outer rotor machine is found around 0.83T as shown in Fig. 5, which is good enough for 1 mm air gap.

The maximum output power from this alternator is found approximately 670 W as shown in Fig. 6, which can be achieved when the torque angle is 53 degrees and the efficiency is 50%. Generally the efficiency of the conventional low-speed alternators varies between 55%-65%. In the proposed design, higher efficiency of around 77.22% has been achieved by using modified slot type, fractional slot number per pole and good slot fill factor as shown in Fig.7

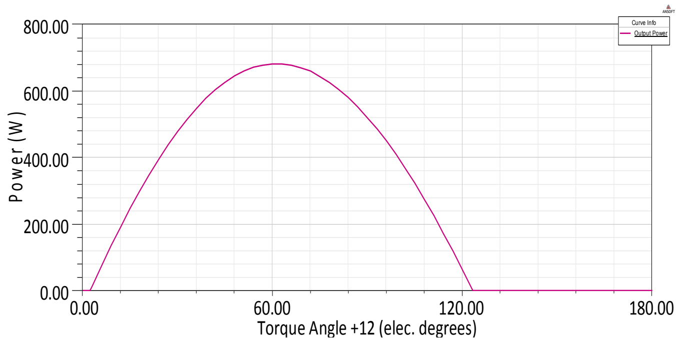

Fig. 6. Output power vs. torque angle plot

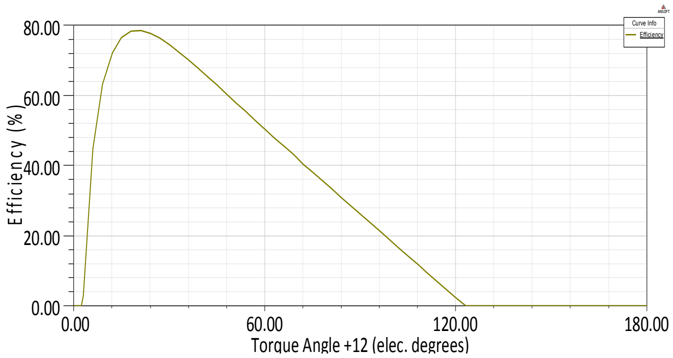

Fig. 7. Efficiency vs. torque angle plot

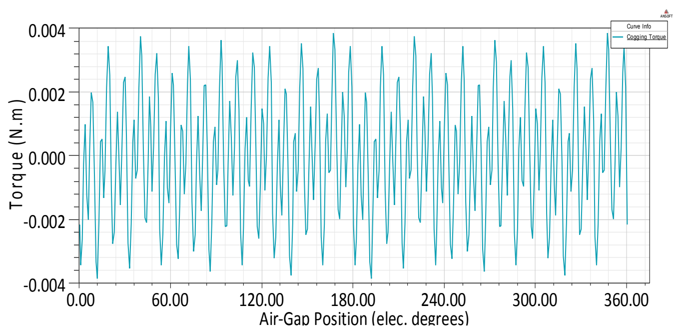

Fig. 8. Cogging torque in two teeth vs. air gap position

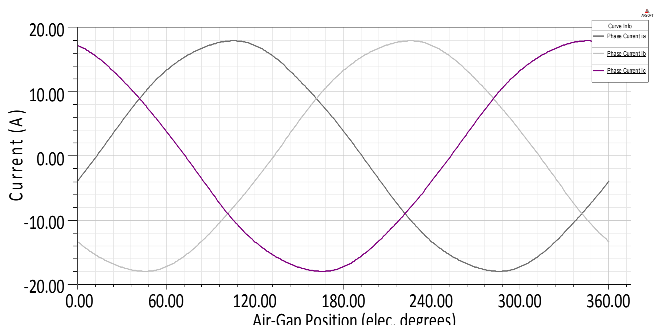

Fig. 9. Winding current vs. air gap position under load

The cogging torque is simulated and found to be around 0.0038 N-m as shown in Fig. 8. Theoretically slot skewing can make zero cogging torque but this is a very time consuming and expensive process. From Fig. 8 it is observed that the cogging torque produced in the proposed design is found to be almost negligible since the modified slot and effective fractional slot per pole ratios are employed.

The three phase RMS currents of this proposed machine is found to be 12.63 A as shown in Fig. 9. To increase the precision of the cogging torque computation, the air gap area was meshed as shown in Fig. 10 by two layers of finite elements instead of a single layer of finite elements which may create important numerical errors.

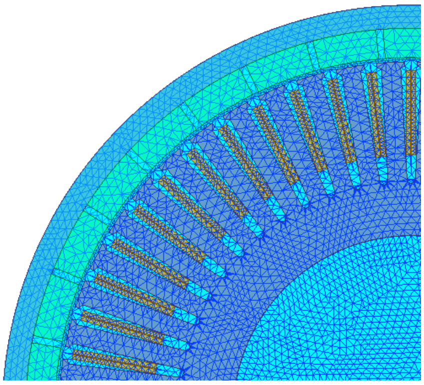

Fig. 10. Mesh detail with air gap region

By solving the magneto-static field problem in 2D for a given stator or rotor position, the magnetic field lines are analyzed which is plotted in Fig. 11. The chart of the magnetic flux density in the computation domain is shown in Fig. 12.

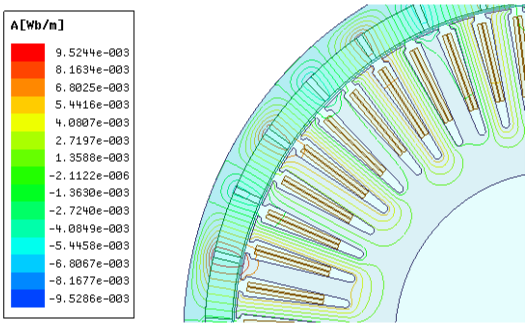

Fig. 11. Magnetic field lines analysis

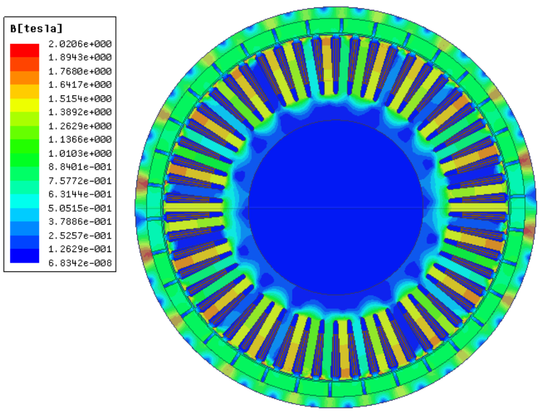

Fig. 12. Magnetic flux density analysis

Table IV illustrates the material consumption of the machine. From the parameters shown in Table IV, it is found that the designed machine has lower copper weight and armature core steel weight providing compact configuration.

Table V shows simulation result of full load operation, which confirms the improved armature thermal load than the same rated conventional machines. It is also found that the armature copper loss has been reduced due to good fill factor. So the overall efficiency has been improved due to minimization of losses than conventional inner-rotor type permanent magnet alternator

TABLE IV. MATERIAL CONSUMPTION DATA

Material consumption	**Value**
Armature wire density	8900 kg/m3
Permanent magnet density	7550 kg/m3
Armature core steel density	7650 kg/m3
Rotor core steel density	7650 kg/m3
Armature copper weight	1.77371 kg
Permanent magnet weight	1.32245 kg
Armature core steel weight	4.04409 kg
Rotor core steel weight	1.12719 kg
Total net weight	8.26744 kg
Armature core steel consumption	10.6254 kg
Rotor core steel consumption	13.496 kg

TABLE V. FULL LOAD OPERATION RESULT

Parameter	**Value**
Peak line induced voltage	27.114 V
RMS line current	12.6349 A
RMS phase current	12.6349 A
Armature thermal load	149.2 A2/mm3
Specific electric load	31025.3 A/m
Armature current density	4.80898 A/mm2
Frictional and winding loss	12 W
Iron – core loss	6.06047 W
Armature copper loss	100.013 W
Total loss	118.074 W
Output power	400.324 W
Input power	518.398 W
Efficiency	77.2233 %
Synchronous speed	100 rpm
Rated torque	38.2281 N-m
Torque angle	13.2208 deg
Maximum output power	669.877 W

VII. Conclusion

The performance of PMA has been presented for 400W small scale exceptionally low-speed (100 rpm) wind power generation system. For this low-speed machine multi-pole system is used with outer radial rotor configuration considering the fractional slot number per pole.

The proposed outer-rotor type PMA provides higher efficiency with minimal armature thermal load, armature current density and armature copper loss at rated speed. Also the outer shape rotor creates a bigger effective output power cross-sectional area than the typical inner-rotor type which makes it more robust in design. So this has advantages like easy installation and cooling with least maintenance, which is perfectly ideal for small scale, low-speed, and gearless wind power system.

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A Novel Model of Electricity Generation to Change the Direction of Grid Expansion and Power Flow Network

Alimul Haque Khan &
ASM Shamsul Arefin
Electrical & Electrical Engineering
Bangladesh University
Dhaka, Bangladesh
Email: alimul_buet@yahoo.com

Maidul Islam
Electrical & Electrical Engineering
Eastern University
Dhaka, Bangladesh
Email: maidul112@gmail.com

Asif Islam
Information Technology &
Electrical Engineering
University of Queensland
Brisbane, Australia
Email: asif038@gmail.com

***Abstract*—The aim of this paper is to explore a new model of electricity generation with a different topology of grid expansion and different direction of power flow network as well as higher penetration rate of renewable energy. Conventional system to generate electricity is to generate large amount electricity which reaches to the consumer end through long transmission line and distribution systems. The expansion of grid follows "generation, transmission, distribution and consumer" network. Expansion of grid nearby the existing one is not so difficult. However, it needs longer time to reach electricity to a residency of remote area because of higher cost associated with long transmission and distribution line. Unavailability of electricity is one of the most important reasons to deprive the population of remote area. It is possible to confirm electricity to the citizens of a remote area by producing small scale electricity at or nearby the consuming spot instead of bearing it through long transmission and distribution lines. Interconnection of multiple small scale generation units may form a different network in comparison to traditional power flow network. A novel method to achieve this has been discussed in this paper. The analyses have been done mainly based on the condition, environment, data and other factors of Bangladesh. This work is not to replace the traditional grid expansion topology rather to assist it with an alternative way.**

Keywords*—*electrification, grid expansion, microgrid

I. Introduction

Once upon a time, the electricity generation was decentralized and smaller. In course of time, the introduction of large power station and long transmission system make the generation possible to be located outside from the city and far from the locality [1]. The efficiency of energy conversion is also increased over time. Recently, loss due transmission and distribution systems has also been decreased [2] [3]. Extensive research is going on this topic. The grids are being interconnected and making larger regional grid connecting several countries. Advantages with several dimensions make the larger centralized generation popular over small decentralized generation system. There is no doubt that, the centralized generation is better in several ways. However, expansion of grid to the remote area is yet dependent the generation of power from large power stations and evacuate it through long transmission and distribution line [4]. Reaching electricity to remote people through this topology is associated with higher cost and most importantly the elongated time. For this reason, expansion of grid to the remote area is being slower in remote area than that of closer area of electrified region. Rural electrification is one of the cornerstones for development and the first step of modernization. Over the last two decades, hundreds of millions of people have attained modern energy access. However, almost one-fifth of the world's population have no access to electricity, and more than 75% of them are living in developing Asia and Sub-Saharan Africa [5]. In this context, a generation model: Consumer is Producer, has been proposed in an attempt to attain higher rate of electrification [6]. A detailed study of this model through this paper may further pave the way for a new way of grid expansion.

II. Common Electricity Generation Topology

Generation of electricity accomplished by mainly three ways. The large power stations which is connected with national grid. Fuel based small generator are available at the smaller region of remote area which is delivering electricity by means of local grid. Stand alone power generation system with no connectivity with any grid are also available [6] [7]. These are described here.

A. Centralized Large Power Production

Hydro turbine, steam turbine, gas turbine based large power stations are used for power generation. The duration of installation is usually long, around two or more years. These power stations are connected to the grid through switch gear and substations. The energy reaches to the end user by means of long transmission and distribution lines. This is a proven, accepted and popular technology. However, it is subjected to installation of long transmission and distribution lines thus involving longer installation time and higher installation cost [2] [3].

B. Smaller Power Production

Due to unavailability of grid connection, people are using the topology of electricity generation like the first era of electrification in many remote areas that is small generator based on fuel. These are being used for a market, village or a

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small group of people. The users are interconnected through a small local grid. This type of grid is also available in large ships. Cost of electricity is a little bit higher than that of previous one [8].

C. Stand Alone Power Production

The sources of power that is not connected with any grid in any way are the stand alone system. Individuals are mainly users of it. Very small power generators, mainly small scale renewable energy generators are the main resources for stand-alone power generation. Solar Home System (SHS) is a perfect example of it. It has reached the number one fastest growing program in the world [9].

III. Common Grid Expansion Topology

The expansion of grid may be done within the electrified region or to the nearby area of the electrified region. Besides these, expansion of grid to the remote area is also accomplished. These are discussed here.

A. Expansion of grid within the electrified region

This includes the expansion of grid due to increased load and due to new developments, house and industries within electrified area. It needs only additional low voltage level distribution line and distribution transformer for expansion [2] [3]. Economic benefit and profit to investment ratio of this type of expansion are very high. Return of investment is quick.

B. Expansion of grid nearby the electrified region

Expansion of grid nearby 5 km of the electrified region needs installation of substation, as well as primary and secondary level of distribution [2] [3]. Profit to investment ratio of this type of expansion is also high. Return of investment is quick.

C. Expansion of grid to the remote area

The rate of expansion of grid to the remote area which is more than 10 km from the electrified area is very low. It needs installation of new transmission lines, substations and distribution lines [8] [9]. Cost associated with this is very high. The rate of return of investment is slow.

IV. Direction of Grid Expansion

Direction of grid expansion (DGE) may be defined as the direction of how the grid is expanding within a large region. The expansion normally takes place to the nearer area of electrified region. The far the area from the grid, the late the area to be electrified. The DGE is normally the direction of electrified area to non electrified area. However, DGE for the local grid is different from that of national grid. It's DGE will be non-electrified area to non-electrified area. However, as the area covered by local grid expands outwards, it is closer to the national grid. Thus the DGE of local grid is actually nonelectrical region towards electrified region. Inter connection of several local grid will make a larger grid. As a result, the distance between national grid and local grid will be decreased. Due to more interconnections among the local grids, the probability of interconnection between local grid and national grid will be increased [10]. In this case, the expansion may be done from the national grid side or from the local grid side [6].

This discussion about DGE may be elaborately described by replacing the term " national grid and local grid" with "local grid and stand alone system". In this case, a stand-alone system can only be interconnected to each other thus DGE will be similar to DGE of local grid. If DGE is considered as stand-alone system towards national grid, it will provide a quick rate of grid expansion for the remote area. This is explained by figure 1. Figure 1 is showing the illustration of grid expansion with time-line indicated by different tile numbers 1, 2, 3, 4, 5 of the figure. Thus there are mainly two DGEs, national grid to remote area and another is remote area to national grid.

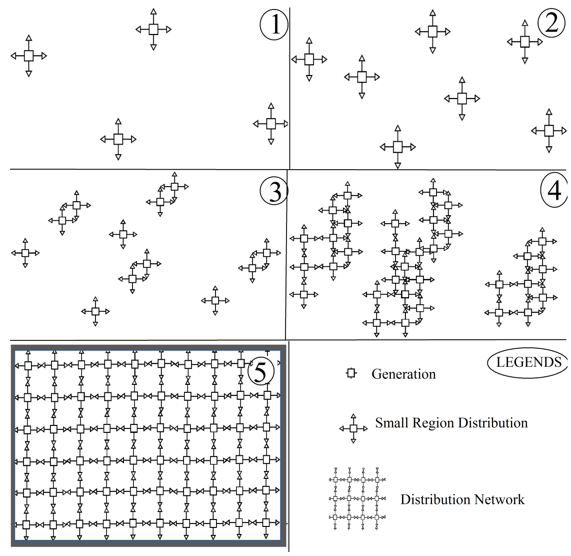

Fig. 1: DGE for remote area to national grid

V. The Proposed Model

"Consumer is Producer (CP)" model has been discussed elaborately in [6]. The producers are the consumers according to this model. The concept is to start electrification from the consumer end, which is opposite to that of the conventional system. Interconnection of two or more users is easier for a smaller region. Therefore, CP model might become the optimal fit for the remote area, where the availability of electricity is more important than the price of electricity. Few modification of this model will make it possible for urban areas as well.

The unit size of the proposed model is larger than that of SHS. However, it is still very small compared to the size of larger traditional power plant. In addition, neither SHS model nor the traditional larger power plant is suitable as power business for the mass scale participation of common population. Moreover, these markets are almost locked for the common people. Hence, if the investment and policy are such that both size of installation and investment remain at an optimum level, the production of energy will be high. Thus, this model will have a higher level of installation capacity within minimum possible time which will result in a quick expansion of grid to the remote area. The model is summarized here with Fig. 2 to Fig. 6 (redrawn with permission) paragraphs showing how the consumer producer units (CPU) form local grid, the expansion of the grid and the merging of this grid in the national grid.

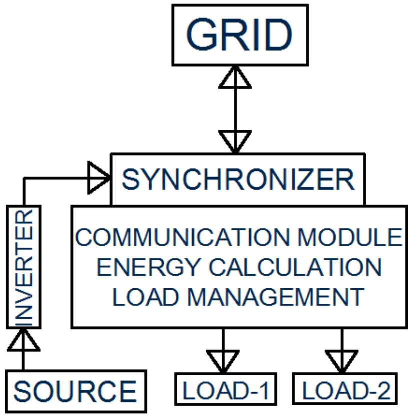

Fig. 2: Consumer Producer Unit (CPU)

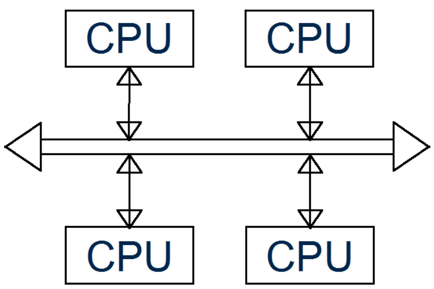

Fig. 3: Interconnection of CPU, forming local grid

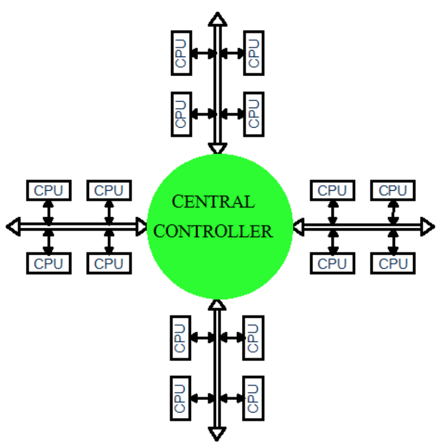

Fig. 4: Interconnection of local grid

A CPU (Fig. 2) consists of energy sources, inverter, synchronizer, communication module, energy meter and several types of loads. Each CPU has its unique identification number. The inter connection of several CPUs form a microgrid. The formation of a microgrid by several CPUs is shown in Fig. 3 id. After that an Interconnected Microgrid can be formed via connecting several microgrids using a central controller as shown in Fig. 4.

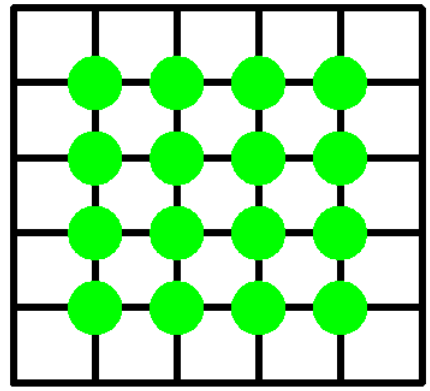

Fig. 5: Microgrid Network

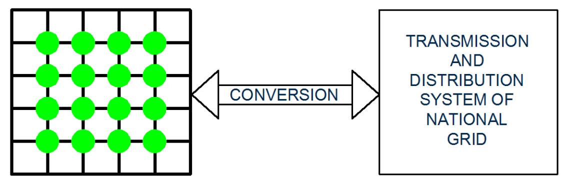

Fig. 6: Reaching to National grid through New Grid expansion topology

When a large number of interconnected microgrids are combined together, it will form a microgrid network. The microgrid network may be considered as a unit power source that will be connected to the nearest transmission and distribution lines. This is shown in Fig. 5. Furthermore, an option is provisioned for this microgrid network to be connected to the nearest national grid when available. This is shown in Fig. 6. It is possible to transfer power to the grid on demand through this connection.

The proposed model of electricity generation is claimed to have the following criteria:

1) Suitable for the remote area considering the area, density of population, load profile, availability of alternative power resources.
2) Minimization of the cost and loss due to evacuation.
3) Easy to install and maintenance. Easier installation as like as plug and play, thus minimum installation time.
4) Economically feasible and cost effective.
5) Creation of market for the common people. As a result, acceleration of general people into the power business should be possible. Thus, it will offer a higher rate of installation.
6) Decrease the carbon emission as well as lower greenhouse gas emission and decelerate the higher rate of global warming.
7) Reliable load management system as well as source management system.

8) Reliable for an extremely critical condition of the power system.
9) Minimum installation and running cost.

VI. Projection Based on Solar Home System Model

The average consumption of a typical family is around 1200 KWh [11] per year. The size of rooftop size is enough to install 2-3 KWp [6] of solar PV panel. Analysis of "PVwatts", an online software offered by National Renewable Energy Lab (NREL), available at [12], shows that 2-3 KWp solar PV panel is able to produce to about 2600 KWh to 3900 KWh [12] of electrical energy over the year in Bangladesh. This energy should be enough to supply the energy for 2 to 3 families. This could be considered as the smallest unit of new grid expansion model. Inter connection among these units will expand the area coverage of electrified region. Interconnections of these units are the key to form a large and expanded electric grid [6].

IDCOL started the Solar Home System (SHS) program in 2003 to ensure access to clean electricity for the energy starved off-grid rural areas of Bangladesh. The program supplements the Governments vision of ensuring Access to Electricity for All by 2021 [9]. About 3.71 million SHSs have already been installed under the program in the off-grid rural areas of Bangladesh till May 2015. As a result, 16 million beneficiaries are getting solar electricity which is around 11% of the total population of Bangladesh. IDCOL has a target to finance 6 million SHS by 2017, with an estimated generation capacity of 220 MW of electricity [9].

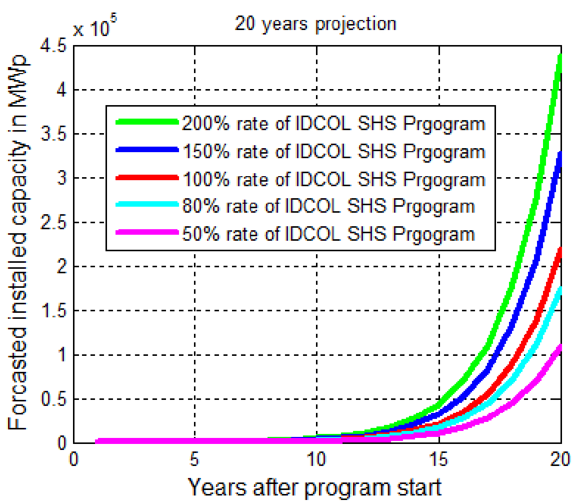

Fig. 7: Forecasted installed capacity of the proposed model based on IDCOL's installation number.

The SHS program of IDCOL has claimed to be the fastest growing program in the world. This was possible because of the appropriate policy that was undertaken. Thus, the policy taken to enhance any program is very important. Proper policy with subsidy and easy purchase would able to make the proposed DGE model achieve higher number of installations like IDCOL's SHS or even more. Considering the several arguments discussed in this section and the rate of the installation of IDCOL, the possible installation capacity of the proposed topology could be possible to forecast. To find the installation capacity by the proposed topology, the number of installation has been multiplied by the unit capacity (2KWp) of each stand alone power generation capacity [9] [6]. This is illustrated in Fig.7.

VII. Conclusion

The "Consumer is Producer" model is an optimum model for the proposed Grid Expansion topology. It can be used to be an alternative and supplementary way to the traditional Grid Expansion topology. Installation of large power plant based on renewable energy is good, but the scope for the implementation is not available everywhere. Moreover, larger power stations also need the evacuation system, which proves very costly although loss of this has been minimized [2] [3]. Hence, involvement of consumer into the large power stations is tough. On the other hand, the installed figure of SHSs is large (more than 3 million), but the amount of generated electricity is still not enough and is not contributing to the national grid [9]. However, SHS is not a business model for the customers, rather for the NGOs. Generally, the number of investors for a smaller (capital) system increases more than that for a larger system. In spite of this, the market of SHS is almost locked for the common people. Hence, if the investment and policy are such that both size of installation and investment remain at an optimum level, the production of energy will be high. As a result, the penetration of renewable energy would increase quickly, which will otherwise be difficult to achieve by incorporating the traditional large system and the SHSs. Extensive use of the new GE topology will reduce the green house emission as well as the rate of global warming.

Acknowledgment

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Facts and Popular Perceptions on Saving Energy and the Environment

Shahriar Khan
Department of EEE
Independent University, Bangladesh
Email: skhan@iub.edu.bd

Abdus Salam
Dept of Aeronautical Engineering
Military Instt of Science and Tech.
Mirpur, Dhaka, Bangladesh

Samina Alam,
Dept of EEE
Premier University,
Chittagong, Bangladesh

Abstract:-- **Although today's major concerns are moving to renewable energy and the saving of energy, there are deeper energy-related issues which are less discussed and explored. To what extent can renewable energy take over from conventional sources? How much into the future should we be concerned about? Electricity generation for stationary applications can be from coal, nuclear power, solar power and wind turbines, whereas transportation relies mostly on increasingly scarce oil. Coal and nuclear fuel will be nowhere close to depletion over the next 100 years. Both governments and commercial organizations mostly benefit from increased energy consumption, and cannot be fully relied upon to pursue saving energy and the environment. It is private citizens who are most concerned about saving energy, being concerned about availability in their own lifetimes and that of their children. However, the general public is less aware of the deeper issues involved. The issues of energy and the environment are interdependent on each other, and determine the quality of life for ourselves and our future generations. As the attitude of people to saving energy determines availability (or depletion) for future generations, this paper explores facts vs. public perceptions on energy. A preliminary survey was conducted, which found that there are genuine concerns about saving energy and the environment. Areas where there were misconceptions were identified. Although the sample size was small (<100), the survey paved they way for a broader survey with a larger sample size.**

Keywords: **Energy, environment, survey, transportation, electricity, generation.**

I. INTRODUCTION

Although today's main concerns are the saving of energy and the environment, and the shift to renewable energy, there are other relevant issues that are less-explored. Today, energy has become a complex mix of the issues of electricity, transportation, fossil fuel, renewable energy, nuclear energy, etc [1-4]. This paper seeks to ask and answer the deeper questions involved in saving energy, addressing the facts and popular perceptions involved.

A. Less Explored Questions on Energy

Some fundamental questions on energy are rarely asked and explored. How much is there a need to save energy? How much is the urgency to save energy in each of the two sectors of transportation and the electric grid? Who are really concerned about saving energy? How much are political governments and commercial organizations concerned about saving energy? What is the role of academia and researchers like in universities, and have they lived up to their roles?

To what extent will solar, wind, and biofuels meet the energy needs of the future? Will these renewables allow the continuity of lifestyles that mankind is used to?

As private citizens greatly determine energy consumption, how much do they understand the various issues involved? Most of us are concerned about energy availability say ten years in future, but how much do we care about what happens 20 years or 40 years or 100 years or even 200 years in future? Are we willing to deplete the fossil fuel resources, leaving our children and unborn generations to a world with very little fossil fuel? Should energy-related information be better supplied to the public so that they can make more informed choices?

A. Past Work on Saving Energy

Numerous energy saving programs have been implemented worldwide [4-14]. Energy saving involves simple steps like shifting from incandescent bulbs to Compact fluorescent lamps (CFLs), reducing usage of air-conditioners, and shifting to more energy-efficient equipment. This approach to reduce energy consumption addresses only part of the much bigger issues of the energy situation of the future. There has been very little research on these deeper issues and how the knowledge should be made available to the public.

B. Importance of Public Perception

Public perception on energy is important for many reasons. The public largely determines the amount of lighting, cooling and heating they use. Their attitudes to saving energy determine how much they turn off lights, fans and air coolers when leaving a room. They determine the room temperatures of their air conditioned rooms. The public chooses whether they use mass transit (buses and subways) or personal automobiles. In case of the latter, individual preferences determine whether they drive an efficient small vehicle or a large gas-guzzling SUV.

C. *Survey Conducted*

A survey was conducted on just fewer than 100 individuals mostly of college-going age. Paper questionnaires were distributed with about 20 questions on energy-related issues. The findings are described in the sections below. Although this is a small sample, it paves the way for a larger survey to be done later.

II. TRANSPORTATION VS. POWER STATIONS

The public gives about equal importance to the energy used in the two major sectors of transportation and electricity generation. Most are unaware of the important differences in the requirements and future prospects of these two sectors.

A. *Energy in transportation.*

Whether transportation is over air, land, or sea, oil (petrol, diesel, aviation fuel) is used (essential) in the vast majority of cases. The exceptions are land vehicles running on natural gas, and electricity-run trains and cars. Nuclear-powered ships and submarines are used for defence and are hardly suitable for use by the public.

This dependence of the transportation sector on oil is expected to continue for many decades. Automobile fuel and air fare costs have risen sharply over the last few decades, owing to the decreasing availability of oil.

Solar and wind power can hardly be used for driving automobiles, ships, and airplanes. Biofuel requires too much land and time, to meet today's huge requirements for oil [15].

In the survey conducted for this paper, 40 % said they "cared very much" about reducing car fuel consumption.

On the issue of electric cars, most were unaware of the real advantages and disadvantages of electric cars over conventional cars. They even were unclear about the advantage/s of the hybrid electric car over conventional cars.

The planned growth in the automobile, aviation and airlines industries indicate that oil will be available in large numbers in coming decades. However, the advent of small cars like the Tata Nano indicate that the trend towards smaller cars will continue in the coming decades.

B. *Energy for Electricity Generation*`

Besides transportation, energy is generated in power stations and consumed in homes, offices, and industry. Interestingly, shortages in this stationary sector will be much less than in the transportation sector; something the public is mostly unaware of.

Half a century ago, electricity generation was largely through hydroelectricity. Very few new hydroelectric power stations are being constructed today. It is said that most possible sites of hydroelectricity have already been used.

Over the last few decade, there has been a shift to coal, gas (20 %), oil (5 %) and to nuclear power stations. In spite of many incentives, renewable energy such as solar and wind, power supplies less than 2 % of the grid worldwide.

In the coming years, less oil and more coal will be used for power generation. As nuclear fuel is nowhere close to depletion, it is expected that nuclear energy may show a significant rise [15].

TABLE 1 . COMPARISON FOR TRANSPORTATION AND STATIONARY APPLICATIONS/

	Stationary (Power stations, homes, industry)	**Transporation (automobiles, ships, planes)**
1	Now runs mostly on coal, gas, oil, and nuclear	Mostly runs on oil. Some cars driven by gas.
2	In coming decades, there will be shift towards coal, nuclear and renewables	Dependence on oil is likely to remain. Automobiles may shift towards compressed natural gas.
3	Public mostly unaware that energy for stationary applications can be met by coal and nuclear for 100 years	Public mostly unaware that energy shortages in transportation will worsen over the coming decades.
4	Public mostly unaware that renewables are too inconvenient to allow generation close to present levels from conventional sources.	Public mostly unaware that renewable energy has little application for transportation, such as in cars, ships and planes.
5	With increasing expense of energy in coming decades, air-cooling may be reduced, as people try to acclimatize to their surrounding temperatures.	In coming decades, shortages in oil are likely to push towards smaller cars and ships. Travel by airplane will become increasingly expensive and out-of-reach.

Nuclear fuel gives off close to zero emissions, but in case of an accident, large areas will become uninhabitable for decades. Discussion on nuclear energy has been focused on possible accidents. The Three-mile accident was in the US, Chernobyl was in the USSR, and Fukushima was in Japan. All three accidents occurred in countries considered very technologically advanced, reminding us that even the best precautions against accidents cannot be foolproof.

The public is mostly unaware that nuclear fuel is nowhere near depletion, and is expected to be available for centuries. The only task is concentration of the ores.

III. FOSSIL FUEL

Fossil fuel has been used for heat generation for thousands of years, but the conversion of fossil fuel to mechanical energy was only with the first steam engines about 300 years ago. At present consumption rates, oil and gas may last for many decades while coal may last about two centuries. The immediate manifestation of this limited nature is the increasing cost of oil and gas. Will ours become known as the generations which squandered the fossil fuel accumulated over millions of years? Are we not properly sharing fossil fuel with coming generations not yet born?

50 % of the respondents of the survey thought that fossil fuel (oil, gas, coal) will be depleted in the next 10 years.

A. Oil

Government policies and public attitudes do not sufficiently reflect the very real need for conserving oil. Gas guzzling SUVs have thrived for three decades or more, in spite of the purported push towards more efficient and cleaner burning cars. The loophole used in the US is that SUVs are built on the chasis of trucks, which allow them to bypass the efficiency and emissions laws in place for cars. In US freeways, a subtle race has emerged towards larger heavier vehicles, which are rightly perceived to be safer in the event of a collision with a smaller car [15].

Popular perception is that mainly oil and gas will suddenly become depleted, whereas in reality, scarcity and high prices will allow availability for even a hundred years. 40 % of the respondents of the survey thought that oil and gas will be depleted in the next 10 years.

Almost all transportation over land, sea, and air is powered by oil. There are certain applications, such as aviation and airplanes, where there is almost no substitute for oil (not even natural gas). The only conceivable substitute may be biofuel which is very difficult, expensive, and time-consuming to produce in large quantities. The public is less aware that there is very little substitute for the oil, essential for airplanes and ships With the likely shortages in oil in coming decades, airplane travel and cargo transportation by ship will become increasingly expensive. Automobiles may be slightly resilient to scarcity of oil, as they can shift towards compressed natural gas, electric vehicles, and electric trains.

There may be some questionable public perception that new discoveries of oil will allow continued production at low cost. In reality, most of the oil and gas reservoirs of the world have already been discovered [ ]. We are going ever deeper under the ground in our quest for oil and gas. The general public is largely unaware of the extremely high technology involved in the drilling for oil. A drillpipe may go 8 km vertically underground, running another 8 km horizontally. The drillpipe may maneuver within a layer of hydrocarbons a few meters thick, with the help of computerized sensors communicating with the surface through the mud pumped for bringing up the shavings.

B. Gas

Gas is the cleanest burning of all the fossil fuels, as most people are aware of. Just about 20 years ago, gas was burnt as a by-product of oil production. An indication of the continuing scarcity of fossil fuel is that gas itself has become valued, often piped hundreds of miles from remote wells to population centers.

Coal

Coal is not usable for transportation, because of difficulty in adapting it's solid structure to internal combustion engines. Coal is not clean burning, giving off visible smoke. Coal is expected to last for another 200 years, and may power most power stations many decades later.

IV. Renewable Energy

There may be some unrealistic expectations among the public regarding renewable energy, which includes solar energy, wind turbines, and biofuels. The reality is that renewable energy can supply nowhere near the large amounts of energy we have become used to.

Both solar and wind energy takes up a great deal of space and require large initial capital investment. Both solar panels and wind turbines are very expensive. Many wind turbines have actually been dismantled because of their high rates of killing bird and bats. Biofuels take up much land which could otherwise be used for growing crops.

Public perception is important for the future direction of renewable energy. In the survey conducted here, 50 % thought we are "not yet doing enough" for promoting renewable energy. 50 % thought that renewable energy can replace conventional energy "a little bit."

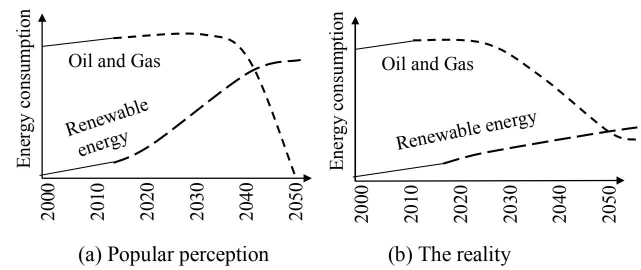

Figure 1 . Popular perception holds that oil and gas will be suddenly depleted, whereas they should be available for a long time [15]. Also the capability of renewable energy is often overestimated by the public.

V. Who is Interested in Saving Energy?

In examining who are interested or disinterested in saving energy, we consider governments, companies, private citizens, and academia.

Governments have a powerful role in formulating and enforcing energy policies. Worldwide, governments are mostly interested in lengthening their tenure. Their vision of the future may be as little as a few years. They are mostly interested in improving the economy, decreasing employment, etc. As economic indicators rise with increasing energy consumption, the government benefits little from saving energy for the long term.

Commercial organizations or companies have a powerful effect on the management of energy Companies are subject to market forces of profit maximization, and the large majority benefit from increased energy production. It is barely in their interest to promote saving energy. They cannot be relied upon to participate much in the saving of energy.

Last are the private citizens, whose concerns and consumption of energy greatly influence the management and future of energy.

In contrast to governments and companies, private individuals care much about non-commercial issues quality-of-life and what may happen years or decades into the future. Individuals are relatively more concerned about their own lifetimes, the lifetimes of their children, or even generations yet unborn. Private individuals are likely to have the greatest concern about saving energy. It may fall upon them to take the initiative for saving energy.

TABLE 2. PARTIES INVOLVED IN ENERGY CONSUMPTION

	Core objectives and interests	**The policies they are likely to follow**
Governments	Maximizing their tenure, improving economy	Produce, export or import oil, with little concern for what happens after decades
Oil companies	Increased oil production, and higher oil prices, regardless of what may happen in a few decades	Increasing oil production, with little worries on possible depletion in the coming decades.
Non-oil companies	Increasing profit, which is usually related to increases energy availability	Companies are fundamentally not concerned about the availability of oil in the coming decades.
The Public	Interested in non-commercial issues, and quality of life of children, and generations yet unborn	May have the greatest interest in saving energy, fossil fuel and the environment
Universities and academia	Long term research on energy	Often funded research supersedes unfunded research.

It falls upon academia and universities to do research on what happens in the long term. However, the results of this research are not well disseminated and less accessible to the public. Often research funded by companies and governments supersedes unfunded and unbiased research.

VI. POPULAR PERCEPTIONS ON SAVING ENERGY

The actual saving of energy depends greatly on popular perceptions about saving energy. What the public thinks about saving energy will shape the consumption of energy in the coming years and decades.

When asked how much they care about saving energy, 60 % said they "cared much" while 25 % said they cared "a little."

When asked whether our governments are doing enough to save energy, 60% said they are "doing moderately, but should do a lot more".

75 % of the respondents felt that companies and industries were doing very little for saving energy.

75 % felt that as private citizens, we should do more to save energy.

60 % said that they "cared very much" about their monthly electricity bill. 60 % said they put "some effort" into reducing their monthly electricity bill.

75 % "always turned off" lights and fans when leaving a room for a few min. About 50 % said they "always turned off" an air cooler when leaving a room for 1 hour.

60 % felt that the use of air coolers should be minimized because they consumed too much energy.

60 % said we should take "some effort" to replace incandescent bulbs with compact fluorescent lamps.

TABLE 3. POPULAR MISCONCEPTIONS VS. THE REALITY

	Popular perception	**The Reality**
Depletion of oil and gas	Oil and gas will suddenly become depleted in some decades.	Oil and gas will show a decline and will be available for much longer, even a hundred years or more. Shortages and higher prices will reduce consumption.
Depletion of Coal	Like oil and gas, coal too will be depleted in many decades	From current consumption rates, coal will last for another 150-200 years, far outlasting oil and gas
Depleted oilfields	Depleted oil and gas fields have no remaining oil and gas in them.	Depleted oilfields have about 40 % or more oil left in them, which is not economically feasible to extract.
Renewa bles	Renewables will largely replace fossil fuel and conventional energy	Renewables have very fundamental limitations that make it highly impractical to supply energy even close to todays supply from conventional sources.
The Electric car	The fully electric car is good for the environment because it has no emissions.	The electric car only moves emissions to the power station. Considering losses in the transmisison, battery, and power electronics, the quantity of emissions may be the same as a conventional car
Nuclear	Nuclear fuel may be depleted, just like oil and gas	Nuclear fuel is sufficient for at least the coming century, and there is no talk of a shortage. Many countries consider nuclear energy to be the main energy source for the coming century.

A. How Much Into the Future Matters to Us

Key to our policies on energy is how much into the future we care about. The concerns about the future largely arise from concerns about availability of energy in our own lifetimes, and the lifetimes of our children and grandchildren.

The question arises as to how much we are responsible to save fossil fuel for the next generation, and the generations yet unborn. A hundred years from today, will we be known as the generations which squandered the fossil fuel of the planet?

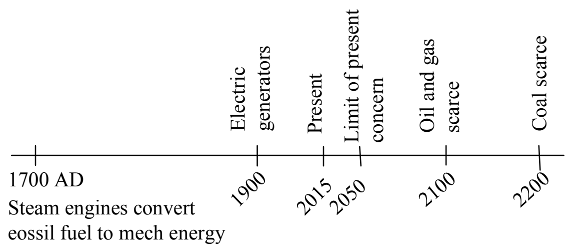

Figure 2. Although fossil fuel has been used for centuries, we are using it at the fastest rates. There is little concern today about what will happen beyond a few decades.

40 % of the respondents of the survey said that they cared about the availability of energy over not more than about 10 years.

60 % of respondents said the availability of energy for their children was very important to them. 50 % said the availability of energy to their grandchildren was very important to them.

TABLE 4. THE PAST VS. THE FUTURE.

	The Past	The Future
1	We cannot change the energy situation of the past	Our future generations, even those not yet born, will be affected by our energy policies and savings today.
2	The present generations do not hold past generations responsible for squandering fossil fuel.	Future generations yet unborn may hold present generations responsible for squandering fossil fuel reserves
3	What happened with energy in past hundreds or thousands of years is of academic and historical interest	The future, a hundred years or later is more than just of academic interest to us.

VII. THE ENVIRONMENT

The issues of energy and the environment have become increasingly interwoven in recent decades. Increased fuel consumption in past decades and centuries has caused increased greenhouse gases, and global warming, accompanied by a decrease in cloud cover [16]. A discussion of energy is not complete without a discussion of the environment.

Popular perceptions on environment will determine energy consumption today, shape policies in the coming decades, and shape the future of energy related technologies.

Both coal and nuclear fuel are far from depletion but are unpopular because of concerns with the environment. Gas is preferred over oil and coal because gas is cleaner burning and less polluting. Electric cars, thanks to their zero-emissions, are preferred by the public over conventional cars.

Over the next few years and decades, as scarcity of oil pushes towards coal and nuclear energy, there will be more smoky air, and greater risk of nuclear power station accidents.

Continuing with the survey described earlier, 74 % of the respondents felt that pollution and destruction of the environment negatively affects our quality of life. Asked whether they cared about reducing pollution and saving the environment, 75 % cared while about 10 % did not. The majority felt the government was working on saving energy and the environment, but should do a lot more.

VIII. CONCLUSION

Even though we are very concerned about saving energy, and promoting renewable energy, we have not explored the large number of related issues, especially for the future. Are the present generations squandering the fossil fuel accumulated over millions of years? Will unborn generations hold the present generations responsible for squandering fossil fuel? Both governments and industry benefit from increased energy consumption, and are unlikely to take a strong interest in saving energy and the environment. As governments and commercial organizations are not structured to promote the saving of energy and the environment, it leaves the public to pursue these issues. The preliminary survey conducted in this research has identified key areas where people are less informed. It is not well known that depletion of oil is a very real concern for the transportation industry, but not for the electric power grid. The public is less aware that it is more important to save oil than to save electricity generated in power stations. Most people were concerned about energy availability only over the next few decades. The public is mostly unaware of the many limitations of renewable energy that make it impossible for it to even come close to replacing fossil fuel. The preliminary survey has paved the way for a more widespread and detailed survey on the public perceptions on saving energy.

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Simulation of Saturation Current in $In_{1-x}Ga_xSb$ Based Solar Cell

Asif Hassan[1], Raktim Kumar Mondol[2], Imran Bin Jafar[3]
Dept. of Electronics and Communication Engineering, Khulna University of Engineering and Technology, Khulna, Bangladesh.[1]
Dept. of Electrical and Electronic Engineering, BRAC University, Dhaka, Bangladesh[2,3]
asif08ece@yahoo.com[1],raktim.live@gmail.com[2],imranjafar@bracu.ac.bd

Abstract- **After the golden era of silicon, nowadays compound semiconductors from III-V group is extensively studied to observe their application in electronic as well as in other field. Solar cell which is providing alternative source in our industries, houses and laboratories. Researchers are now trying to find out new features by using these inorganic materials based solar cell which can easily be paved the way of better controlling and maximizing the efficiency. In previous literature, *InSb* and *GaSb* based solar cell has already been studied. In this paper, $In_{1-x}Ga_xSb$ based solar cell is analyzed through their electronic responses. Here, we will observe the bandgap energy response for different proportion of gallium, temperature dependent energy, temperature dependent saturation current which will help in predicting a good level of solar efficiency.**

Keywords— solar cell; bandgap energy; saturation current; compound semiconductor.

I. INTRODUCTION

Silicon based electronic study has dominated over 30 years. It has been seen that electronic behavior is the dominant feature to predict the materials performance on other field. In the modern age, reusing the nature's energy is a talk of concerning issue. For the scope of this cost effective source, they are implementing the semiconductor materials in the field of renewable energy source. As the day's passes, researchers are replacing silicon based semiconductor with compound semiconductors [1]-[3] as well as try to find their promising application on solar cell. It is because, for the hope of controlling their solar properties, finding extra opportunities than previous silicon based solar cell with better efficiency. Nowadays, analytical researches are now propagating with experimental research work to validate each other from mathematical point of view. Analytical calculation sometimes remain close to experimental nature, for this anyone can easily ensure the scientific results before going to experiment on it. After understanding the knowledge, applications of silicon based solar cell [4]-[5], a competition started to increase efficiency in solar cell and now it is the major concern in the scientific research. Already III-V inorganic compounds are investigated on solar cell with a 24.5% efficiency [7] which is increased in [8].In these scheme, the influencing parameters are saturation current level, bandgap energy and temperature dependent energy which actually results in optimizing solar efficiency.

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Recently, researchers are trying to modify these materials by fabricating several compounded materials to make another compound material with a definite proportional presence, to observe their characteristics on solar cell through analytically [9]-[10] such like $In_{1-x}Ga_xAs$. Antimonite (Sb) which is another semiconductor material studied in [11].Albeit, the application of compounded materials from Sb is not investigated yet.

In this paper, we will observe the bandgap energy of $In_{1-x}Ga_xSb$, temperature dependent energy and saturation current which can be potential parameters on analyzing solar cell efficiency in future.

II. THEORY

Solar (or photovoltaic) cells convert the sun's energy into electricity. Actually, ability of the organic or inorganic materials to emit electron when a light fall on it. Hence, some electronic parameters are the dominant character on visualizing the performance of the process. The bandgap energy for $In_{1-x}Ga_xSb$ is calculated from the similar theory as described in [12]

$$E_g\ (In_{1-x}Ga_xSb) = (1\text{-}x)\ E_g(\text{InSb}) + x\ E_g(\text{GaSb}) - bx(1\text{-}x) \tag{1}$$

Where E_g(InSb) =0.17eV at 300k, E_g(GaSb) =0.726eV at 300k, and x denotes the proportion of gallium in this compound, b=bowing parameter (here b= 1 is used).

Bandgap energy which is the energy difference between the lowest point of the conduction band (CB) and the highest point of the valence band (VB).It is one of the predominant features to observe the carrier movement in semiconductor materials. Now we can write the bandgap energy for $In_{1-x}Ga_xSb$ from Eq.(1) using all value as stated in previous paragraph

$$E_g = 0.17 - 0.44x + x^2 \tag{2}$$

The band gap energy on solar cell based semiconductor as well is dependent on temperature variation which is denoted as E_g (T).It is derived as [13]

$$E(T) = E(0) - E_{b=2,3,4}(T) \quad (3)$$

The energy in the first term denotes the value for T=0 is an arbitrary value. The second is denoted as

$$E_{b=2,3,4}(T) = \frac{a\Theta}{2}\left[\left(1 + \sum_{n=2}^{4} b_n(\Delta)\left(\frac{2T}{\Theta}\right)^n + \left(\frac{2T}{\Theta}\right)^6\right)^{1/6} - 1\right] \quad (4)$$

where

$$b_2(\Delta) = \frac{\pi^2 \Delta^2}{1+\Delta^2}$$

$$b_3(\Delta) = 1 - 4\Delta^2 + 3\Delta^4$$

$$b_4(\Delta) = 2(1+\Delta^2)$$

It is seen that E (T), E_g (T) both energy differs by only 5%. Hence, E_g (T) can easily be calculated from Eq.(3).Now, the Δ and $\frac{a\Theta}{2}$ values are used from experimental value given in Table 1.

TABLE I. INDIVIDUAL Δ AND $\frac{a\Theta}{2}$ VALUE FOR $InSb$, $GaSb$

Compound	$\Theta(k)$	v	Δ	$a\Theta/2\,(meV)$
InSb	155	1.66	0.41	20
GaSb	204	1.46	0.44	39

For the $In_{1-x}Ga_xSb$,we have taken average value of Δ *and* $\frac{a\Theta}{2}$ as used in previous literature.

It is seen that, solar cell efficiency varies in proportion to saturation current level through materials. Hence, the governing equation is used as [14]

$$I_0 = e^{\frac{E_g(T)}{k_B T}} \quad (5)$$

where I_0 is the solar saturation current.

III. Results and Discussion

At first we will observe the bandgap energy response for varying the proportion of gallium in $In_{1-x}Ga_xSb$

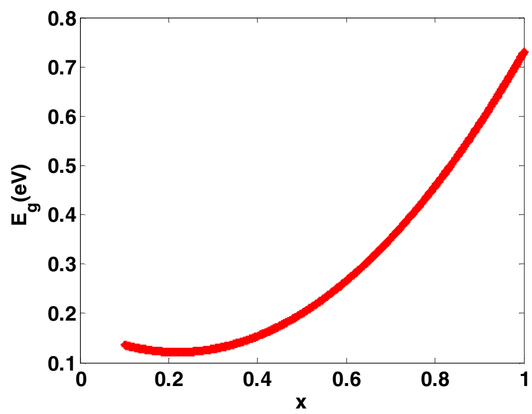

Figure 1. Bandgap energy (eV) vs. proportion of gallium in $In_{1-x}Ga_xSb$.

As stated that, bandgap energy which is the energy difference between CB and VB .From the Fig.1 it is seen that the if the proportion of gallium increase, it exponentially increases the bandgap energy. Hence, lower proportion of gallium is required which actually ensures lower amount of bandgap energy which in turn require a minimum amount of external excitation to move the carrier from VB to CB.

Those carriers in the state of conduction, can easily excite from the photon energy of sun light. For this cause, temperature in the materials in touch with sun light varies, which again changes the bandgap energy of the $In_{1-x}Ga_xSb$ as seen from Eq. (3).

Here we will observe the response of $In_{1-x}Sb$ and Ga_xSb individually. After that, we can observe the variation in $In_{1-x}Ga_xSb$ by taking the averaged amount of some parameters (Δ *and* $\frac{a\Theta}{2}$) those are used in $In_{1-x}Sb$ and Ga_xSb .

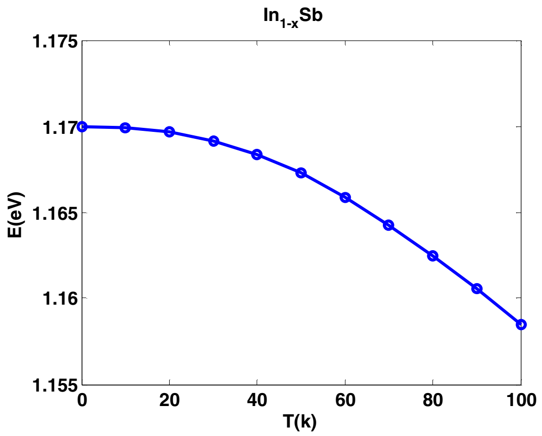

Figure 2. Energy (eV) vs. temperature (k) in $In_{1-x}Sb$.

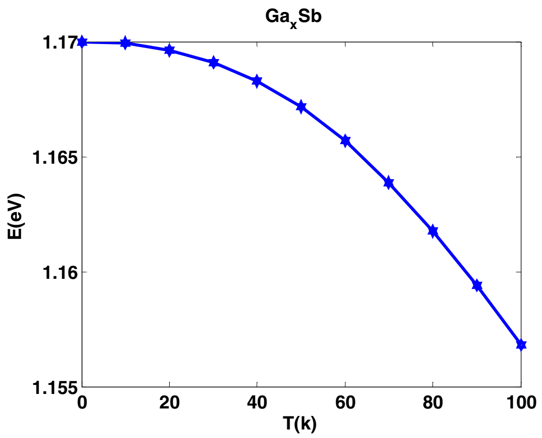

Figure 3. Energy (eV) vs. temperature (k) in Ga_xSb .

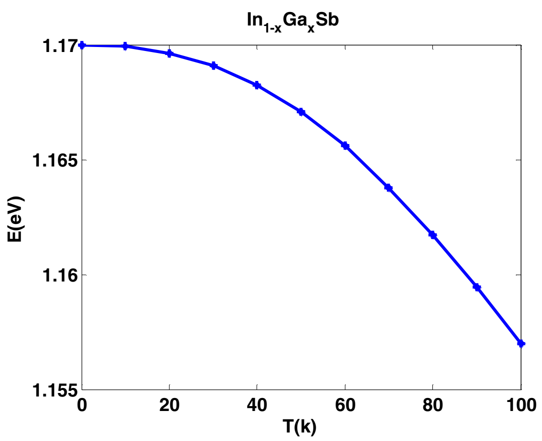

Figure 4. Energy (eV) vs. temperature (k) in $In_{1-x}Ga_xSb$.

From the Fig.2, 3, 4 it is seen that, the energy versus temperature variation is parabolic nature. It denotes the energy is reducing for increasing temperature. It is also observe that, due to averaging the parameters the response of $In_{1-x}Ga_xSb$ closely mimics to Ga_xSb nature.

Due to this *E(T)*variation, as said bandgap energy varies only by ± 5% than value found in *E (T)*.

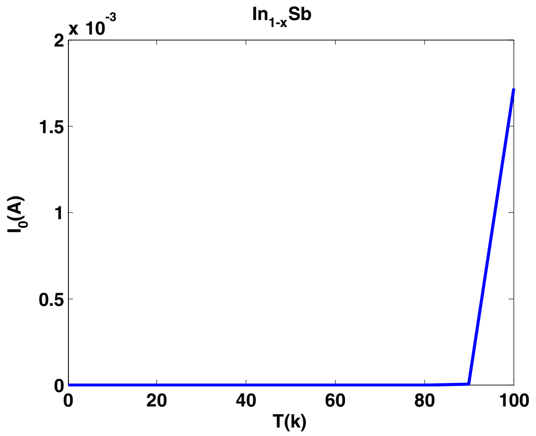

Figure 5. Saturation current (A) vs. temperature (k) in $In_{1-x}Sb$.

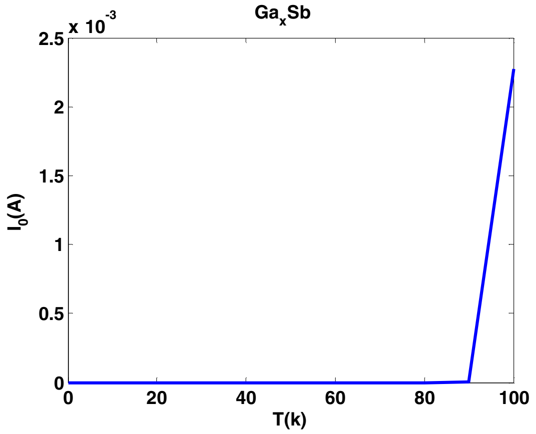

Figure 6. Saturation current (A) vs. temperature (k) in Ga_xSb .

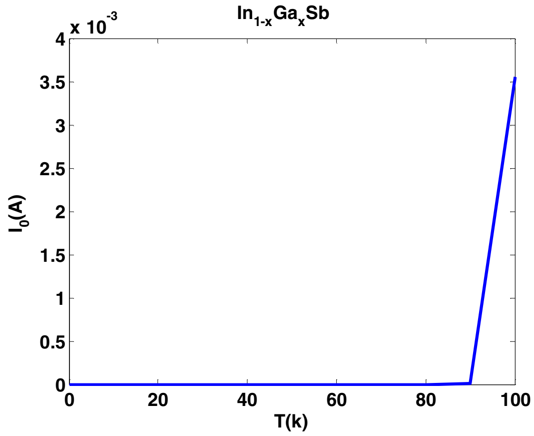

Figure 7. Saturation current (A) vs. temperature (k) in $In_{1-x}Ga_xSb$.

Albeit, the energy values are close to each other for $In_{1-x}Ga_xSb$, $In_{1-x}Sb$ and Ga_xSb . From the saturation current response, it is seen that the current is increased in

$In_{1-x}Ga_xSb$ than $In_{1-x}Sb$, Ga_xSb . The up worded curve shows that, temperature has a positive effect on increasing the saturation current. That means, lower proportional presence (x) of gallium in $In_{1-x}Ga_xSb$ will exponentially increase the saturation current if external temperature in touch with the compounded materials increases linearly.

IV. CONCLUSION

Saturation current level is the influencing as well as limiting factor in any inorganic solar cell. Here first it is observed that a minimum amount of bandgap energy is required by triggering the proportion of gallium (x) in $In_{1-x}Ga_xSb$ based solar cell. Temperature variation on the surrounding of these materials causes a positive effect on increasing saturation current which is a predicting factor on better level of efficiency in solar cell. Hence, it is a compromising issue between the temperature variation and proportion of gallium to get a well-defined level of efficiency in $In_{1-x}Ga_xSb$ based solar cell.

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Study of PV Implementation for Electricity Generation in Bangladesh

Md. Abu Bakr Siddique*, M.Tanvirul Hoque**, Tashfique Sibgat Ullah, Rakibul Hasan Sagor, Md. Shahid Ullah
Department of Electrical and Electronic Engineering
Islamic University of Technology
Gazipur-1704, Bangladesh
*absiddique@iubat.edu,**m.tanvirulhoque10@gmail.com

***Abstract*—The goal of this paper is to make effective use of solar energy of Photovoltaic (PV) module so that we can get maximum power output from sunlight. Since the performance of a PV cell depends on maximum efficiency factors, mainly on solar radiation and temperature, this paper examines the performance parameters of PV module for various locations by analyzing twenty-two years average solar radiation data in Bangladesh. To examine the performance parameters, the Solarex MSX60, a typical 60W PV module is chosen. The mathematical model for the chosen module is implemented on Matlab. The result of this paper shows the effects of variation of solar radiation on PV module within Bangladesh. Eventually, this paper proposes suitable locations for implementing solar PV modules based on maximum efficiency within Bangladesh.**

***Index Terms*—PV cell, solar radiation, temperature, maximum power point (MPP), performance parameter.**

I. Introduction

As the worlds population increases by the passage of time, the demand of renewable energy is increasing day by day. Now-a-days, solar energy as renewable energy source is being given considerable attention as it is harmless for environment and human being.

Solar PV is a key technology for capturing the benefits like having no waste, no moving parts, no emissions, less transportation costs, not requiring water during power production and has no adverse effects on the environment[1].

The sun is the source of almost all energy for all living beings on earth.The suns core is so hot and compressed that large amount of hydrogen atoms turn into helium, in a process called nuclear fusion. This transformation produces massive amounts of energy. A little amount of suns energy comes to earths surface and this amount is estimated as $10^{18} kWh/a$ [2].

PV modules are essentially large area p-n junctions. When light shines on them, they can produce current which is directly proportional to the incident radiation[3].

Bangladesh is a land of area 147,570sq km with its 160 millions people and increasing every year, resulting in a considerably high electricity demand each year. As a result, Bangladesh experiences unmanageable shortage of electricity every year especially in summer. Over 70% of Bangladesh lies outside the national grid[4]. Bangladesh is situated between latitudes 24.20°N and 25.35°N and longitudes 88.20°E and 89.30°E which is an ideal location for solar energy utilization[5]. Daily average solar radiation varies between 4 to 6.5kWh per square meter[6]. So solar energy can be used as an alternative source not only to get rid of everyday load shedding miseries but also to reduce the power shortage.

II. Modeling of the PV cell

A PV cell is basically a silicon semiconductor junction device that contains a p-n junction similar to a diode. It generates electricity proportional to the incident sunlight. The equivalent circuit of a simple PV cell can be modelled by a current source in parallel with a diode, a shunt resistance expressing a leakage current and a series resistance describing an internal resistance to the current flow as depicted in Figure 1[7]

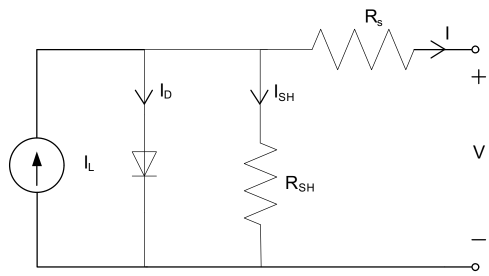

Figure 1. Electrical model of PV cell.

The photocurrent I_L of the PV cell is directly proportional to the solar insolation. The output current I of the cell is $I = I_L - I_D - I_{SH}$ .As $R_{SH} \approx \infty$,so $I_{SH} \approx 0$.

$$I = I_L - I_D \tag{1}$$

If I_S is the saturation current of the diode then,

$$I_D = I_S[e^{[\frac{q*(V+IR_S)}{nkt}]} - 1] \tag{2}$$

Thus the equations for the I-V characteristics of the PV cell are:

$$I = I_L - I_S[e^{[\frac{q*(V+IR_S)}{nkt}]} - 1] \tag{3}$$

$$I_L = I_L(T_1)(1 + K_0(T - T_1)) \tag{4}$$

$$I_{L(T1)} = G * I_{SC(T1,nom)}/G_(nom) \tag{5}$$

$$K_0 = (I_{SC(T2)} - I_{SC(T1)})/(T_2 - T_1) \tag{6}$$

$$I_S = I_{S(T1)} * (T/T_1)^{3/n} * e^{-qVg/nk*(1/T-1/T1)} \tag{7}$$

$$I_{S(T1)} = I_{SC(T1)}/(e^{qVoc(T1)/nkT1} - 1) \tag{8}$$

$$R_S = -dV/dI_{Voc} - 1/X_V \tag{9}$$

$$X_V = I_{S(T1)} * q/nkT_1 * e^{qVoc(T1)/nkT1} \tag{10}$$

Here n is known as diode quality factor which is 1 for ideal diode. R_S is a small resistance which represents internal losses due to current flow. The Boltzmanns constant,

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$k = 1.380658 * 10^{-23} JK^{-1}$. A real PV cell is characterized by the following electrical parameters[8]:

Short circuit current: Current that flows when $V = 0$ .It is due to the generation of light generated carriers. For an ideal PV cell $I_{SC} = I_L$ .Therefore, it is the largest amount of current which can be drawn from the PV cell.

Open circuit voltage: Maximum voltage available from a PV cell when $I = 0$ .The voltage of a PV cell at night is termed as V_{OC} . Mathematically,

$$V_{OC} = nkT/q * ln(I_L/I_S + 1) \quad (11)$$

Here nkT/q is the thermal voltage and T is the absolute temperature of the PV cell.

Maximum power point: Operating points that provides maximum output power. Mathematically,

$$P_{max} = V_{max} * I_{max} = V_{OC} * I_{SC} * FF \quad (12)$$

Here FF is the fill factor.

Efficiency: Determined as the fraction of incident power which is converted to electricity.

$$\eta = P_{max}/P_{incident} = V_{max} * I_{max}/P_{in} \quad (13)$$

Fill factor: It is the ratio of the maximum power from the PV cell to the product of V_{OC} and I_{SC}. Expressed as:

$$FF = P_{max}/V_{OC} * I_{SC} = V_{max} * I_{max}/V_{OC} * I_{SC} \quad (14)$$

Fill factor is determined from measurement of the I-V curve and for good PV cells its value is greater than 0.7.

In our experiments, we use Solarex MSX60 60W PV module to examine the performance parameters at different locations. This module consists of 36 multi-crystalline silicon solar cells configured as two series strings of 18 cells each. When light incidents on it, it produces photocurrent, I_L directly proportional to the solar irradiation. A Matlab program was developed for implementing the model of this PV module. This program calculates the current I using typical electrical parameters of the module and the variable voltage V , irradiation G and temperature T.

TABLE I
TYPICAL ELECTRICAL CHARACTERISTICS OF MSX60 60W PV MODULE

Parameter	Value
Maximum power P_{max}	60W
Voltage at P_{max}, V_{max}	17.1V
Current at P_{max}, I_{max}	3.5A
Minimum P_{max}	58W
Short-circuit current I_{SC}	3.8A
Open-circuit voltage V_{OC}	21.1V
Temperature coefficient of I_{SC}	$(0.065 \pm 0.015)\%/°C$
Temperature coefficient of V_{OC}	$-(80 \pm 10)mV\%/°C$
Temperature coefficient of power	$-(0.5 \pm 0.05)\%/°C$
$NOCT^3$	$47 \pm 2°C$
Maximum system voltage	600V
Maximum series fuse rating	20A

III. AVERAGE SOLAR RADIATION IN BANGLADESH

The average solar radiation in Bangladesh is sufficient enough to keep significant contribution in country's energy supply. Twenty-two years average solar radiation data according to NASA Surface Meteorology and Solar Energy website[9] is analysed to find out the variation of solar radiation in Bangladesh. Figure 2, Figure 3, Figure 4 show the average solar radiation during summer (March-June), monsoon

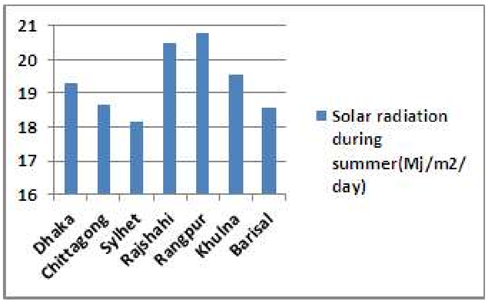

Figure 2. Solar Radiation during March-June in Bangladesh.

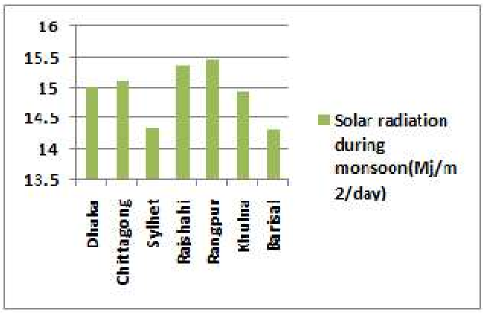

Figure 3. Solar Radiation during July-October in Bangladesh.

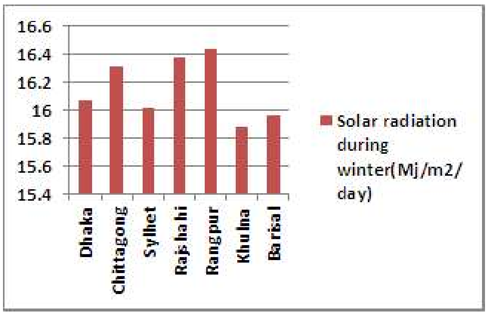

Figure 4. Solar Radiation during November-February in Bangladesh.

(July-October) and winter (November-February) respectively in seven different divisions of Bangladesh.

If we merge the three figures, we can see that the average solar radiation of Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Khulna and Barisal are 16.799MJ/ m^2/day, 16.695MJ/ m^2/day, 16.171MJ/ m^2/day,17.414MJ/ m^2/day,17.555MJ/ m^2/day, 16.788MJ/ m^2/day and 16.285MJ/ m^2/day respectively. The comparison between the maximum solar radiation and the minimum solar radiation throughout the country shows that the Rangpur and the Rajshahi divisions have more solar radiation than the others. But Dhaka and Chittagong have less solar radiation variation throughout the whole year than the other divisions. Comparatively less variation in solar radiation helps to design PV module with less battery storage capacity and hence the cost of the module reduces[2]. Solar radiation is at its highest values during summer (March-June) and at its lowest values during monsoon (July-October). The maximum values of radiation for Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Khulna and Barisal are 19.302MJ/ m^2/day, 18.671MJ/ m^2/day, 18.153MJ/ m^2/day, 20.494MJ/ m^2/day, 20.762MJ/ m^2/day, 19.535MJ/ m^2/day and 18.559MJ/ m^2/day respectively and should be taken as the input of the PV cell during summer

(March-June). Similarly, the minimum values of radiation for Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Khulna and Barisal are 15.025MJ/ m^2/day, 15.103MJ/ m^2/day, 14.343MJ/ m^2/day, 15.379MJ/ m^2/day, 15.466MJ/ m^2/day, 14.939MJ/ m^2/day and 14.325MJ/ m^2/day respectively and should be taken as the input of the PV cell during monsoon (July-October). Again, the middle values of the radiation for Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Khulna and Barisal are 16.071MJ/ m^2/day, 16.313MJ/ m^2/day, 16.019MJ/ m^2/day, 16.373MJ/ m^2/day, 16.442MJ/ m^2/day, 15.881MJ/ m^2/day and 15.967MJ/ m^2/day respectively should be taken as the input of the PV cell during winter (November-February).

IV. Simulation Results

The output power of a PV cell varies with the variation of solar irradiation when temperature is fixed and the characteristic of output power varies with the variation of ambient temperature when solar irradiation is fixed.For our research, we are interested to see the performance parameters of MSX60 in seven different divisions for three different seasons: Summer (March-June), Monsoon (July-October) and Winter (November-February).

It has been found that the average temperature in Dhaka is 28°C during summer and from figure 2,the average solar radiation is 224watt/ m^2. The average temperature and the average solar radiation are 27.9°C and 217watt/ m^2 respectively during summer in Chittagong. The average temperature and the average solar radiation are 27°C and 211watt/ m^2 respectively during summer in Sylhet. The average temperature and the average solar radiation are 29°C and 238watt/ m^2 respectively during summer in Rajshahi. The average temperature and the average solar radiation are 27°C and 240watt/ m^2 respectively during summer in Rangpur. The average temperature and the average solar radiation are 29.1°C and 227watt/ m^2 respectively during summer in Khulna. The average temperature and the average solar radiation are 28.4°C and 215watt/ m^2 respectively during summer in Barisal.

Similarly, it has been found that the average temperature in Dhaka is 29°C during monsoon and from figure 3, the average solar radiation is 174watt/ m^2. The average temperature and the average solar radiation are 28.3°C and 175watt/ m^2 respectively during monsoon in Chittagong. The average temperature and the average solar radiation are 28°C and 166watt/ m^2 respectively during monsoon in Sylhet.

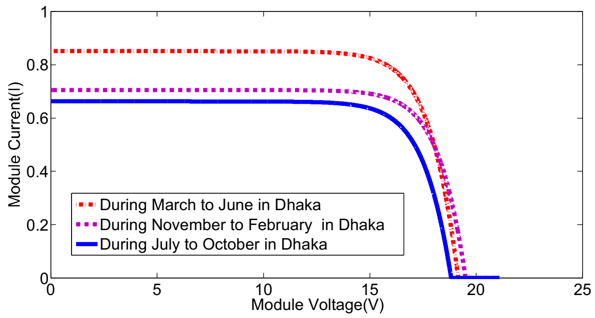

Figure 5. Simulated V-I curve of MSX60 for Dhaka

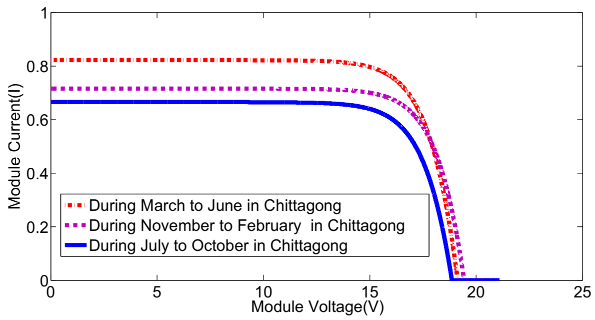

Figure 6. Simulated V-I curve of MSX60 for Chittagong.

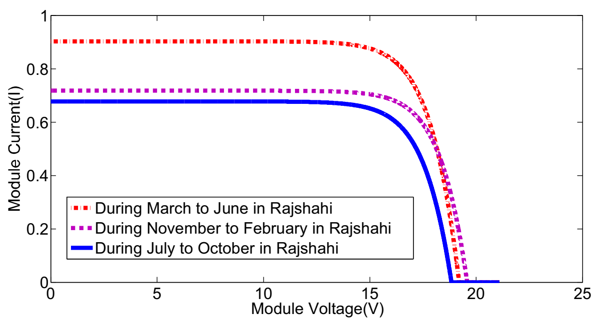

Figure 7. Simulated V-I curve of MSX60 for Rajshahi.

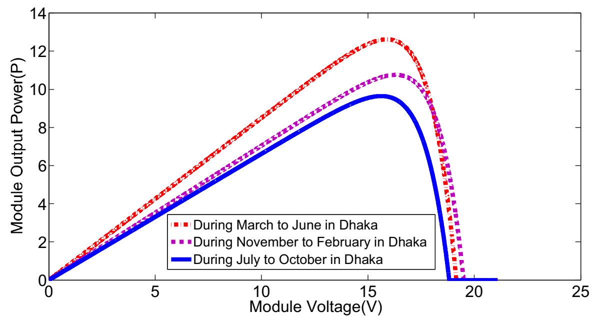

Figure 8. Simulated P-V curve of MSX60 for Dhaka.

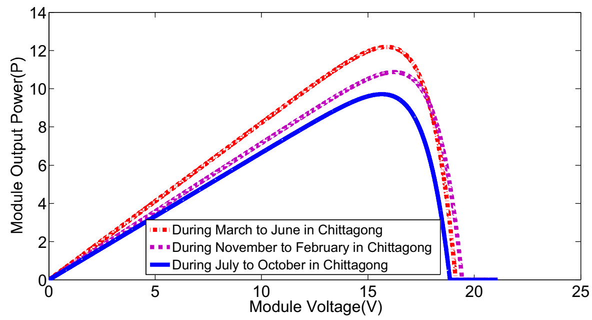

Figure 9. Simulated P-V curve of MSX60 for Chittagong.

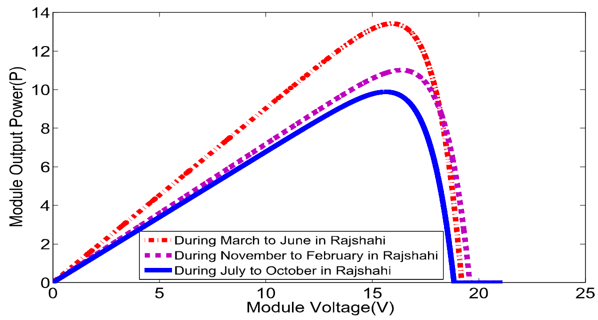

Figure 10. Simulated P-V curve of MSX60 for Rajshahi.

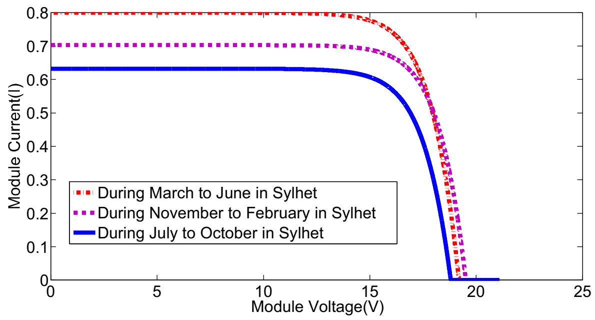

Figure 11. Simulated P-V curve of MSX60 for Sylhet.

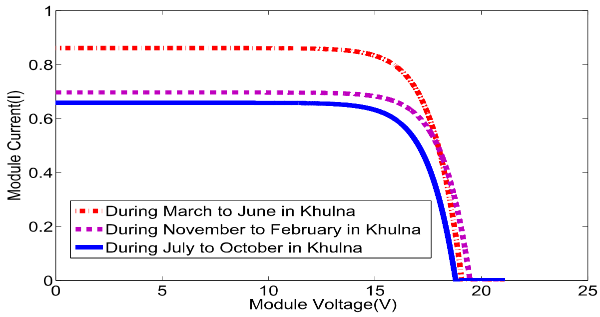

Figure 12. Simulated V-I curve of MSX60 for Khulna.

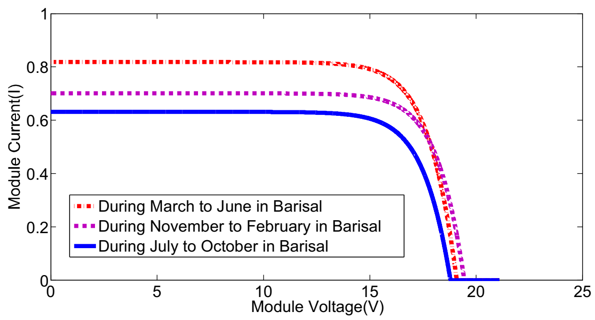

Figure 13. Simulated V-I curve of MSX60 for Barisal.

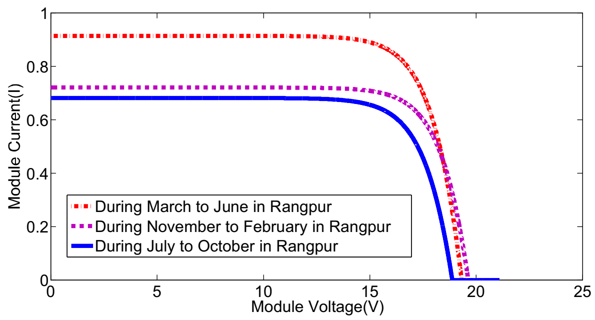

Figure 14. Simulated V-I curve of MSX60 for Rangpur.

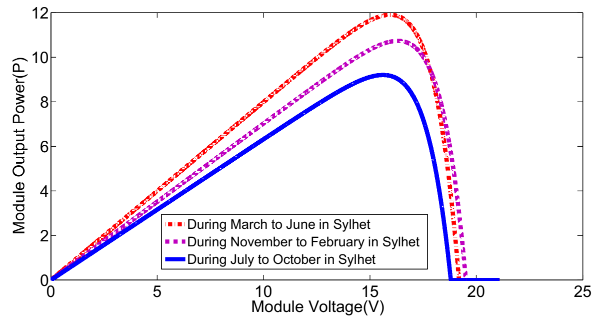

Figure 15. Simulated V-I curve of MSX60 for Sylhet.

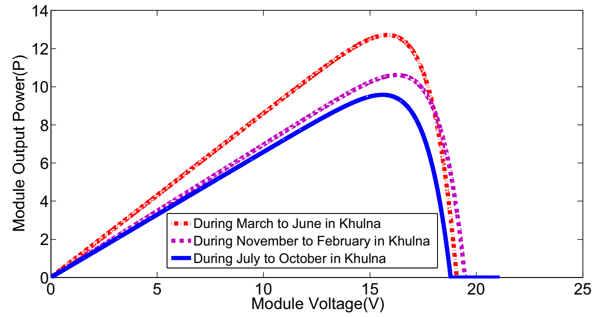

Figure 16. Simulated P-V curve of MSX60 for Khuna.

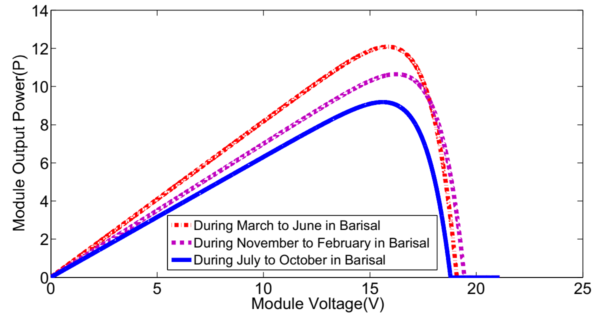

Figure 17. Simulated P-V curve of MSX60 for Barisal.

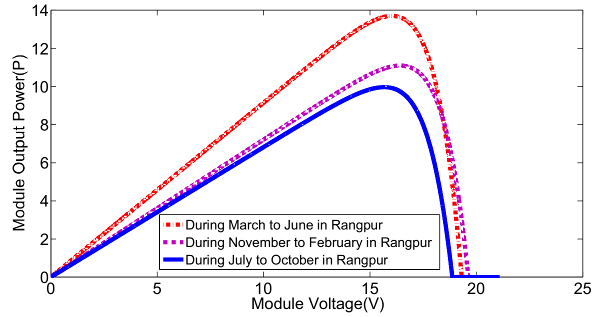

Figure 18. Simulated P-V curve of MSX60 for Rangpur.

The average temperature and the average solar radiation are 28.9°C and 179watt/ m^2 respectively during monsoon in Rajshahi. The average temperature and the average solar radiation are 28.5°C and 180watt/ m^2 respectively during monsoon in Rangpur. The average temperature and the average solar radiation are 29°C and 173watt/ m^2 respectively during monsoon in Khulna. The average temperature and the average solar radiation are 28°C and 167watt/ m^2 respectively during monsoon in Barisal.Again, it has been found that the average temperature in Dhaka is 21.1°C during winter and from figure 4, the average solar radiation is 187watt/ m^2. The average temperature and the average solar radiation are 22°C and 189watt/ m^2 respectively during winter in Chittagong. The average temperature and the average solar radiation are 21°C and 186watt/ m^2 respectively during winter in Sylhet. The average temperature and the average solar radiation are 20.4°C and 190watt/ m^2 respectively during winter in Rajshahi. The average temperature and the average solar radiation are 20°C and 191watt/ m^2 respectively during winter in Rangpur. The average temperature and the average solar radiation are 21.4°C and 184watt/ m^2 respectively during winter in Khulna. The average temperature and the average solar radiation are 22°C and 185watt/ m^2 respectively during winter in Barisal. Figure 5 and Figure 8 demonstrate the current-voltage curve and power-voltage curve of MSX60 influenced by solar radiation and temperature of Dhaka. Similarly, Figure 6 and Figure 9, Figure 7 and Figure 10, Figure 11 and Figure 15, Figure 12 and Figure 16, Figure 13 and Figure 17, Figure 14 and Figure 18 demonstrate the corresponding similar aspects of Dhaka for Chittagong, Rajshahi, Sylhet, Khulna, Barisal and Rangpur.

V. Analysis on the System Performance

Performance of the module varies due to environmental parameters such as solar radiation, temperature and weather conditions. We considered the average solar radiation of day and night. If we consider only the day time then the performance of the PV cell will increase significantly as average solar intensity becomes higher at the day time. The maximum average solar radiation of day and night is 203.67watt/m but if we consider only day time then it will be about 1100watt/m[10]. So the output power of the PV cell will be maximum at that time, but the average output power will be lesser than that.

From our experimental results, we analyse the solar insolation and the temperature data for seven divisions of Bangladesh during summer (March-June), monsoon (July-October) and winter (November-February). For the maximum performance we can take Rangpur and Rajshahi division as the reference, where the maximum output of MSX60 is found when the module output voltage is around 16V and the maximum output power is about 14watts during summer. Compared to Rangpur and Rajshahi, Dhaka, Chittagong and Khulna have lower maximum power output estimated about 13watt during summer. And the lowest power is found in Sylhet and Barisal having about 12watt during summer.

During winter the output power is lower than the summer and during monsoon it becomes the lowest. During winter the maximum power of Rangpur and Rajshahi is about 12.5watt. And the maximum power of Dhaka, Chittagong and Khulna are about 11.5watt while the maximum power of Sylhet and Barisal is about 10.5watt during winter. Again, during monsoon the maximum power of Rangpur and Rajshahi divisions are about 11watt. And the maximum power of Dhaka, Chittagong and Khulna are about 10watt while the maximum power of Sylhet and Barisal is around 8.5watt during monsoon.

Here it is observed that the variation of maximum output power is less in Dhaka and Chittagong divisions throughout the year which is very helpful to design PV module with good battery storage capacity. But we get maximum power output in Rangpur division and Rajshahi division during March-June. Thus if we can maintain good battery storage capacity of PV modules then both Rangpur and Rajshahi division are recommended places to implement large numbers of solar PV modules.

VI. Conclusion

We analyse the performance of a typical 60W PV module of MSX60 throughout Bangladesh. The V-I curves and maximum power outputs are determined in different divisions of Bangladesh. Every time the maximum power output is found in voltage around 16V. We should mention that for maximum power at most of the time of the day the Maximum Power Point Tracking (MPPT) system should be introduced[11]. From the output result we can see that the variation of current and power is less in Dhaka and Chittagong divisions. So large scale PV system can be introduced in these two regions as less variation in current and power is helpful for good storage design. Also Rangpur and Rajshahi divisions are preferable if we can maintain good storage system.

This paper is an important step to install a complete Photovoltaic system in Bangladesh. A good PV system will provide clean energy as well as it will lessen the power crisis in Bangladesh.

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A Hybrid of 30 KW Solar PV And 30 KW Biomass System for Rural Electrification in Bangladesh

Sayed Ahammad
Technical Procurement
Electricity Generation Company of Bangladesh Ltd.
Dhaka, Bangladesh
Email: eeesumon03@gmail.com

Alimul Haque Khan, Tabassum E Nur & Sanchita Ghose
Electrical and Electronic Engineering
Bangladesh University
Dhaka, Bangladesh
Email: alimul_buet@yahoo.com

***Abstract*—This paper is mainly addressing the design and analysis of a hybrid Solar and Biomass System for rural electrification in a remote area in Bangladesh by Decentralized Distributed Generation & Rural Power Distribution Management. Energy is crucial input in the process of economic, social and industrial development. Energy plays a vital role in our daily life. But the conventional source of energy to produce electricity is decreasing day by day significantly. In this regards non-conventional or renewable energy resources such as bio-energy, Solar, Wind, Ocean and Geothermal are taking this challenge. A large proportion of the world's population lives in remote rural areas and far away from grid. The installation and distribution costs are considerably higher for remote areas. Moreover, there is greater transmission line losses and poor supply reliability. There is growing interest in harnessing renewable energy sources since they are available in abundance, pollution free and inexhaustible. Not only that, The combining of technologies means Hybrid technology provides interesting opportunities to overcome certain technical limitations and to mitigate fuel price increases, deliver operating cost reductions, and offer higher service quality than traditional single-source generation systems. A hybrid system is a dynamic system that exhibits both continuous and discrete dynamic behavior a system that can both flow and jump.**

Keywords*—hybrid solar & biomass design, renewable energy, carbon trading

I. INTRODUCTION

Bangladesh is a developing country in the southern Asia of Asian Country. Bangladesh, with its 152 million people in a land mass of 147,570 sq km, has shown tremendous growth in recent years. A booming economic growth, rapid urbanization and increased industrialization and development has increased the country's demand for electricity. Presently, 62% [1] of the total population (including renewable energy) has access to electricity and per capita generation is 321 KWh [2], which is very low compared to other developing countries. The power supply is not sufficient to meet the peak demand in Bangladesh. In the rural areas, only about 25 percent population have grid electricity connection where about 75 percent of that out of grid electricity. At this time, the country is facing a dour electricity exigency due to growth of almost each and every sector. According to the Rural Electrification Board in Bangladesh the present peak and off peak hour the scarcity of electricity is almost 15-20 percent of generation. Due to the limitations of use natural fuels and also the shortage of fossil fuels, the government already has focused on the renewable energy and about its technology and hybrid system.

II. SOLAR TECHNOLOGY

Sun is the primary source of energy. It is renewable, inexhaustible and environmental friendly. Bangladesh is blessed with large amount of sunshine all the year with an average sun power of 500W/m2/day [3] [4]. There are a variety of technologies that have been developed to take advantage of solar energy. Name of Some Technologies are :

1) Concentrating Solar Power (CSP)
2) Solar Photovoltaic (PV)
3) Solar Thermal
4) Solar Fuels

The major components of the system are PV modules, dc to dc converter, battery and inverter. The capacity of these components can be determined by estimating the load to be supplied. The basic unit of photovoltaic technology is photovoltaic or solar cell. A typical crystalline silicon (c-Si) PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer (100 - 350 microns) of boron-doped (P-type) silicon. An Electrical field is created where the these two materials are in contact, called P-N junction and the direction of Electric Field from n to p side. When sunlight strikes the surface of a PV cell, Each photon frees exactly one electron which is directed by the electric field and flows toward the load. Multi or Poly crystalline silicon solar cell is more widely used due to lower cost of manufacturing and ease of availability. PV panel manufacturers generally guarantee 90% of initial performance after 10 years and 80% after 25 years [5].

Solar cells are generally very small, and each one may only be capable of generating a few watts of electricity and voltage of around 0.6V. About 40 or 60 or 72 cells are typically connected in series to make a module. Typical output range of a module from 100 W to 360 W, but most commonly used wattage is 245-250 W in a 60 cell configuration. The modules are in turn assembled into PV arrays up to several meters on a side.

A. Storage Battery

A rechargeable battery, storage battery, or accumulator is a type of electrical battery. It comprises one or more electrochemical cells, and is a type of energy accumulator. The lifespan of the battery depends on many parameters related to the way they are operated and to external conditions, in

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particular the ambient temperature. For instance, typical lead-acid batteries designed for solar energy applications will lose between 15% to 20% of their lifespan [3] [5] the number of charge/discharge cycles they can perform) for each 5C above the standard temperature of 25C. In addition, the deeper the battery is discharged at each cycle (depth of discharge), the shorter its lifespan. This implies that to reach an optimal battery lifespan, one has to install a large enough battery to achieve a suitable depth of discharge. Considering the battery cost (around 20% to 30% of total system cost), we need to provide good attention to select it.

B. Charge Controller

Charge controller, otherwise called as charge regulator, is the core of every solar system, and is required to monitor and control the flow of power into and out of the battery. It also regulates the power flow from solar panel to the battery to ensure that the battery is not overcharged. It disconnects the loads when the battery voltage fall below a critical voltage. The charge controller must also ensure that the connected loads do not over-discharge the battery, thereby damaging it. Most "12 volt" panels batteries need around 14 to 14.5 volts to get fully charged.

The rectifier and charge controller component should be chosen so that both the PV and the genset can charge the battery. The rated charging current should match the battery maximum charge current. The charge controller should be able to manage the various charge steps, including regular equalization and float charge to maximize battery lifespan.

C. Solar Inverter

A solar inverter is used to convert the DC output of a solar panel into a utility frequency alternating current that can be fed into a grid. Battery backup inverters are special inverters which are designed to draw energy from a battery, manage the battery charge via an on-board charger, and export excess energy to the utility grid. Solar inverters are used for other purposes like maximum power point tracking and anti-islanding protection. An inverters lifespan can extend to more than ten years, but this component is a high-technology product and the replacement of a failing component has to be undertaken by a technician from the supplying company.

D. Biomass Power Plant

Using biomass solely for electricity generation is seen as an inefficient use of biomass. Typically overall efficiency of Biomass Steam Turbine Power Plant is 18% 24%. Only a small portion of the total energy created from burning biomass actually gets converted into electricity. Combustion of biomass produces heat, which is used to generate steam, which in turn rotates a turbine to create electricity.

When steam passes through a turbine it only loses a portion of its thermal energy. When it exits the turbine it still has a relatively high thermal energy and normally this heat is vented to the atmosphere through smoke stacks. Combined heat and power systems (CHP) focus on capturing this heat and using it for productive purposes [6]. By attaining a higher efficiency in energy creation, CHP can result in energy cost savings, waste heat reduction and lower CO_2 emissions. Processing plants that require high amounts of heat and electricity such as pulp and paper mills are ideal for this application. The key to a successful CHP plant is that there must be a demand for the heat that is captured from the electricity generating process. Biomass particles size ranges varies from 5 cm to few mm. The feedstock should preferably be free due to the heat needed to vaporize the water within the particle; however maximum moisture content up to 30% to 50%.

III. Analysis and Design Result a Typical Context of Power Needs in Rural Areas

The typical load curve for a rural village is generally composed of a prominent peak in the evening corresponding to lighting use, a morning/midday peak, and a base load. The base load is generally present in the morning, and in some cases extends to night hours. In many cases the peak load is two to five times higher than the highest power level of the base load. The energy demand in rural areas during night hours is quite limited (or non-existent in small villages) and hence the load level during the night is generally very low compared to the evening and morning peaks. This is shown in Tabel I.

TABLE I: Load Estimation

Details	Number	Rating (Watt)	Total Load (Watts)	Hrs of Operation	Energy (WH)
Compact fluorescent lamps (18W)	450	18	8100	12	97200
Fan	150	70	10500	12	126000
TV	50	80	4000	6	24000
2-Pin	150	150	22500	6	135000
Water Pumps	8	1500	12000	6	72000
Street Light (TFL)	30	30	900	12	10800
		Total	58000		465000

A. Plant Capacity and Energy Forecast

The Required Plant Capacity is 60 KW from this typical solar biomass hybrid system shown in Fig. 1. The total units that will be consumed per day are 465.0 KWh or Units. The target is to generate 200 Units by Solar Plant % 300 units by Biomass. (Assuming Daily Operation Hour of Biomass Plant is 12 to 14 Hrs). About 150 Units fo energy will be stored in the Battery Bank to meet demand at Night.

B. Design for Solar Plant

The design consideration of Solar PV power plant is given below:

- Total watt = 30 KW
- Total Watt Hours = 200 KWh
- Solar Irradiation= 5.00 (For Bangladesh) [3] [4]

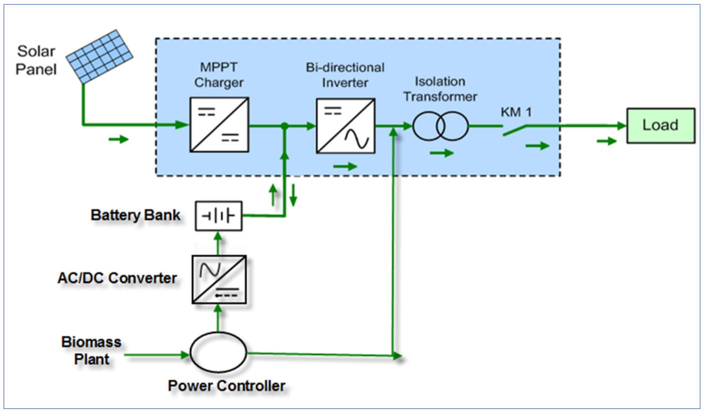

Fig. 1: Block Diagram of Solar-Biomass Hybrid System.

- AC Cable loss= 1%
- Inverter efficiency= 89%
- Diode and Connection Loss=0 .5%
- DC wiring loss= 2%
- Soiling efficiency= 96%
- System availability = 99%
- Temperature increase loss= 4%
- Battery efficiency= 85% [Typical value are taken]. Thus, considering these above loss, final efficiency of this system= 66%.
- Solar Panel Capacity Required $= \frac{Watt\ Hours}{System\ Efficiency \times Solar\ Irradiation} = \frac{200000}{66\% \times 5}$ $= 60640\ Watts$
- Panel Rating Selected= 240 W
  Therefore, the number of Panel/Module is required = (60640/240) = 253.

C. *PV Array Sizing and Characteristics*

For PV array sizing, PVsyst has been used here [7]. The literature covered by [10] [9] are also another strong basement of this calculation. Here, Poly crystalline silicon solar cell and 60 cells Module/Panel has been considered with specification of

- Power, $P = 230 - 250W$
- Open circuit voltage $V_{oc} = 36 - 37V$
- Voltage at maximum power point, $V_{mpp} = 29.5 - 30V$
- Short circuit current, $I_{sc} = 8.75A$
- Current at maximum power point, $I_{mpp} = 8.0A$

11 Modules will be connected in series (Say, These makes a row), Then such kind of 23 rows will be connected in parallel and make an Array. The series parallel combination of solar PV module is shown in Fig. 2.
Area Required for PV Array: $20 \times 60 sq\ meter$ (Including 70% Spacing within each Module, Module Size: $1m \times 1.6m$).
Operating Characteristics:

- $Vmpp = 330V(11 \times 30V)$
- $Impp = 184A(23 \times 8A)$
- $Voc = 407V(11 \times 37V)$
- $Isc = 201A(23 \times 8.75A)$

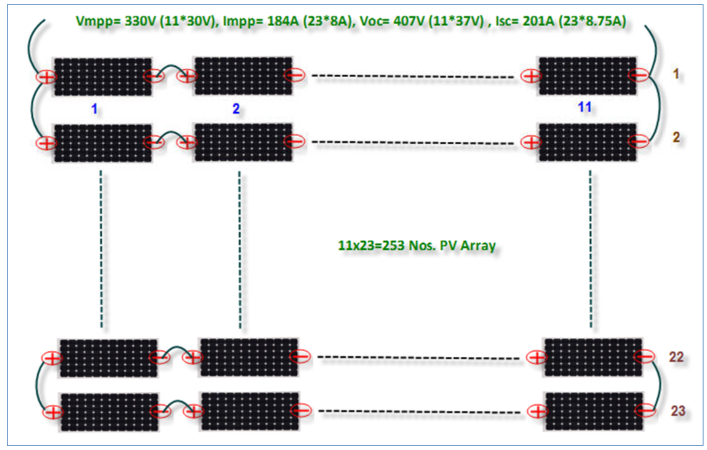

Fig. 2: Series Parallel Combination of Solar PV Module

D. *Inverter Size*

Total Watt Required = 30 KW. It is good practice to oversize the inverter from the actual requirement. Thus, the inverter size will be equal to $30 \times 1.3 = 40KW$. Output of Inverter= 415V AC, 3Phase, 40 KVA pure sine wave inverter is recommended in other to prolong the lifespan of the inverter.

E. *Battery Size*

For a storage of 150 Units of energy at Battery for Night and autonomy of one day. Specificatio of the battery is as follows:

- Inverter efficiency= 89%
- Battery loss= 85%
- Depth of discharge= 60%,
- Battery Voltage (Volts) = 240V
- The size of battery $= \frac{150000KWh}{0.89 \times 0.85 \times 0.6 \times 240V} = 1377Ah$. Counting the safety margin, the battery could be selected as 1500Ah, 2V instead of 1377 Ah.
- Total number of battery required $= \frac{240V}{2V} = 120$
- Each battery dimension $= L \times W \times H = 8.27in \times 10.8in \times 32.7in$
- Maximum charging current= $185A$.
- Area required for battery, excluding spacing is $100in \times 108in \times 32.7in$.

F. MPPT Charge Controller

The rated charging current should match or close to the battery maximum charge current. The design consideration of $30KW_p$ solar PV power supply,

$$P = VI \quad (1)$$

Where,

- I is the expected charging current
- V is the voltage of the battery
- P is the power supply rating= 30KW

Hence $I = P/V = 30000/240 = 125Amps$, which is less than the Maximum grid charging current of Battery.Thus, a rating with 125 Amps charging controller has been selected to charge the battery banks.

G. Biomass Requirement and Resource Availability

The target is to generate 300 units (KWh) of energy from 30KW Biomass Plant. Assuming daily operation hour of biomass plant is 12 to 14 Hrs,

- Overall system efficiency $= 18\%$[6]
- Calorific value of biomass $= 4000Kcal/kg = 16800KJ/Kg.[Note : 1Kcal = 4.2KJoule]$
- input energy for 1KWh of output energy is $= \frac{1KWh}{22\%} = 5.55KWh = 2 \times 10^4 KJ.$
  Note: $1KWh = 1KW \times 3600second = 3.6 \times 10^3 KJ$
- For 1 KWh generation, Biomass is needed per hour is $= \frac{2\times10^4 KJ}{16800KJ/Kg} = 1.19Kg.$
- For 10 Hours effective operation (300 KWh generation), Biomass Requirement is$= 1.19Kg\ per\ KWh \times 300KWh = 357Kg$

H. Simple Pay Back Period from Hybrid System

In calculation of Simple Pay Back Period from Hybrid System,the followings are assumed.

- Total Installation Cost: $Tk.35,00,000 + Tk.96,00,000 = Tk.1,31,00,000.$
- Selling Rate of Per Unit Cost (to Government)$= Tk.12/unit.$
- Per Year Generation = $1,82,500Units$ [1,09,500 Units by Biomass & 73,000 Units by Solar]
- Fuel Cost/per Unit= $1.18kg/KWh \times Tk.2.00/kg = Tk.2.36/unit.$
- Maintenance Cost for Biomass Plant = $Tk.3,50,000.$
- Maintenance Cost for Solar Plant = $Tk.96,000$
- Total Return= $Tk.[(12\times1,82,500)(2.36\times1,09,500+3,50,000+96,000)] = Tk.14,85,580(\$18,570)$
- Simple Pay Back Period (S.P.B) $= \frac{1,31,00,000}{14,85,580} = 8.82\ years$ (It could be assumed as 10 years)

Here, Government needs to pay Tk. 12 ($0.15) /unit from Hybrid System, whether normally Government has to pay around Tk. 20 ($0.25) /unit from Diesel/ Heavy Fuel Oil (HFO) System [12]. The summary of Biomass plant and PV power plant are shown in Table II and Table III.

TABLE II: SUMMARY OF BIOMASS PLANT

Plant capacity	30KW
Cost of installation	Tk 35,00,000 ($ 43,750)
Maintenance cost	Tk 3,50,000 ($ 4,375)
No of consumers	150
Operation hours	12~14 hrs
Fuel Requirement	1.19 kg of crop/kWh
Cost of fuel	Tk 2.00/kg ($ 0.031)
Operating period	20 years

TABLE III: SUMMARY OF SOLAR PV POWER PLANT

Plant capacity	30KW
Cost of installation	Tk 96,00,000 ($ 1,20,000)
Maintenance cost	Tk 96,000 ($ 1200)
No of consumers	150
Operation hours	6.0~7.0 Hrs
Operating period	20 years

IV. CARBON REDUCTION POTENTIAL

A Carbon Credit is a generic term for any tradable certificate or permit representing the right to emit one tonne of carbon dioxide or the mass of another greenhouse gas with a carbon dioxide equivalent (tCO_2e) equivalent to one tonne of carbon dioxide [4] [8]. Certified Emission Reductions (CERs) are a type of emissions unit (or carbon credits) issued by the Clean Development Mechanism (CDM) Executive Board for emission reductions achieved by CDM projects and verified by a DOE under the rules of the Kyoto Protocol. The design considerations are:

- CO_2 emission from Biomass per unit generation (During Construction & operation) = 7 tons/TJ= 26 gram/Kwh; [1tons/TJ= 3.612 g/Kwh]
- CO_2 emission from solar pv plant per unit generation [During Construction % operation] = 20 tons/TJ = 72 gram/kwh.
- Generated power from biomass per year $= 300X365 = 1,09,500KWh.$
- Per year we can generated power per year $= 200X365 = 73,000KWh.$
- CO_2 emission from biomass per year $= 1,09,500 * 0.026kg = 2.85\ tons/year = 2.85\ Carboncredit.$

- CO_2 emission from Solar PV per year $= 73,000 * 0.072 = 5.25\ tons/year = 5.25\ Carboncredit$.
- From total hybrid system, the carbon emitted per year $= 2.85 + 5.25 = 8.10\ tonnes/year$

TABLE IV: EMISSION OF CO_2 PER YEAR & THE POSSIBILITY OF EARNING MONEY

CO_2 emission Rate	**Carbon credit /Per year (tonnes/ year) for 1,82,500 KWh Generation**	**Money will be earned through carbon credits ($) per year N.B: CER Rate $0.70**	**Average money ($) can be earned through carbon credits per year**
From Coal: 1400 gram/ KWh	[(1400*1,82,500)/1000000] =255.5	[(255.5-8.10)*0.70] =173	128
From Oil: 1150 gram/ KWh	209.9	141	
From Natural Gas: 600 gram/ KWh	109.5	79	

Installed Off-Grid Solar PV System in Bangladesh [11] in shown in Table V.

TABLE V: INSTALLED OFF-GRID SOLAR PV SYSTEM IN BANGLADESH

Name of Solar PV System (Off-Grid)	**Capacity**	**Installed Year**	**Total Cost per Watt (Tk/Wp)**
32.75 kWp at WAPDA Building, Dhaka.	32.75 kWp	December' 2009	BDT 500 Tk./ Wp
20.16 KWp Solar PV System at the Office of the Prime Minister, Dhaka.	20.16 kWp	December' 2009	BDT 500 Tk./ Wp
37.5 kWp Solar Roof Top System on15th floor of Bidyut Bhaban, Dhaka.	37.5 kWp	2011-2012	BDT 300 Tk./ Wp
27.2 kWp Solar Power System at Chandpur 150 MW Combined Cycle Power Plant.	27.2 kWp	2012-2013	BDT 300 Tk./ Wp

If the same energy ($1,09,500KWh + 73,000KWh = 1,82,500KWh$)/per year is generated through conventional energy resources like coal, Gas, Oil etc. Then carbon dioxide emitted per year & the possibility of earning money (approximate and average) through carbon credits per year are given in Table IV.

Therefore, it seems that the total cost [installation & Operation] for an off-Grid Solar PV system [including Battery System] is decreasing gradually.

V. CONCLUSION

There are many remote villages in Bangladesh which are far away from the main grid so those are still un-electrified. Due to the distance problem, losses increases and installation cost for transmission and distribution line goes high. This paper discussed the renewable hybrid system with solar PV and biomass which helps in overcoming all these problems in a cost effective way. In this paper the load requirement of this village is calculated and in order to satisfy this load the energy requirement is predicted. As we know that the reserve natural gas in Bangladesh is diminishing quickly, Government should take proper steps to promote the renewable energy activities. Both sun light and the biomass are available in Bangladesh abundantly. It can be concluded that solar and biomass hybrid system is a viable green technology source for rural electrification.

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Design of High Efficient and Stable Ultra-Thin CdTe Solar Cells with ZnTe as a Potential BSF

Mrinmoy Dey[1*], Maitry Dey[2], M. A. Matin[1], Nowshad Amin[3, 4]

[1]Department of Electrical and Electronic Engineering, Chittagong University of Engineering and Technology, Chittagong-4349, Bangladesh

[2]Department of Electrical and Electronic Engineering, Premier University, Chittagong-4203, Bangladesh

[3]Solar Energy Research Institute (SERI), The National University of Malaysia, 43600 Bangi, Selangor, Malaysia

[4]Department of Electrical, Electronic and Systems Engineering, The National University of Malaysia, 43600 Bangi, Selangor, Malaysia

[*]mrinmoycuet@yahoo.com

***Abstract*—The polycrystalline ultra-thin cadmium telluride (CdTe) is familiar as the potential solar cell material for its higher efficiency, cost-effective, cell stability and clean generation of solar electricity. In this study, a numerical analysis has been performed utilizing AMPS (Analysis of Microelectronic and Photonic Structures) simulator to examine the cell performances (*Voc*, *Jsc*, FF and conversion efficiency) of ultra-thin CdTe solar cell. During the research, reduction of CdTe layer was done in the proposed cell and found that 1µm absorber layer is enough for acceptable range for cell conversion efficiency. The possibility of this ultra-thin CdTe absorber layer was examined, as one with 100 nm ZnTe back surface field (BSF) layer to minimize the recombination losses at the back contact and to reduce the barrier height in the valence band of the proposed cell. Higher conversion efficiency of 22.53% (*Jsc* = 24.28 mA/cm^2, FF = 0.875, *Voc* = 1.06 V) has been achieved with only 0.8 µm of CdTe absorber layer along with 100 nm ZnTe BSF where as conversion efficiency is 18.68% (*Jsc* = 21.47 mA/cm^2, FF = 0.85, *Voc* = 1.02 V) without BSF layer. Moreover, the proposed CdTe solar cell showed better stability as the normalized efficiency of the proposed cell linearly decreased with the increasing operating temperature at the gradient of -0.16%/°C.**

Keywords—Ultra-thin, AMPS, Solar cell, ZnTe BSF, Stability.

I. INTRODUCTION

Cadmium Telluride (CdTe) is recognised as leading candidate for efficient, cost-effective and stable solar cells for thin film technology. The CdTe is a II-VI compound semiconductor material with a direct band gap of 1.45 eV which is very close to the optimum band gap for solar cells and it has a high absorption co-efficient over 5×10^5/cm. The challenges of the improvement of cell efficiency, material usages and the thermal stability of the solar cell can be analyzed by numerically to explore the hidden potentiality of the CdTe solar cell for higher cell performance.

The thickness of approximately 2µm CdTe thin film solar cell will absorb nearly 100% of the incident solar radiation. CdTe technology has another advantage as its flexibility to the method of manufacture. Polycrystalline layers of a CdS/CdTe cell can be deposited by using a variety of low cost techniques, such as close-spaced-sublimation (CSS), physical vapour deposition (PBD), chemical bath deposition (CBD) and magnetron sputtering. The highest theoretical efficiency for CdTe is about 29% at standard solar spectrum. In 1972 Bonnet et al. published their landmark paper on CdTe thin film solar cell reporting an efficiency of 6% [1]. An efficiency of 15.8% was attained in 1993 by Ferekides et al. [2]. First Solar announced a world record for CdTe photovoltaic solar cell achieving conversion efficiency of 21.5 % [3].

Polycrystalline n-CdS (2.42 eV) window layer is chosen by many researchers as it is the best suited hetero-junction partner with p-CdTe absorber layer. This research work motivates ultra-thin CdS/CdTe solar cells with the insertion of BSF layer for higher conversion efficiency. Usually, Cu is used as a back contact material but it leads to the degradation of efficiency with time due to Cu diffusion to the front contact. It was found from the research work that the insertion of suitable BSF was more effective when numerically applied to the champion and baseline case CdTe solar cells with thinner absorber layer. As a result, BSF was inserted to the proposed cell and found very much promising results to implement of the ultra-thin CdTe solar cell.

Many researchers are trying to increase the conversion efficiency of CdS/CdTe solar cells using different BSF in between absorber layer and back contact. These BSF are Sb_2Te_3 as discussed by Bätzner et al. [4], As_2Te_3 as discussed by Romeo et al. [5], Cu_2Te as discussed by Hossain et al. [6], PbTe as discussed by Matin and Dey [7], GeTe as discussed by Dey et al. [8]. The specific BSF material preferred in this work is Zinc Telluride (ZnTe) to investigate its hidden potentiality for CdTe solar cell.

In this research work, numerical analysis was done by utilizing well known AMPS simulator [9] to explore the possibility of ultra-thin CdS/CdTe cell with ZnTe BSF layer to improve cell performances of the CdTe solar cells. It was showed from numerical analysis that less than 1 µm CdTe absorber layer with ITO/Zn_2SnO_4 front contact, CdS as window layer and ZnTe as BSF material are suitable materials for high efficient (22.53%) ultra-thin and stable CdS/CdTe cell.

II. MODELING AND SIMULATION

AMPS-1D program is used in worldwide to design solar cell structure by more than 200 groups [10]. The baseline structure of CdTe cell was utilized to estimate the highest efficiency of CdS/CdTe solar cell and it was modified to investigate the possibility of efficient ultra-thin solar cells with suitable BSF inclusion. In this work, numerical modeling and simulation were done by using AMPS-1D simulator to explore the effect of ZnTe BSF insertion on ultra-thin CdTe solar cell. The baseline structure of CdTe solar cell proposed by Gloeckler was initially modified by adding an extra layer of Zn_2SnO_4 between SnO_2 (TCO) and CdS layer [11].

In this research work, the first modification in the typical CdS/CdTe cell was to reduce CdS layer to 80 nm with Zn_2SnO_4 buffer layer. The second modification was to change the CdTe doping concentration to ~10^{17} cm^{-3} which is now achievable for p-CdTe absorber layer material. The second last modification is to reduce the CdTe absorber layer thickness to the extreme limit for achieving ultra-thin CdS/CdTe solar cell. The last modification was the placing of ZnTe BSF to reduce the minority carrier recombination loss at the back contact of the ultra-thin CdS/CdTe solar cell.

The conventional structure of CdTe solar cell is illustrated in Fig.1 and the modified proposed ultra thin CdTe solar cell (Glass/SnO_2/Zn_2SnO_4/CdS/CdTe/ZnTe/Ni) structure for higher cell performance is shown in Fig. 2.

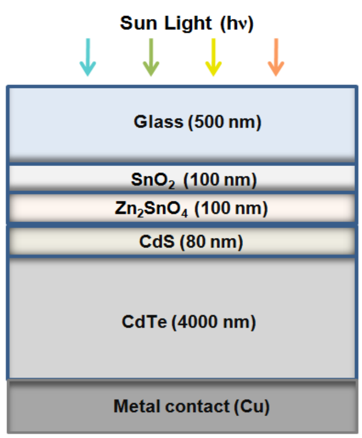

Fig.1 The conventional structure of the CdTe solar cell

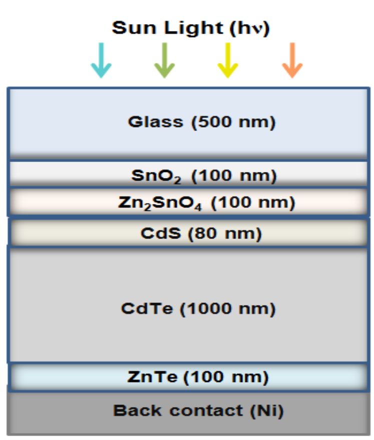

Fig.2 The proposed structure of CdTe solar cell

In this analysis, the four layers of the proposed cell are n-Zn_2SnO_4 buffer layer, n-CdS window layer, p-CdTe absorber layer and p-ZnTe BSF layer. This modified modeling showed the possibility of getting a higher performance (around 22%) CdS/CdTe solar cell consists of 100 nm of Zn_2SnO_4, 80 nm of CdS, 1 µm of CdTe and 100 nm of ZnTe BSF layer. The number of parameters that can be varied is larger than 50 in numerical analysis of a particular solar cell model [12]. As a result, a problem related to design with 50 variables is too uncertain to solve reliably without the help of computer. At the same time, it is necessary to minimize the number of variable parameters at reasonable values by fixing many of them though it is really dispute to select the practically achievable parameters for different layers of the proposed cells. Many of the parameters depend on fabrication techniques and deposition methods and can thus vary even between devices fabricated in the same batch from the same technology.

In this work, Table I shows the used material parameters, which were selected based on experimental data, literature values or in some cases reasonable estimations [13].

TABLE I THE MATERIAL PARAMETERS USED FOR THE NUMERICAL ANALYSIS OF THE PROPOSED CELLS

Parameters	n-CdS	p-CdTe	ZnTe
Thickness, W (µm)	0.08	0.1-2.9	0.1
Permittivity, ε/ε0	9	9.4	14
Electron mobility, µc (cm^2/Vs)	350	500	70
Hole mobility, µp (cm^2/Vs)	50	60	50
Carrier concentration, n, p (cm^{-3})	1×10^{17}	1×10^{17}	7.5×10^{19}
Band gap, Eg (eV)	2.42	1.45	2.25
Density of state in conduction band, Nc (cm^{-3})	1.8×10^{19}	7.5×10^{17}	1×10^{16}
Density of state in valence band, Nv (cm^{-3})	2.4×10^{18}	1.8×10^{18}	1×10^{17}
Electron affinity, χ (eV)	4.50	4.28	3.65

III. RESULTS AND DISCUSSION

A. *Absorber Layer Optimization*

In this study, the starting point was a three layer device model (SnO_2/CdS/CdTe) structure of the CdTe baseline case [13]. The increasing value of *Jsc*, FF and *Voc* causes the improvement of cell conversion efficiency of the proposed cell. Researchers kept the CdTe absorber layer is around 5 µm or above in most highly performance CdS/CdTe solar cells. As a result, further numerical analysis was done with the proposed cell to reduce the thickness of CdTe absorber layer in order to preserve the usages of CdTe materials and the cost of the fabricated cells in the end.

Several research groups all over the world interested much to manufacture CdS/CdTe cells with thinner CdTe absorber layer as its lower production cost and consequently time and energy. In a typical CdTe solar cell structure, the absorber thickness is usually keep over 5μm. 80% of the CdTe material could be saved if the thickness of CdTe material reduction from 5 μm to less than 1 μm and the film deposition rate can be kept unchanged. Then the deposition time and energy could be at least four times lower. Therefore, thinner solar cells are produced without compromising much with their performance and it leads to manufacture of lower cost solar cell devices since they require less materials, less fabrication time and energy. Thus, a new configuration with ZnTe BSF could be implemented in the CdS/CdTe solar cell structure to restrain the possible recombination losses at the back contact of such ultra-thin CdTe absorber layer.

B. ZnTe BSF Layer Insertion

In order to reduce the possible recombination loss and the barrier height at the back contact of ultra-thin CdTe solar cell, a medium band gap (Eg) material ZnTe (Eg = 2.25 eV) was placing at the back contact caused reduction of back surface recombination rate at the CdTe/ZnTe interface. This medium band gap material would act as a BSF to bounce back the carriers (electrons) from the CdTe/ZnTe junction and thus would contribute in the enhancement of carriers.

From the numerical analysis, all the layers of the solar cell structure are similar to the previous optimized cell except an additional 100 nm ZnTe BSF layer just before the final back contact metal of the proposed modified cell. Now the modified cell with the entire cell parameters of Table I were simulated along with 100 nm Zn_2SnO_4, 80 nm CdS, 1 μm CdTe and 100 nm ZnTe BSF layers. The AMPS simulated results are shown in Table II to compare the cell performances together with thermal stability with and without BSF layer.

It is apparent from Table II that the proposed cell without BSF shows conversion efficiency of 18.68% whereas the conversion efficiency increased to 22.43% with the placing of 100 nm ZnTe BSF layer in between absorber layer and final back contact metal.

TABLE II THE OUTPUT PARAMETERS OF PROPOSED CELLS WITHOUT BSF LAYER AND WITH BSF LAYER

Parameters \ Structures	Base Case	ZnTe BSF
Open circuit voltage, *Voc* (V)	1.02	1.05
Current density, *Jsc* (mA/cm^2)	21.470	24.348
Fill factor, FF	0.850	0.872
Efficiency (%)	18.68	22.43
Temp. co-efficient (%/°C)	-0.18%	-0.16%

Table II shows that the proposed modified cell structure with ZnTe BSF have higher *Voc*, *Jsc* and FF compare with the same cell structure without BSF because of reduced back surface recombination and improved back contact formation with p-CdTe. Simulated J-V characteristics of both the cells are shown in Fig. 3 to analysis the cause of higher CdS/CdTe solar cell performance.

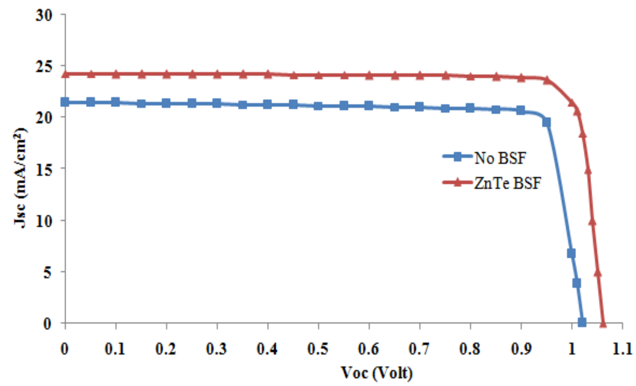

Fig.3 J-V characteristics of the proposed cells

Calculations have been carried out for the CdS/CdTe/ZnTe configuration to find the effect of reduction in thickness of CdTe absorber layer with BSF insertion. In Fig. 4, the simulation results for variation of CdTe absorber layer thickness from 0.1 μm to 4 μm with and without 100 nm ZnTe BSF layer are shown together for comparison of the cell performance parameters.

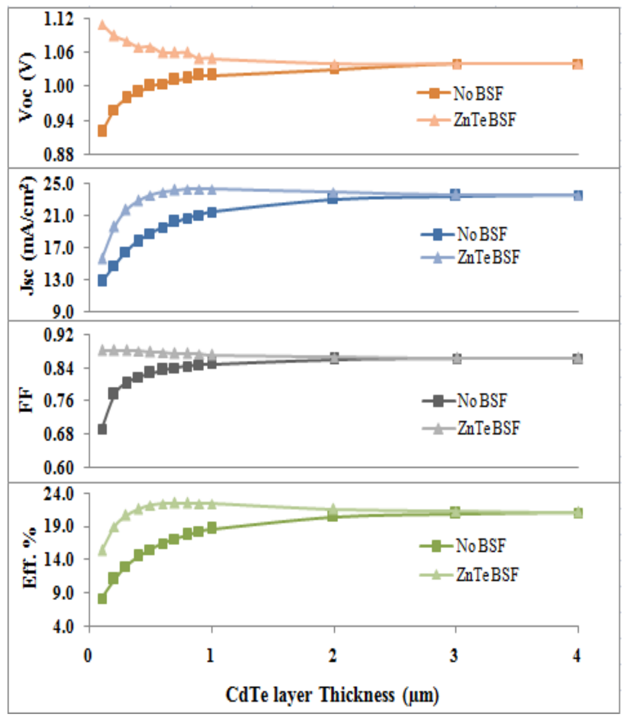

Fig.4 Effect of the CdTe thickness variation for the proposed cells with and without ZnTe BSF

It is seen from the Fig. 4, both *Voc* and FF show decreasing trend for the cell without BSF whereas the *Voc* and FF show increasing trend with decrease of the CdTe layer thickness in the presence of highly doped ZnTe BSF. In fact, the increase of *Voc* and FF both has the largest contribution to improve the efficiency of ultra-thin CdTe solar cell in this numerical analysis. These results of cell performances with the insertion of BSF layer are agreeable to the related published works [7, 8]. In this work, the CdTe solar cell conversion efficiency showed highest value of 22.53% (*Jsc* = 24.28 mA/cm^2, FF = 0.875, *Voc* = 1.06 V) at 0.8 μm of CdTe absorber layer with ZnTe BSF layer.

C. *Effect of Operating Temperature*

The operating temperature plays a very important role in practical case and it affects the cell performances of the solar cell. The stability of the proposed cells at higher operating temperatures can be investigated with ZnTe BSF placing. At higher operating temperature, parameters such as the electron and hole mobility, carrier concentration, density of states and band gap of the materials are affected. In order to investigate the effects of higher operating temperature on the performances of the solar cells with ZnTe BSF, simulations were carried out with cell operating temperature ranging from 25°C to 145°C and the simulated results are shown in Fig. 5.

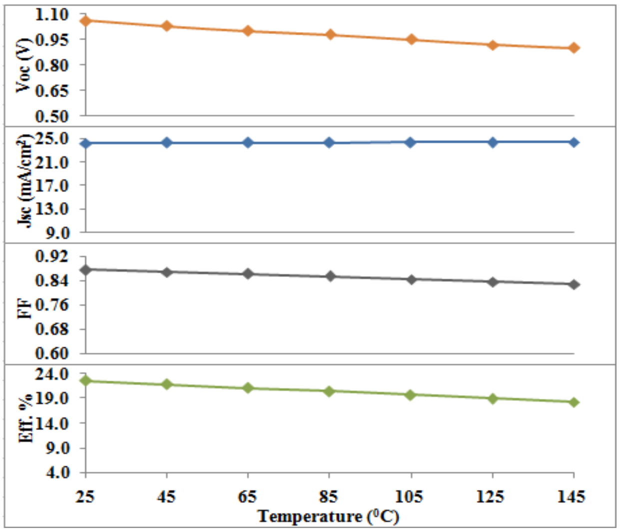

Fig.5 Effect of temperature on cell performances

It is obvious from Fig. 6 that without BSF layer and with ZnTe BSF layer, the normalized efficiency of the cells linearly decreased with the increase of operating temperature at a temperature coefficient (TC) of -0.18%/°C and -0.16%/°C respectively. This TC indicates better stability of the cells with BSF at higher operating temperature, which are in good agreement with related published works [7,8].

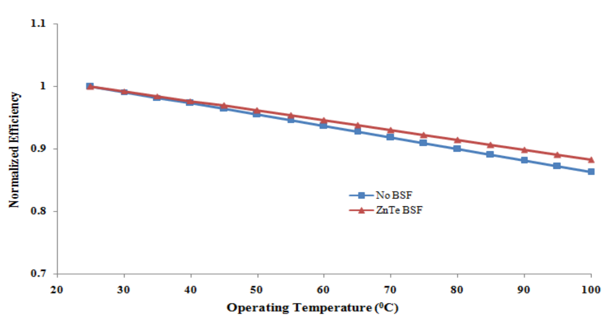

Fig.6 Effect of operating temperature on normalized efficiency

IV. CONCLUSION

The potential BSF material ZnTe was investigated for the possible BSF effect in ultra-thin CdTe cell with an insertion of 100 nm BSF layer, the highest efficiency was found where the ZnTe BSF with 0.8 μm CdTe absorber layer showed the best conversion efficiency of 22.53% (Jsc = 24.28 mA/cm^2, FF = 0.875, Voc = 1.06 V). It was found from the CdTe baseline case cell (SnO_2/CdS/CdTe) structure that 1 μm thick CdTe absorber layer is possible with acceptable range of efficiency of 18.68% (Jsc = 21.47 mA/cm^2, FF = 0.85, Voc = 1.02 V) without BSF layer. The thermal analysis of the proposed cells with ZnTe BSF layer showed better stability at higher operating temperatures with a linear TC of -0.16%/°C whereas proposed cell without BSF having TC of -0.18%/°C.

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