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Implementation Procedure and Financial Model of Solar Mini grid at Rural Areas in Bangladesh

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Abstract

In rural areas, effective implementation of PV systems increase the quality of life, generate income, improve children education by providing good quality of light and reduce health hazard and risk of fire by reducing kerosene burning. Around 1.4 million solar home and 10,000 PV micro utility systems are installed in the rural areas of Bangladesh by February 2013 by various installers. Under the PV micro utility model, an entrepreneur installs the PV system at his own premise and shares the electricity generated with his neighbors. This paper discuss about the implementation procedure and financial model of PV Mini grid at rural areas for further expansion and upgrading of PV systems in Bangladesh. It is understood that appropriate policy towards PV micro/mini utility, initiative to available PV accessories locally within the country and proper monitoring and dedicated maintenance support can make PV micro utility program more successful in Bangladesh like SHS.

Keywords: PV Mini grid, Bangladesh, Implementation model, Recommendation for further expansion

1. Introduction

The Government of Bangladesh has its vision and policy to bring the entire country under electricity service by the year 2020 [1] currently, In Bangladesh, only about 47% of the population has access to grid electricity [2]. The present installed electricity generation capacity is about 6837.50 MW. The per capita electricity consumption in Bangladesh is 182 kWh p.a. that is still among the lowest in the world [2]. Currently, the country is facing huge electricity shortage because of high demand of electricity. Bangladesh could not increase the generation of electricity much during the last few years due to shortage of natural gas and weak policies favoring electricity production. According to the Bangladesh Power Development Board, the present peak hour shortage of electricity is around 15-20% of generation [6]. This shortage is 44 % according to the recent report of World Bank[3].

Solar photovoltaic appear to be the only appropriate options for renewable electricity generation in Bangladesh. The daily average solar radiation varies between 4 and 6.5 kWh/m^2 [4] SHS project has been implemented under Infrastructure Development Company Limited (IDCOL) and till now around 1.4 million solar home systems and 10, 000 PV MU systems are installed in Bangladesh [5]. Rural electrification through solar PV technology is popular in Bangladesh. Solar program mainly targets those areas, which have no access to conventional electricity and have little chance of connecting to the grid within 5 to 10 years.

PV systems increase the quality of life, generate income, improve children education by providing good quality of light and reduce health hazard and risk of fire by reducing kerosene burning. Effective implementation of SHS can contribute toward the poverty alleviation as well [6, 7]. These PV systems in Bangladesh are also feasible both technically and financially [8, 9]. Around 47% people have the access of electricity in Bangladesh and per capita electricity use is 183 kWh p.a. [2]. At the time, 41.2% people are poor 9.3% are very poor [10]. During field visit, users were asked about their interest to buy individual PV system. Most of the users reported that they did not want to maintain individual solar system if they have good quality source of power as they did not have grid electricity. So, it is obvious that the PV micro/mini utility system still has huge potential in the rural villages of Bangladesh. Especially in the places where there is no possibility to obtain grid electricity in the next 10-15 years. This paper discusses about the implementation procedure and financial model of PV mini grid

in Bangladesh. Recommendation for further expansion and upgrading also described with the implementation model.

2. Research Methodology

A field visit was done from October 2011 to January 2012 to collect the data from filed and field survey was followed by the interview and discussion with the different SHS and PV micro utility installer (Grameen Shakti, BRAC and RSF and CMES Bangladesh) to get the authentic data. Secondary data are also collected from related websites as well. Based on the survey future implementation model of PV mini grid in the rural areas are discussed along with the financial model. Recommendations for further expansion and up gradation are also talked about based on survey.

3. Implementation of PV mini grid in Bangladesh

Government of Bangladesh has the vision to provide electricity to all its citizens by 2021. To full fill this vision, the government has the plan to produce 500 MW power from solar energy by 2015. But this plan will not be successful without proper policy and plan about PV micro and mini grid.

Figure 1: (a) 1.8 KW PV AC systems at Jhenaidah (b) 10 kW PV project at Rangamati

Past experience of GS and CMES, suggest that it is very difficult to install and maintain PV MU systems without help from the government. There are so many risks involved such as possibility of grid electricity and users discontinuation after buying individual systems. Till now there is only policy for SHS, but no policy about solar micro and mini grid. CMES installed PV MU system at around 15 market places of Bangladesh but most of them stopped after 3 to 4 years. Only one project ran for 08 years. Availability of grid electricity and individual SHS were the main reasons of failure of those projects.

The Local Government Engineering Department (LGED), Bangladesh installed 1.8 KW PV AC systems at Gangutia under Shoilkupa Upozila in Jhenaidah district under SRE project from donor support (Figure1a) [11]. The project was basically a non profitable and installed for demonstration purpose. Users were paying minimal monthly rent just for the maintenance of the system. But problem arose when needed to replace battery as it involved huge cost. And, the question was that who would go for finance for this replacement. Bangladesh Power Development Board (BPDB) has installed three 10 KW project in the CHT region (Figure 1b) in Bangladesh and the purpose was again to demonstrate, and not to make profit. During field visit in one of this project at Borokal, Rangamati, it was found that users were paying only 60 BDT/month/light. Most importantly, project was out of service during the field visit due to the problem about the inverter. Local technician of the project reported that they needed to wait until new inverter arrives.

In Bangladesh, still there are many places like *char* (places within the river) and hilly areas where grid electricity will not be possible by next 15-20 years. So, the government should think of appropriate policies to implement PV micro and mini grid by private sector as like SHS under IDCOL.

The government already has plans about PV mini grid with the help of ADB as shown in figure 2. According to the model, electricity from the solar module will be sent to a controller and from which electricity will go to the grid through inverter. For night time use, access electricity from the controller will go to battery. Street lighting, houses, small industry and even water treatment plant for the rural villagers can be included as load for the grid. Prequalification of potential investors will be made and tender document will be issued to a prequalified investors. Power division will select one investor for each place through an open and competitive bidding process. Power cell will prepare bidding documents and select RAPSS (Remote Area Power Supply System) operator. RAPSS operator will be enlisted with IDCOL as partner organization (PO) to access loan and grant facilities of this program. Figure 3 shows the implementation process of solar mini grid in Bangladesh. IDCOL will receive low interest loan for mini grid from the RAPSS fund to execute this program. Government of Bangladesh will establish this fund by receiving contribution from development partners, government resources,

repayment of loan made from the RAPSS fund and any other donation from individuals, enterprises, institution, agencies, sharing development funds available in other sectors etc.

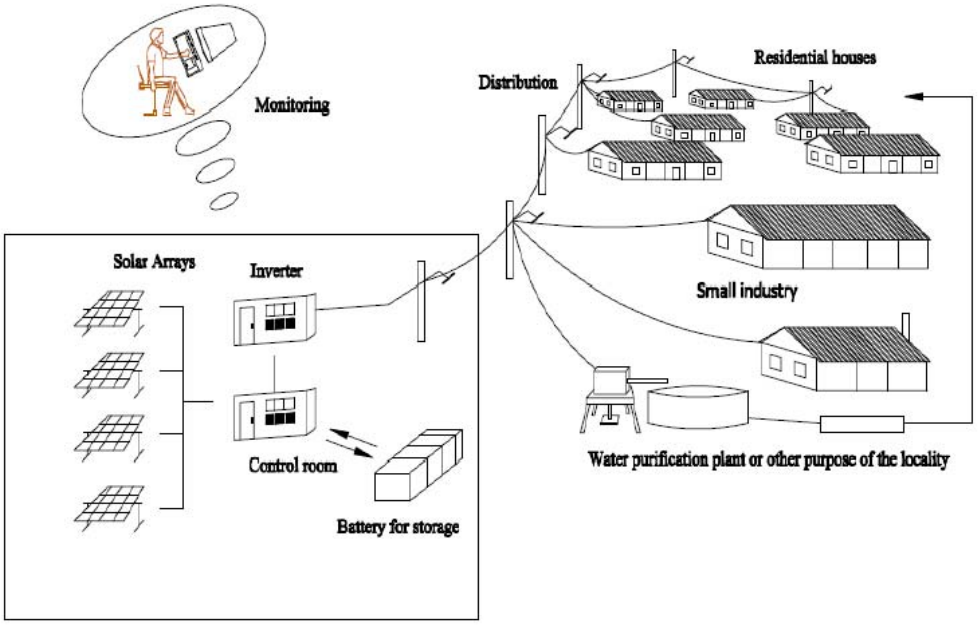

Figure 2: Solar village electrification model by using mini grid

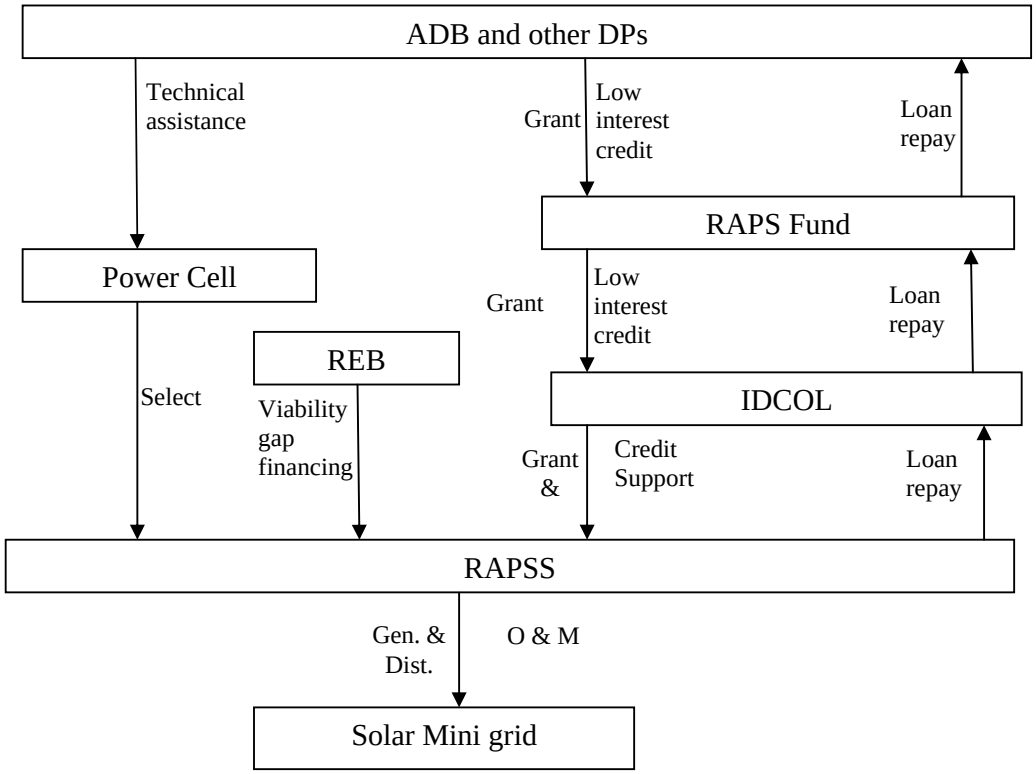

Figure 3: Solar mini grid implementation model

RAPSS operator will generate electricity and supply it to the customers as determined by the government. They will also collect the monthly bills from the customers. IDCOL will provide necessary financial and promotional support to the POs for successful implementation of the program. Besides, since the offered tariff will be higher than the average retail electricity price, the government will provide subsidy through REB. So, it is necessary to complete the feasibility study and implement the plan as early as possible. There will be another revolution about solar PV implementation in Bangladesh if this policy is successful.

4. Recommendations for further expansion and upgrading

4.1 Appropriate initiative to available PV accessories locally within the country and control cost:

Along with PV micro/mini grid, at present, the government should also think about appropriate policies to produce all the PV equipments within the country.

Currently, except for solar Panel all other equipments are produced within the country. Though in the last 5 years, the cost of PV panel has reduced significantly but the cost of PV in Bangladesh varies with dollar as panels are imported. During the last 5 years, the dollar rate increased by around 16% and that has affected the cost of PV panel. There is no company producing PV cell in Bangladesh. Some companies like Baneco Solar Energy, Ava Renewable energy, Electro Solar and Green Infinity Ltd are assembling solar module/ panels importing PV cell from China, Germany, Taiwan, India, etc. Raihm Afrooz Renewable is also trying to assemble solar panel but all these efforts could not reduce the cost of PV panel as their cost is almost same as imported panel. The government should try to help to produce PV cell within the country. On the other hand, all the equipments cost are increasing except solar PV. Battery cost increased 87.5% from year 2003 to 2007 [6]. Other cost like overhead, transportation and cost of installation has also increased significantly. So, the government should make a policy through IDCOL to make available of all the quality accessories locally and control the cost of equipments.

4.2 Different type of packages for PV MU:

There are no POs except GS in Bangladesh that offer PV MU system in the rural villages of Bangladesh. Laos is one of the good examples of solar PV application and Sunlabob is the main installer of solar PV in Laos, like GS in Bangladesh.

Sunlabob currently has three attractive packages for PV MU namely Sale, Rent and management under solar community systems. Detail on this has been described already in the section 2.1. Under these packages users can be the owner or just user and users can take the responsibility of maintenance or not. So, user cans choose according to their affordability and desire. These packages are very popular in Laos [12]. Such possibilities and options could also be made available for Bangladeshi users/customers.

4.3 Proper panel orientation

Improper panel orientation can reduce the panel output significantly. It was observed that in the whole country, the standard of 23^0 inclination angle was followed [13]. But the latitude of Bangladesh varies from around 20 degree 34 minute to 26 degree 38 minute [10].

Table 1: Latitude of the major places of Bangladesh with the proposed inclination angle

Place	Latitude (Google Earth, 2012)	Proposed
Rangpur	25 degree 52 minute	25 degree
Dinajpur	25 degree 37 minute	
Sylhet	24 degree 54 minute	
Mymensingh	24 degree 45 minute	
Rajshahi	24 degree 22 minute	24 degree
Gazipur	23 degree 59 minute	
Dhaka	23 degree 42 minute	
Chadpur	23 degree 13 minute	23 degree
Khulna	22 degree 49 minute	
Barishal	22 degree 42 minute	
Rangamati	22 degree 42 minute	
Bhola	22 degree 41 minute	
Chittagong	22 degree 22 minute	

The latitudes of the major places of Bangladesh are shown in table 1. The proposed inclination angle is also shown in the table. Latitude of Rangpur district is 25 degree 52 minute where as it is 22 degree 22 minutes for Chittagong. So, it is better to divide the country in to three or four zones and fix the inclination angle accordingly. IDCOL should change its regulation accordingly.

4.4 Way to use surplus energy

Three days autonomy is maintained in Bangladesh for the solar PV system design. These three days autonomy ensures electricity supply even in the rainy season and smoggy weather. But this kind weather appears only three/four times in year. Most of the time the sky is clear and sunshine hours are also reasonable. After full charging of battery, charge controller limits the current flow to the battery and a significant amount of energy is lost. Charge controller normally shows high, medium and low charge status of battery. During field visit, it was seen that, many user used small DC fan directly from battery without the permission from GS in the day time during summer when charge controller showed high charge region which was not good for battery.

Further thoughts and research are needed to use this extra energy which is otherwise lost. A little modification can be done in a charge controller so that user can use small DC fan or radio from charge controller when battery stops taking charge from controller.

4.5 Maintenance free battery

problems associated with batteries can be solved by providing maintenance free batteries. These kinds of batteries are sealed and there is no need to fill distilled water. According to manufacturers, life of maintenance free batteries is even more than the present batteries.

As cost is also similar to existing batteries, GS and other POs can go for maintenance free batteries. Most importantly, it has self protection from over discharge, so users need not send their battery for booster charge that needs normally 24 hours.

4.6 LED Lamp

Use of LED lamp in place of Fluorescent lamp could be another important improvement of PV MU systems in Bangladesh. A 50 W_p system can allow 08 (seven 2.5 W and one 5 W) LED lamps in place of current 04 fluorescent lamp.

4.7 **Proper monitoring and dedicated maintenance support**

Proper monitoring and dedicated maintenance is the key for expanding any new technology. Though most of the users were satisfied about the maintenance service, still some users were not happy about the maintenance service. Dust accumulation on panel was the common problem found in many case. Most of the market places are crowded and near roads and so dust accumulation rate in the panel were more than solar panel used at home. Mostly users of the system were not aware of that which leads to a low output of panel. After replacement, many user were found to use low quality local lamp from market which is not authorized by GS as GS bulb was a little bit costly than local bulb. Some users were also found to use inefficient mobile charger from local market without consulting with GS. Besides, corrosion in battery contact terminal was another problem found during field visit. Around 23% batteries had some corrosion in their contact terminal. Output of battery could reduce due to this. PV MU and SHS installer should provide a user manual for the client where all the dos and don'ts can be given clearly so that user can maintain the system properly. So, proper maintenance and monitoring systems should be enhanced by the system installer.

5. Conclusions

Solar home system is an established technology in Bangladesh. Around 1.4 million solar home systems are installed in the rural areas of Bangladesh. On the other hand PV micro utility systems are creating attention recently and 10,000 such systems are installed so far. Recommendations for further expansion and up gradation are discussed based on the experiences obtained from field visit. In Bangladesh, still there are many places like *char* (places within the river) and hilly areas where grid electricity will not be possible by next 15-20 years. So, the government should think of appropriate policies to implement PV micro and mini grid by private sector as like SHS under IDCOL. Bangladesh government is also thinking about PV micro and mini grid for further implementation of solar PV in Bangladesh. It was understood that appropriate policy towards PV micro utility, initiative to available PV accessories locally within the country and proper monitoring and dedicated maintenance support are the key essentials. Solar village electrification model with implementation model are

also discussed. It is suggested that KW range PV mini grid under the RAPSS can be successful for further expansion of PV systems in Bangladesh.

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Performance of Nanofluid with different Nanoparticles inside a solar collector

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Abstract

The forced convective flow and heat transfer characteristics of nanofluid inside a flat plate solar collector is analyzed numerically. The water- alumina/copper nanofluid and water-alumina nanofluid are used as the operational fluids through the fluid passing pipe of the solar collector. The governing partial differential equations with proper boundary conditions are solved by Finite Element Method using Galerkin's weighted residual scheme. The behaviors of nanofluids using both nanoparticles and single nanoparticle related to the performance such as temperature and velocity distributions, average heat transfer, collector efficiency, mean temperature and velocity are investigated systematically. These performances include the solid volume fraction namely ϕ of nanoparticles. The results show that the better performance of heat loss through the pipe of the flat plate solar collector is found by using the alumina and copper nanoparticles than only alumina nanoparticle.

Keywords: Forced convection, flat plate solar collector, finite element method, water based nanofluid with double nanoparticles.

1. Introduction

Of all the sources of renewable energy especially solar energy has the greatest potential when other sources in the country have depleted. Because of the desirable environmental and safety aspects it is widely believed that solar energy should be utilized instead of other alternative energy forms, even when the costs involved are slightly higher. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating climate change and keep fossil fuel prices lower than otherwise. These advantages are global. The fluids with solid-sized nanoparticles suspended in them are called "nanofluids". Applications of nanoparticles in thermal field are to enhance heat transfer from solar collectors to storage tanks, to improve efficiency of coolants in transformers.

There are so many methods introduced to increase the efficiency of the solar water heater by Xiaowu and Hua [1], Xuesheng et al. [2], Hussain [3] and Ho and Chen [4]. But the novel approach is to introduce the nanofluids in solar water heater instead of conventional heat transfer fluids (like water). The poor heat transfer properties of these conventional fluids compared to most solids are the primary obstacle to the high compactness and effectiveness of the system. The essential initiative is to seek the solid particles having thermal conductivity of several hundred times higher than those of conventional fluids. The suspended metallic or nonmetallic nanoparticles change the transport properties and heat transfer characteristics of the base fluid. Hwang et al. [5] studied the stability and thermal conductivity characteristics of nanofluids. In this study, they concluded that the thermal conductivity of ethylene glycol was increased by 30%.The absorptance of the collector surface for shortwave solar radiation depends on the nature and colour of the coating and on the incident angle. Usually black colour is used. Various colour coatings had been proposed in Tripanagnostopoulos et al. [6], Orel et al. [7] and Wazwaz et al. [8] mainly for aesthetic reasons. A low-cost mechanically manufactured selective solar absorber surface method had been proposed by Konttinen et al. [9]. The principal requirement of the solar collector is a large contact area between the absorbing surface and the air. Kent [10] studied laminar natural convection in isosceles triangular enclosures for cold base and hot inclined walls numerically. Nasrin et al. [11-12] analyzed effective heat transfer phenomena by different nanofluids on natural convection inside a solar collector.

From the literature review it is mentioned that no numerical or experimental work has been done introducing a nanofluid having different nanoparticles. In this paper, we investigate numerically the forced convection through the fluid passing pipe of a flat plate solar collector utilizing water based nanofluids having double nanoparticles

such as alumina and copper as well as single nanoparticle alumina. So, the objective of this article is to present flow and heat transfer phenomena by a nanofluid with two nanoparticles through a solar collector.

2. Problem Formulation

Fig. 1 shows a schematic diagram of a solar collector. The fluid in the collector is water-based nanofluid containing Al_2O_3 and Cu nanoparticles. The nanofluid is assumed incompressible and the flow is considered to be laminar. It is considered that water and all nanoparticles are in thermal equilibrium and no slip occurs among them. It is assumed that both the nanoparticles are spherical shaped and diameters are 5 nm. The density of the nanofluid is approximated by the Boussinesq model. The governing equations for steady laminar forced convection flow in terms of the Navier-Stokes and energy equation (dimensional form) are given as:

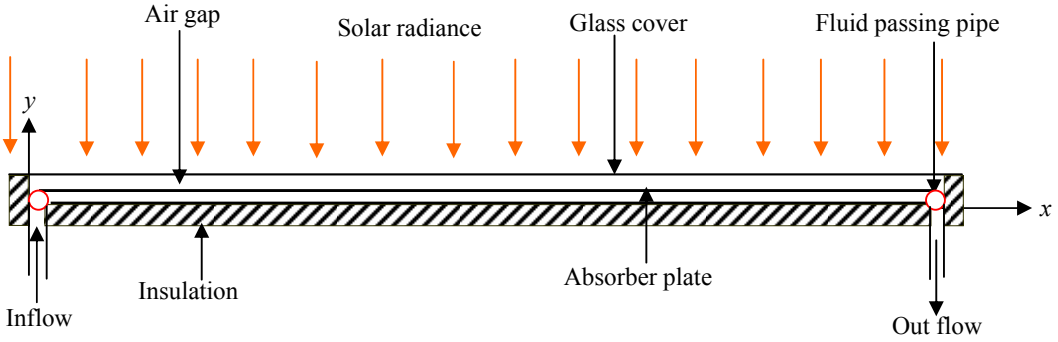

Fig. 1: Schematic diagram of the solar collector

The non-dimensional equations for forced convective flow are

$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}=0 \tag{1}$$

$$U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}=-\frac{\rho_f}{\rho_{nf}}\frac{\partial P}{\partial X}+\frac{1}{Re}\frac{\nu_{nf}}{\nu_f}\left(\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}\right) \tag{2}$$

$$U\frac{\partial V}{\partial X}+V\frac{\partial V}{\partial Y}=-\frac{\rho_f}{\rho_{nf}}\frac{\partial P}{\partial Y}+\frac{1}{Re}\frac{\nu_{nf}}{\nu_f}\left(\frac{\partial^2 V}{\partial X^2}+\frac{\partial^2 V}{\partial Y^2}\right) \tag{3}$$

$$U\frac{\partial \theta}{\partial X}+V\frac{\partial \theta}{\partial Y}=\frac{1}{Re\,Pr}\frac{\alpha_{nf}}{\alpha_f}\left(\frac{\partial^2 \theta}{\partial X^2}+\frac{\partial^2 \theta}{\partial Y^2}\right) \tag{4}$$

where $Pr=\frac{\nu_f}{\alpha_f}$ is Prandtl number, $Re=\frac{U_i L}{\nu_f}$ is Reynolds number, $\rho_{nf}=(1-\phi_1-\phi_2)\rho_f+\phi_1\rho_{s1}+\phi_2\rho_{s2}$ is density, $(\rho C_p)_{nf}=(1-\phi_1-\phi_2)(\rho C_p)_f+\phi_1(\rho C_p)_{s1}+\phi_2(\rho C_p)_{s2}$ is heat capacitance, $\alpha_{nf}=k_{nf}/(\rho C_p)_{nf}$ is the thermal diffusivity, the effective viscosity of the nanofluid by the Pak and Cho correlation [13] is taken as modified form $\mu_{nf}=\mu_f\left\{1+39.11(\phi_1+\phi_2)+533.9(\phi_1^2+\phi_2^2)\right\}$ and the effective thermal conductivity (modified form) of Maxwell Garnett (MG) model [14] is $k_{nf}=k_f\dfrac{(k_{s1}+k_{s2})+2k_f-2\phi_1(k_f-k_{s1})-2\phi_2(k_f-k_{s2})}{(k_{s1}+k_{s2})+2k_f+\phi_1(k_f-k_{s1})+\phi_2(k_f-k_{s2})}$.

The above equations are obtained by using the following dimensionless dependent and independent variables

$$X=\frac{x}{L},\ Y=\frac{y}{L},\ U=\frac{u}{U_i},\ V=\frac{v}{U_i},\ P=\frac{p}{\rho_f U_i^2},\ \theta=\frac{T-T_i}{T_c-T_i}$$

If I is the intensity of solar radiation, in W/m^2, incident on the aperture plane of the solar collector having a collector surface area of A, m^2, then the amount of solar radiation received by the collector is: $Q_i=I.A$

Basically, it is the product of the rate of transmission of the cover (λ) and the absorption rate of the absorber (κ). Thus, $Q_i=I(\lambda\kappa)A$

The rate of heat loss (Q_o) depends on the collector overall heat transfer coefficient (h) and the collector temperature $Q_o=hA(T_c-T_a)$. Thus, the rate of useful energy extracted by the collector (Q_u), expressed as a rate of extraction under steady state conditions, is proportional to the rate of useful energy absorbed by the collector, less the amount lost by the collector to its surroundings. This is expressed as:

$Q_u = Q_i - Q_o = I(\lambda\kappa)A - hA(T_c - T_a)$, where T_c and T_a are the temperature of the collector and ambient temperature outside the collector. The rate of extraction of heat from the collector may be measured by means of the amount of heat carried away in the fluid passed through it, that is: $Q_u = mC_p(T_o - T_i)$

A measure of a flat plate collector performance is the collector efficiency (η) defined as the ratio of the useful energy gain (Q_u) to the incident solar energy over a particular time period:

$$\eta = \frac{\text{useful gain}}{\text{available energy}} = \frac{mC_p(T_o - T_i)}{AI}$$

where m is the mass flow rate of the fluid flowing through the collector; C_p is the specific heat; and T_i and T_o are the mean fluid inlet and outlet temperatures, respectively. The computation domain is the fluid passing pipe which is attached to the absorber plate. At the top and bottom walls of the pipe maintain heat flux $q = I(\lambda\kappa)A - hA(T_c - T_a)$.

The dimensionless boundary conditions are:
at the top and bottom walls of the pipe: non-dimensional heat flux
at the inlet opening: $\theta = 0$, $U = 1$
at all solid boundaries of the pipe: $U = V = 0$
at the outlet opening: convective boundary condition $P = 0$

The average Nusselt number at the top surface of the pipe takes the form $Nu = -\int_0^1 \left(\frac{k_{nf}}{k_f}\right)\frac{\partial\theta}{\partial Y}dX$. The mean bulk temperature and average velocity of the fluid may be written as $\theta_{av} = \int \theta\, d\overline{V}/\overline{V}$ and $\mathrm{V}_{av} = \int \mathrm{V}\, d\overline{V}/\overline{V}$, where $\overline{V}$ is the volume of the pipe.

3. Numerical Approach

The Galerkin finite element method of Taylor and Hood [15] and Dechaumphai [16] is used to solve the considered problem. The equation of continuity has been used as a constraint due to mass conservation and this restriction may be used to find the pressure distribution. The finite element method is used to solve the Eqs. (2) - (4), where the pressure P is eliminated by a constraint. The continuity equation is automatically fulfilled for large values of this constraint. Then the velocity components and temperature are expanded using a basis set. The Galerkin finite element technique yields the subsequent nonlinear residual equations. Three points Gaussian quadrature is used to evaluate the integrals in these equations. The non-linear residual equations are solved using Newton–Raphson method to determine the coefficients of the expansions. The convergence of solutions is assumed when the relative error for each variable between consecutive iterations is recorded the convergence criterion ε. The thermophysical properties of the nanofluid are taken from Ogut [17] and given in Table 1.

Table 1: Thermo-physical properties of base fluid and different nanoparticles

Physical Properties	Fluid phase (Water)	Al_2O_3	Cu
C_p(J/kgK)	4179	765	385
ρ (kg/m^3)	997.1	3970	8933
k (W/mK)	0.613	40	400
$\alpha\times10^7$ (m^2/s)	1.47	131.7	1163.1

3.1 Grid Independent Test

An extensive mesh testing procedure is conducted to guarantee a grid-independent solution for Re = 400 and Pr = 6.6 in a solar collector. In the present work, five different non-uniform grid systems with the following number of elements within the resolution field are examines: 60, 240, 960, 3840 and 15360. The numerical scheme is carried out for highly precise key in Nu for water-Al_2O_3 nanofluid (ϕ = 5%) as well as base fluid (ϕ = 0%) for the aforesaid elements to develop an understanding of the grid fineness as shown in Table 2. The scale of the average Nusselt numbers for 3840 elements shows a little difference with the results obtained for the other elements. Hence, considering the non-uniform grid system of 3840 elements is preferred.

Table 2: Grid Sensitivity Check at Pr = 6.6, ϕ = 5% (water/alumina nanofluid) and Re = 400

Nodes (elements)	506 (60)	1788 (240)	6692 (960)	25860 (3840)	101636 (15360)
Nu (nanofluid)	7.82945	9.19176	10.17518	10.84991	10.85001
Nu (basefluid)	6.62945	7.99976	8.88701	9.551698	9.551718
Time (s)	126.265	312.594	398.157	481.328	929.377

3.2 Code Validation

The present numerical solution is validated by comparing the current code results for collector efficiency - temperature difference [T_i - T_a] profile of water with the graphical representation of Kalagorirou [18] for flat plate solar thermal collector at irradiation level 1000 W/m^2. Solar thermal collectors and applications were reported by Kalagorirou [18]. Fig. 2 demonstrates the above stated comparison.

4. Results and Discussion

In this section, numerical results of isotherms and streamlines for various values of solid volume fraction ($\phi = \phi_1 + \phi_2$) of Al_2O_3/Cu /water nanofluid through a fluid passing pipe of a flat plate solar collector are displayed. The considered values of ϕ are ϕ (= 1%, 3%, 5%, 7% and 10%) while the Prandtl number Pr = 6.6 and Re = 400 are kept fixed.

The effect of ϕ (= $\phi_1 + \phi_2$) on the thermal, velocity and heat flux fields are presented in Fig. 3 (a)-(c). Increasing ϕ (solid volume fraction of alumina and copper nanoparticles equally), the temperature lines near the upper and lower parts of the riser pipe become flatten whereas at the lower ϕ (= 1% = 0.5% + 0.5%) they are bended due to concentration of solid particles is dominated across the pipe. With the rising values of ϕ from 1% to 5%, the temperature distributions become distorted resulting in an increase in the overall heat transfer. This is because the thermal conductivity of the solid particles is very high. This means that higher heat transfer rate is predicted by the nanofluid having two nanoparticles namely Al_2O_3 and Cu. It is worth noting that as the solid volume fraction of Al_2O_3 and Cu nanoparticles increases, the thermal boundary layer near the top and bottom surfaces of the riser pipe becomes thick which indicates a steep temperature gradients and hence, an increase in the overall heat transfer from the absorber plate containing pipe to the outlet edge. But further increasing ϕ to 10% (= 5% + 5%) there is no perturbation observed in the isothermal lines at all. Thus adding more solid volume fraction is not advantageous.

The corresponding velocity field indicates that at ϕ = 1% the velocity of nanofluid is high. Thus the nanofluid quickly passes the pipe by getting heat from upper and lower walls as a result the streamlines appear the whole riser pipe. In the velocity vector, initially the flow covers the entire domain of the pipe while it concentrates near the middle of the pipe of flat plate solar collector due to increase solid volume fraction ϕ from 1% (= 0.05% + 0.05%) to 10% (= 5% + 5%) of water-alumina/copper nanofluid. This happens because of escalating solid concentrations of flow. Nanofluid having larger density does not move freely.

The heatlines are smooth and it is observed that the lines are perfectly perpendicular to the isothermal lines and the upper and lower walls. This further indicates that the heat flow is conduction dominant. From the Fig. 5(c) it is clearly observed that the heatlines with greater strength become smaller in size at the middle of the flow pipe for ϕ = 5% (2.5%+2.5%). This happens due to more thermal conductive heat flux and as it is seen the case of the lowest solid volume fraction, the strength of heatline goes to low. The heatlines remain constant for further increasing ϕ from 5% to 10%. This means that major amount of heat flux or transport occurs for ϕ = 5% of water-Al_2O_3/Cu nanofluid.

In Fig. 4(i)-(iii) average Nusselt number (Nu) at the upper hot surface, mean temperature (θ_{av}), magnitude of average velocity vector (V_{av}) with various solid volume fraction is accounted for nanofluid having double and single nanoparticle as well as clear water. Nu enhances sharply with growing ϕ upto 5% and then remains unchanged with advance mixture of solid volume faction for water based nanofluid having double as well as single nanoparticles. Rate of heat transfer enhances by 15% and 11% with the variation of ϕ from 1% to 5% for water-alumina/copper and water-alumina nanofluids respectively. Fig. 4(ii) displays that θ_{av} grows sequentially for ϕ upto 5% for both mixture of nanofluid. Mean temperature remains constant for further increasing values of solid volume fraction from 5% to 10%. It is well known that total thermal conductivity of Al_2O_3 and Cu nanoparticles is higher than only Al_2O_3 nanoparticle. Higher thermal conductivity is capable to carry more heat. Thus average bulk temperature of water-Al_2O_3/Cu nanofluid has found higher. There is no change of water (ϕ = 0%) due to the deviation of nanoparticles volume fraction. Consequently V_{av} has notable changes with different values of solid concentration of different mixtures of nanofluid. Growing ϕ devalues mean velocity of the nanofluid through the riser pipe of the flat plate solar collector. Here water-alumina nanofluid has higher mean velocity than the water-alumina/copper nanofluid. Less solid concentrated nanofluid has greater velocity than highly concentrated nanofluid.

Fig. 5(i)-(ii) expresses the collector efficiency η (%)-solid volume fraction ϕ (%) for the nanofluid with single and double nanoparticles and mid-height temperature (dimensional) of water-alumina/copper nanofluid. From Fig. 5(i) it is observed that adding low quantities of nanoparticles leads to the remarkable enhancement of the efficiency until a volume fraction of approximately 5%. After a volume fraction of 5%, the efficiency begins to level off with increasing volume fraction. The authors attribute this unchanging to the high increase of the fluid absorption at high particle loadings. The main difference in the steady-state efficiency occurs in water based nanofluid having alumina and copper nanoparticles. Collector efficiency rises from 44% to 58% and from 44%

to 54% with growing the solid volume fraction ϕ from 0% to 5% for water based nanofluid having double and single nanoparticles respectively. On the other hand the inlet temperature of fluid is maintained at 300K and then it increases gradually with the contact of heated upper and lower solid boundaries of the riser pipe. And finally the output temperature of water-alumina/copper nanofluid becomes 344K, 350K, 354K, 358K, 358K and 358K for ϕ = 0%, 1%, 3%, 5%, 7% and 10% respectively.

5. Conclusion

The results of the numerical analysis lead to the following conclusions:

- The structure of the fluid isotherms and streamlines through the pipe is found to significantly depend upon the solid volume fraction of water-alumina/copper nanofluid.
- The Al_2O_3/Cu nanoparticles with ϕ = 5% are established to be more effective in enhancing performance of heat transfer rate than Al_2O_3 nanoparticle.
- Collector efficiency rises for nanofluid having two nanoparticles than nanofluid with single nanoparticle.
- Mean temperature rises for water- Al_2O_3/Cu nanofluid than water- Al_2O_3 nanofluid.
- Average velocity field devalues due to growing ϕ.

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$$X = \frac{x}{L}, Y = \frac{y}{L},$$

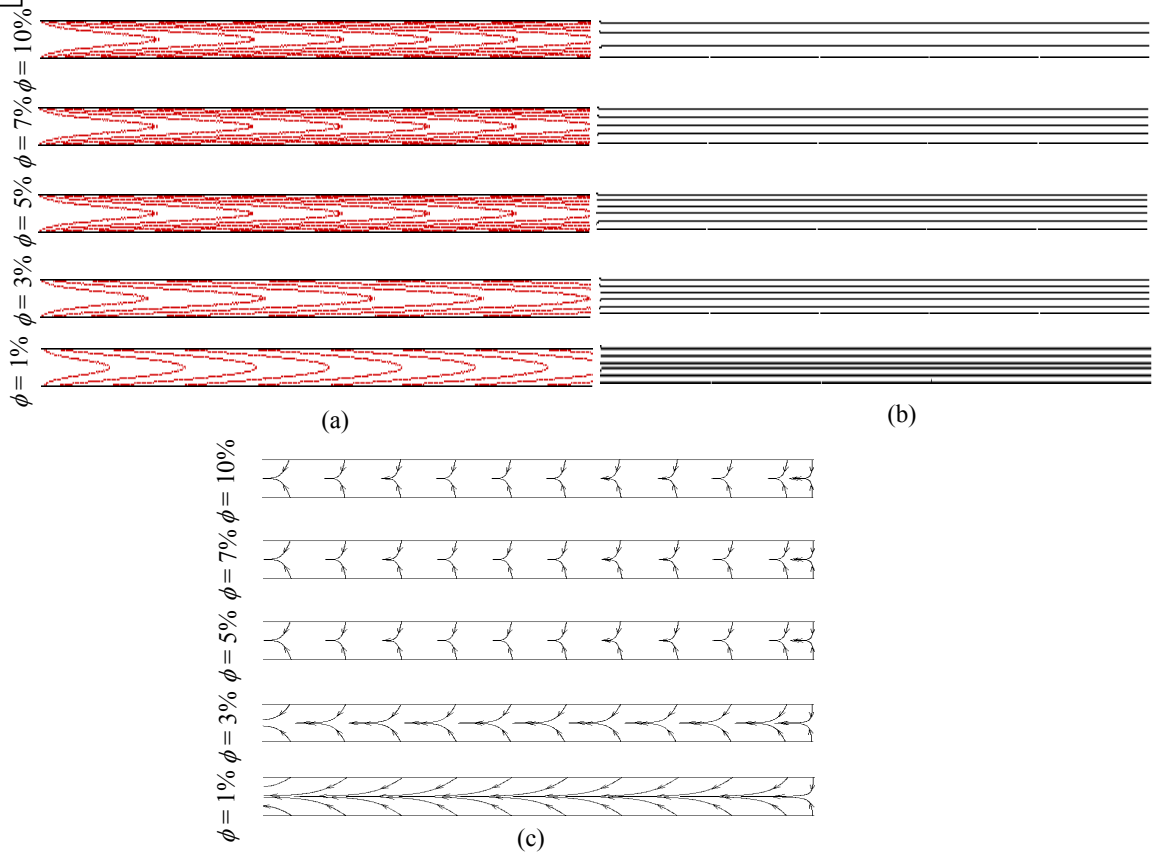

Fig. 3: Effect of ϕ of water-alumina/copper nanofluid on (a) temperature, (b) streamfunction and (c) heatfunction

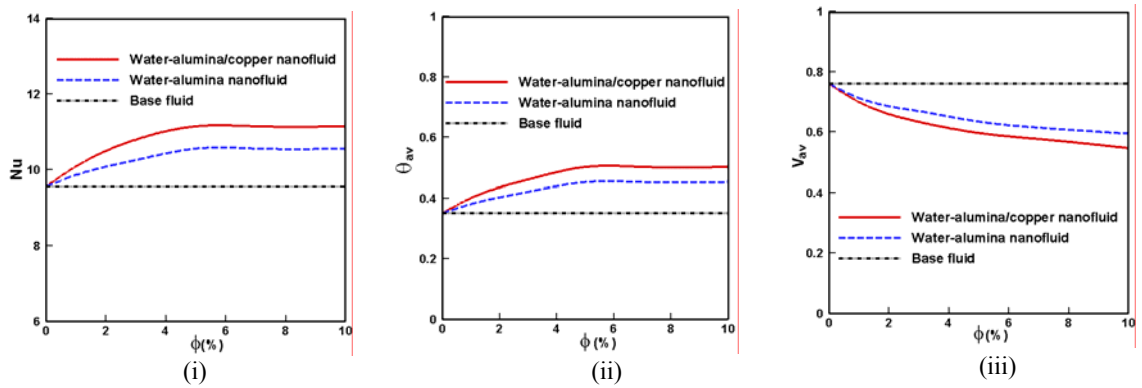

Fig. 4: Effect of ϕ of nanofluid with single and double nanoparticles on (i) *Nu,* (ii) θ_{av} and (iii) V_{av}

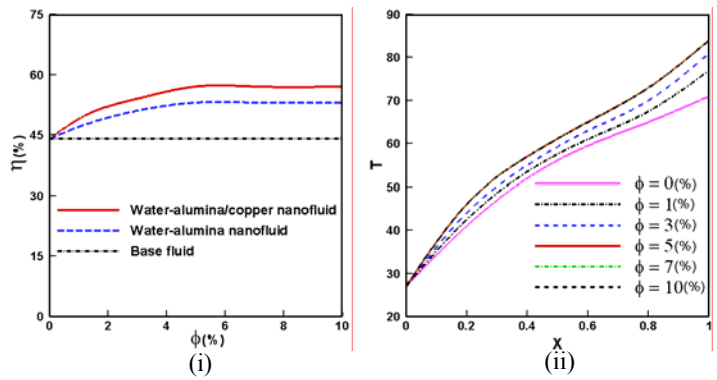

Fig. 5: Plots of (i) η and (ii) mid-height temperature

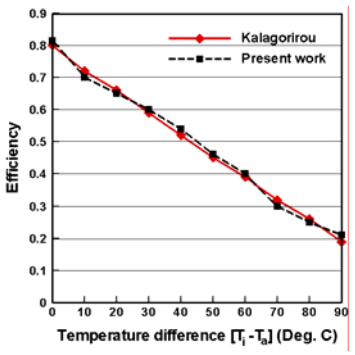

Fig. 2: Comparison of present code with Kalagorirou [18] at I = 1000 W/m^2

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Effect of Energy Efficiency Design Index on Container Vessel Design

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Abstract

EEDI (Energy Efficiency Design Index) is an index quantifying the amount of CO_2 (Carbon Dioxide) that a ship emits in relation to the goods transported. The International Maritime Organization (IMO) adopted EEDI index in order to reduce the emission of Greenhouse Gases (GHG) by shipping as a mandate to the Kyoto Protocol. All new ships over 400 gross tonnages from the 1st of January, 2013 have to fulfill the minimum criteria of the EEDI. EEDI actually defines the minimum energy efficiency level expressed in tones of CO_2 emitted per 'Capacity mile' which all news ship must comply. The aim of this paper is to find the impact of EEDI on ship design parameters and hydrodynamics for container vessels. The EEDI is calculated with the current IMO formulation and guideline. Finally, the results are presented as the effect of the variations of ship design parameters such as Length, Beam, Draught and Prismatic Coefficient on EEDI and hydrodynamics of ship. Guide lines and suggestion have also been made based on the results to achieve the required EEDI. Since this index has been criticized right from the beginning, an effort is also made to analyze the criticism against the present EEDI formulation, guideline and reference line.

Keywords: EEDI, IMO, MARPOL, GHG, Froude Number, MEPC.

1. Introduction

As a mandate to Kyoto Protocol in order to reduce global [1] CO_2 emission, Marine Environmental Protection Committee (MEPC) under IMO has developed the EEDI which has been came into force on the 1st January, 2013 to create stronger incentives for further improvements in ships' fuel consumption. Around 90% of global trade is carried by sea [2] for being the most economical mode of transport and second IMO Green House Gas (GHG) Study in 2009 [3] estimated that shipping industry in the world has emitted 1.046 million tonnes of CO_2 in 2007, which corresponds to 3.3% of the global emissions at that time. It is also estimated in the study that by 2050, in the absence of policies, CO_2 emissions from international shipping may grow by a factor of 2 to 3 as compared to the emissions in 2007 due to present trend of rise of shipbuilding industry.

The main objectives of IMO are to achieve a minimum energy efficiency level for new ships and stimulate the technical development of all the components influencing the fuel efficiency of a ship. The regulations apply to all ships of 400 gross tonnages and above. Simply EEDI is described as the emissions of a vessel under design condition divided by the transport work done in same condition. The Regulation has a set of initial values for the required EEDI which are individualized for each ship type through a reference line. The reference line of each ship type will also give the value of the required EEDI for each ship's size. Finally, the regulation includes a step–by-step phase-in scheme for reduction of the required EEDI values.

For most ship owners, shipping and ship design companies, it becomes interesting and scary in some way. Researchers like Jack Devanney along with some other researchers have already made their stands against EEDI. It is been criticized that EEDI formulation violates basic Naval Architectural Formula or hydrodynamics of ship and it actually influences to build smaller and slower vessels. It is of a great interest to investigate the ship design particulars in lieu of EEDI and to check the influence. The investigation in this paper has been carried out for Container Vessels. The impacts of EEDI on Container vessel design have been discussed thoroughly and the results with suggestion are presented for better design in terms of EEDI.

2. Brief Description of EEDI

2.1 Mathematical Formulation

The following gives the brief description and calculation procedure of EEDI [4]. Basically EEDI formula consists of four parts which gives different ship design criteria. The formulation is developed in the following manner:

$$\text{EEDI}_{\text{attained}} = \frac{\text{CO}_2\text{Emission}}{\text{Transport work}}$$

$$= \frac{\text{Power} * \text{Specific Fuel Consumption} * \text{CO}_2\text{Conversion Factor}}{\text{Capacity} * \text{Speed}}$$

$$= \frac{\text{Emission from Main Engine} + \text{Emission from Auxiliary Engine} + \text{Emission for running shaft motor} - \text{Efficient Tech. Reduction}}{\text{Capacity} * \text{Reference Speed}}$$

$$= \frac{\text{Emission from Main Engine} + \text{Emission from Auxiliary Engine} + \text{Emission for running shaft motor} - \text{Efficient Tech. Reduction}}{\text{Capacity} * \text{Reference Speed}}$$

$$= \left[\left(\prod_{j=1}^{n} f_j\right) * \left(\sum_{i=1}^{nME} P_{ME(i)} * C_{FME(i)} * SFC_{ME(i)}\right) + \left(P_{AE} * C_{FAE} * SFC_{AE}\right) + \left(\left(\prod_{j=1}^{n} f_j * \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} * P_{AEeff(i)}\right) * C_{FAE} * SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} * P_{eff(i)} * C_{FME} * SFC_{ME}\right)\right] * \frac{1}{f_i * f_c * \text{Capacity} * V_{ref} * f_w}$$

$$= \frac{\text{kw} * \frac{g_{fuel}}{\text{kwh}} * \frac{g_{CO2}}{g_{fuel}}}{\text{Tonne} * \text{knotical mile/h}}$$

$$= \frac{g_{CO2}}{\text{Tonne} * \text{knotical mile}}$$

The calculated EEDI for a ship will be called the attained EEDI. This attained EEDI must be less than the reference EEDI [5] or reference line. This reference line becomes stringent at different phases.

The Reference line values shall be calculated as follows:

$$\text{Reference line value} = a \times b^{-c} \quad (1)$$

Where a, b and c are the parameters given in Table 1 [6]. The reference line is based on the vessel database of Lloyd's Register Fair play [7]. Figure 1 gives a sample reference line for Container Vessels as per Lloyd's Register Fair play database. The present EEDI rules will be more stringent in different phases [6]. Table 2 shows the phase in scheme for reduction of required EEDI for different ship types.

Table 1. Reference line parameter value for different types of vessel

Ship type defined in regulation	a	b	c
Bulk carrier	961.79	DWT	0.477
Gas tanker	1120.0	DWT	0.456
Tanker	1218.8	DWT	0.488
Container ship	174.22	DWT	0.201
General cargo ship	107.48	DWT	0.216
Refrigerated cargo carrier	227.01	DWT	0.244
Combination carrier	1219.0	DWT	0.488

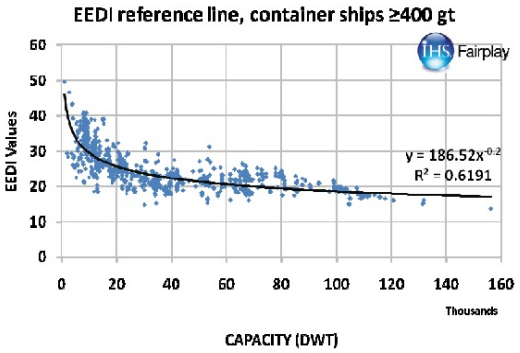

Fig. 1. Reference line sample for Container vessel

Table 2. Phase in scheme for reduction of required EEDI for different ship types.

Ship Type	Size (DWT)	Phase 0 1st Jan 2013– 31st Dec 2014	Phase 1 1st Jan 2015 – 31st Dec 2019	Phase 2 1st Jan 2020– 31st Dec 2024	Phase 3 1st Jan 2025–and onwards
Container ship	≥15000	0	10	20	30
	10,000– 15,000	n/a	0-10*	0-20*	0-30*

* Reduction factor to be linearly interpolated between the two values dependent upon vessel size. The lower value of the reduction factor is to be applied to the smaller ship size.

3. Impact of EEDI on ship design and hydrodynamics of ship

3.1 Methodology

In order to carry on this analysis, propulsion power is predicted by the Holtrop-Mennen [8] [9] method and EEDI (attained and reference) with current IMO adopted formulation. A parametric analysis is then made considering all hydrodynamic parameters to observe the effect on EEDI. Then EEDI is presented graphically against each parameter. Effective power (P_E)/Displacement curve is plotted against each parameter to observe whether this curve follows the attained $EEDI_{ATTAINED}$ curve or not. Since $EEDI_{ATTAINED}$ is proportional to the Power (kW)/Capacity (tonne) when Specific Fuel Consumption (SFC) and V_{REF} are constant $EEDI_{ATTAINED}$ curve should have the same trend line as the effective power (PE)/Displacement has.

It should be noted that the change of EEDI has to be calculated by considering the dependency of all parameters together to have the actual change in EEDI. As the ship design parameters and coefficients are interlinked to one another it is important to investigate the total impact. For this reason after considering the impact of individual parameters of on EEDI, best design parameters are calculated considering the dependency of those parameters to each other.

3.2 Change in EEDI for Changing rent Individual Ship Design Parameters for Container Vessel

The major ship's hydrodynamic design parameters, such as the Speed (V), Length (L_{WL}), Breadth (B_{MLD}), Draft (T), L/B ratio, B/T ratio and Prismatic coefficient (C_P) are considered in the analysis. Table 3 shows the ranges of all these parameters that have been considered in the analysis.

Table 3. Design parameters considered for to investigate the impact of speed on EEDI.

Analysis Type	V (knots)	L_{WL} (m)	Froude No. F_N	B_{MLD} (m)	T (m)	L/B	B/T	C_P
Change in Speed(V)	10-39	200	0.11-0.45	33.3	11.1	6	3	0.6
Change in Length (L_{WL})	20	100-250	0.2-0.32	16.7-41.7	5.56-13.9	6	3	0.6
Change in Beam (B_{MLD})	20	200	0.23	22.2-33.3	7.41-11.1	6-9	3	0.6
Change in Draft (T)	20	200	0.23	33.3	8.23-11.1	6	3-4	0.6
Change in L/B	20	200	0.23	22.2-33.3	7.41-11.1	6-9	3	0.6
Change in B/T	20	200	0.23	33.3	8.23-11.1	6	3-4	0.6
Change in C_P	20	200	0.23	33.3	11.1	6	3	0.55-0.7

3.2.1 Change in vessel speed (V)

The results for changing EEDI with respect to speed have shown in Figure 2 and 3 which in brief is as follows:

- Speed has a significant impact on EEDI.
- An increase in speed increases the attained EEDI drastically.
- A rapid increase in both $EEDI_{ATTAINED}$ and PE/Displacement ratio is also evident after a certain speed limit.
- Both $EEDI_{ATTAINED}$ and PE/Displacement ratio are following the similar trend line.
- $EEDI_{REFERENCE}$ cuts $EEDI_{ATTAINED}$ line at 21.3 knots meaning that with these design particulars, the vessel is not allowed a speed more than 21.3 knot/hour.

3.2.2 Change in Waterline Length (L_{WL})

The results for changing EEDI with respect to length have shown in Figure 4 which in brief is as follows:

- Length has significant impact on EEDI
- An increase in length decreases attained EEDI.
- A rapid change in $EEDI_{ATTAINED}$ and PE/Displacement ratio is also evident after a certain length.
- Both $EEDI_{ATTAINED}$ and PE/Displacement ratio are following the similar trend line.

3.2.3 Change in Breadth (B_{MLD})

The results for changing EEDI with respect to beam have shown in Figure 5 which in brief is as follows:

- An increase in beam decreases $EEDI_{ATTAINED}$.
- Beam has insignificant impact on EEDI and PE/Displacement and these two lines follow similar trend line.

3.2.4 Change in Draught (T)

The results for changing EEDI with respect to draught have shown in Figure 6 which in brief is as follows:

- An increase in draft decreases $EEDI_{ATTAINED}$.
- There is no significant or rapid change in EEDI and PE/displacement curve.

- Both $EEDI_{ATTAINED}$ and PE/Displacement ratio are following the similar trend line.

3.2.5 Change in L/B ratio

The results for changing EEDI with respect to L/B have shown in Figure 7 which in brief is as follows:

- L/B has significant impact on EEDI.
- An increase in L/B ratio increases $EEDI_{ATTAINED}$.
- Both $EEDI_{ATTAINED}$ and PE/Displacement ratio are following the similar trend line.

3.2.6 Change in B/T ratio

The results for changing EEDI with respect to L/B have shown in Figure 8 which in brief is as follows:

- B/T has insignificant impact on EEDI.
- An increase in B/T ratio increases $EEDI_{ATTAINED}$.
- Both $EEDI_{ATTAINED}$ and PE/Displacement ratio are following the similar trend line.

3.2.7 Change in C_P

The results for changing EEDI with respect to C_P have shown in Figure 9 which in brief is as follows:

- C_P has insignificant impact on EEDI and there is no significant change in EEDI and PE/Displacement curve.
- An increase in C_P increases attained EEDI.
- Both $EEDI_{ATTAINED}$ and PE/Displacement ratio are following the similar trend line.

3.3 Summary of the analysis

Based on the results as described in section 3.2, following suggestion as in table 4 for individual parameters is summarized.

Table4. Suggestion to change the individual ship parameter to improve EEDI.

Vessel type	Speed	Length	Beam	Draft	L/B	B/T	Prismatic Coefficient Cp
Container	Decrease	Increase	Increase	Increase	Decrease	Decrease	Increase

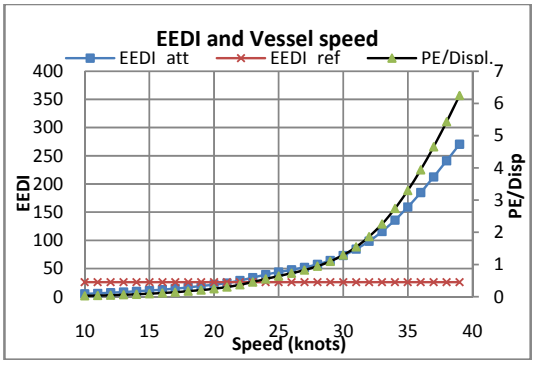

Fig. 2. EEDI for various speed and Froude No.

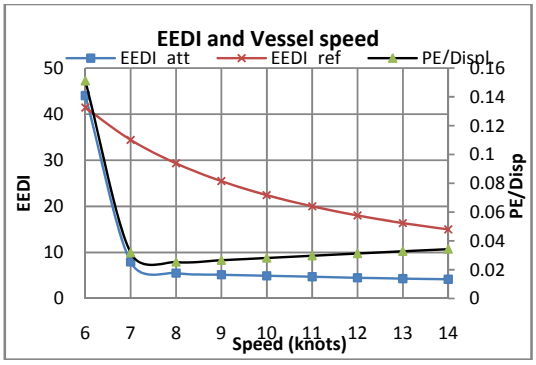

Fig. 3. EEDI at constant Froude No. (0.2) and various speed (Length variable)

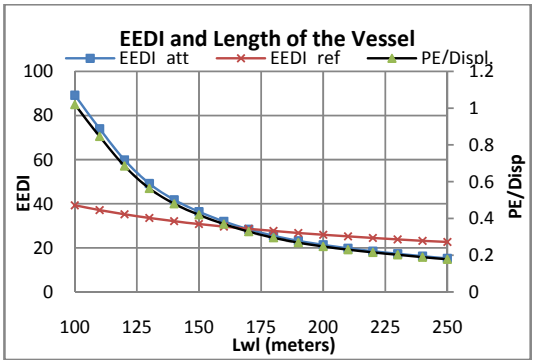

Fig. 4. Changes in EEDI for various Lengths

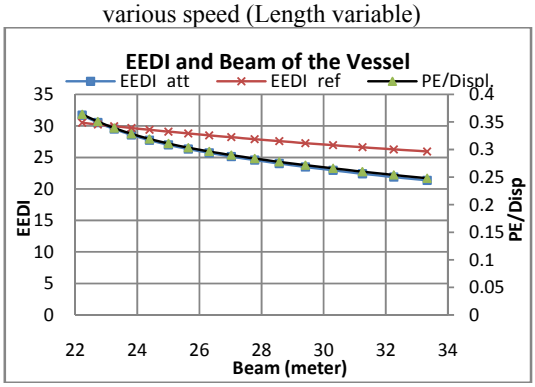

Fig. 5. Changes in EEDI for various Beams

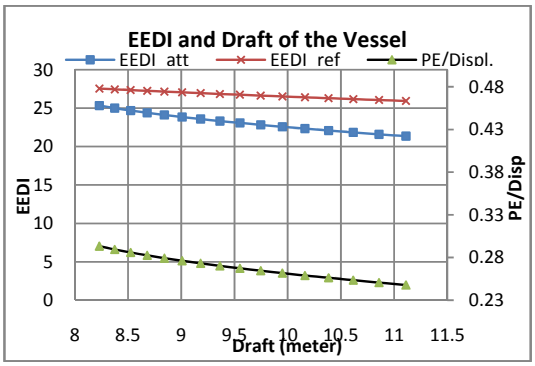

Fig. 6. Change in EEDI at various draft (T)

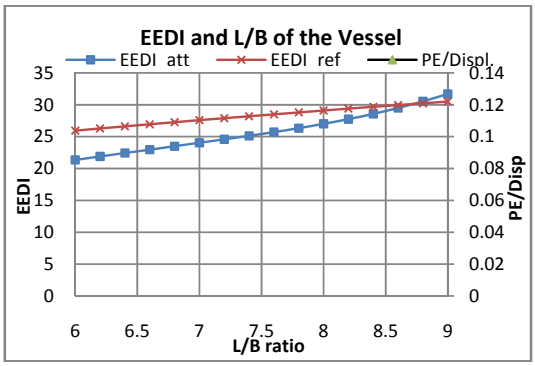

Fig. 7. Change in EEDI at various L/B ratio

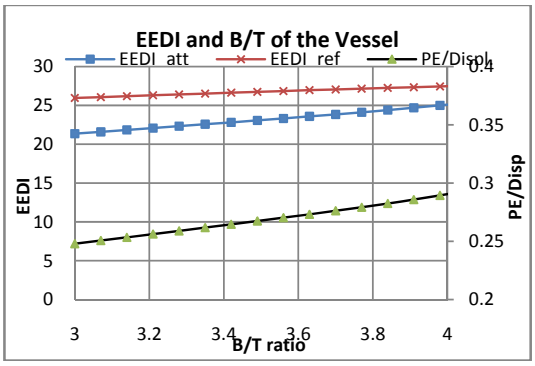

Fig. 8. Change in EEDI at various B/T ratio

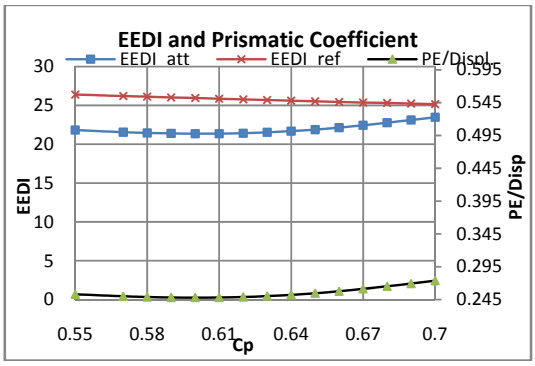

Fig. 9. Change in EEDI at various Prismatic Coefficient (C_P)

3.4 Best Design parameters for Container

In the previous section it has been shown how the individual ship design parameters should be changed in order to have better performance with respect to EEDI. But in reality these parameters are interlinked to each other. For example, while increasing length we may find better EEDI (Fig. 4). But an increase in length will change the L/B ratio for fixed beam as well and overall hydrodynamic coefficients may also be changed. This is also true for B/T ratio and other parameters. Since these hydrodynamic parameters interact each other, in order to achieve the best EEDI for a given case, a Naval Architect must go for a holistic design approach. Holistic design approach will consider the dependency of each parameter and give us the best design parameters in terms of EEDI.

Table 5 and 6 show the result of analysis of two different sized container vessels to observe maximum possible speed and capacity, where the combined impact of all the parameters are considered and optimized for the best result in terms of EEDI, Speed and Capacity.

It has been criticized that small vessels are allowed to have higher EEDI. Fig. 1 also supports this which means IMO is suggesting building small vessels. But if we look at Table 5 and 6 we will find that it is not true. Bigger vessels are allowed to have higher speed than the smaller one as per present EEDI formulation. Though the reference line allows smaller vessels to have higher EEDI does not mean that smaller vessel can attain low EEDI. The attained EEDI for small vessel is also very high (Table 5 and 6). Another major criticism against EEDI is that, it breaks the hydrodynamic rules of Naval Architecture. Fig. 2-9 shows that, $EEDI_{ATTAINED}$ curve follows the same trend as PE/Displacement. So, it can also be concluding here that, EEDI does not contradict the hydrodynamic rules of Naval Architecture.

But it is true that, no matter how we modify or improve the hull design, it will not be enough to have a vessel that will have the same present speed with 30% reduced EEDI (Phase 3 of CO_2 reduction). The present efficient hulls are good enough in most cases to comply the current phase 0 and with some modification of hull parameters and improved hull design, phase 1 requirements can be achieved without reducing the speed, but it is not possible to move further phases at present technology.

Table 5. Optimum dimension for maximum speed

Max Speed (knots)	L (m)	F_N	L/B	B (m)	B/T	T (m)	C_P	Capacity (Tonne)	R_T (kN)	$EEDI_{ATT}$	$EEDI_{REF}$
24	250	0.25	5	50	4	12.5	0.65	44824	2444	21.69	21.89
11.8	100	0.19	5	20	4	5	0.65	2868	265	37.87	37.95

Table 6. Optimum dimension for maximum capacity

Max Speed (knots)	L (m)	Fn	L/B	B (m)	B/T	T (m)	Cp	Capacity (Tonne)	R_T (kN)	$EEDI_{ATT}$	$EEDI_{REF}$
21	250	0.216	5	50	3	16.67	0.8	73558	3655	19.73	19.83
14.2	100	0.233	5	20	3	6.67	0.8	4707	389	33.83	34.36

4. Conclusions

According to IMO the adoption of EEDI will reduce up to 200 million tonnes of CO_2 from the atmosphere annually by 2020 if the world trade goes as it is today and by 2030 this number will be 420 million tonnes [2]. Though the main intention of adopting EEDI is to reduce the CO_2 emission from the shipping industry, it will also force the shipping industry to have more and more energy efficient ships. If we do not have efficient innovative technology in the near future, power and speed cut off will be the only solution to achieve required EEDI at higher phases. This may give and enormous impact on global economy since 90% of the global cargo is carried out by marine transports.

Though EEDI is not an accurate emission indicator at present, it is better to have an emission control instrument at the design stage. Different work groups at MEPC under IMO are continuing their work to eliminate the problems associated with EEDI formulation and reference line values. The committee has approved draft amendments to MARPOL Annex VI, with a view to adoption at MEPC 66, to extend the application of EEDI to ro-ro cargo and passenger ships, LNG carriers, cruise passenger ships, and to exempt ships not propelled by mechanical means. Therefore there is every confidence in the international maritime organizations, shipbuilders and owners that the EEDI will result in more energy efficient ships, in reduced emissions of GHGs, in environmental effectiveness and in a significant contribution by a global industry to the global efforts to stem climate change.

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Design and development of a vertical axis low speed wind generator

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Abstract

Mostly Bangladesh is a flat land with average wind speed of around 3.5 m/s. However in the coastal areas wind speed reaches up to 7-9 m/s. The potential of deploying low speed wind turbines is promising. With these view, a low speed vertical axis wind turbine together with a wind generator have been designed which can work at low speed of wind available in Bangladesh. The wind turbine and wind generator have been fabricated using locally available materials and fabrication technology. The output of the generator should be 250 W and usable watts should be at least 200 W at low cost. The generator will produce power at 450 rpm. A pulley system power drive is used to rotate the generator.
Keywords: wind turbine, wind generator, low speed turbine, fabrication technology

1. Introduction

The civilization is dependent on electric power. There is a relationship between GDP growth rate and electricity growth rate in a country [1]. It will therefore, be necessary to tap all sources of renewable energy and to use these in an efficient converted form for benefit of the people of Bangladesh. Primarily this will be done in remote inaccessible un-electrified area in a standalone system which is environment friendly and also save cost of grid expansion. This type of energy conversion will reduce pressure on the national power supply system.
Generation of electricity through wind turbine, using available low speed of wind in Bangladesh is very much effective to provide electricity to the rural people. Because only 10% of these users have electricity connection and there are some parts of Bangladesh which will not get connected to the national grid within next 30 years [2].Bangladesh Centre for Advance Studies (BCAS) and Local Government Engineering Department (LGED) with assistance from Overseas Development Administration (ODA) of UK launched the Wind Energy Study Project (WEST) Project in 1995 at seven places in Bangladesh. These sites are Potenga, Cox's Bazar, Tecknaf, Noakhali, Charfassion, Kuakata and Kutudia. It was found that avarage anual mean wind speed in meter per second are 3.95, 3.34, 2.94, 2.96, 2.96, 4.07, 4.52 and 4.21 respectively. Later on LGED and BUET jointly studied the wind speed at 15 different places in Bangladesh. Their findings were not so satisfactory for high power wind generation. Since wind speed in Bangladesh is low, therefore low wind speed generator might be feasible. During the months starting from late October to February wind speed remains either calm or too low. This period is called lull period. The remaining seven months wind speed is quite good for this low speed wind generator. The peak wind speed occurs during the months of May, June and July. It will be an efficient way to generate electricity by using a newly designed wind generator for a low speed vertical axis wind turbine which can work at the available low speed of wind in Bangladesh. To meet the situation, a wind generator have been designed, fabricated and operated with capacity100W- 200 W at low cost.

2. Theory of wind Turbine

To estimate performance of a particular wind turbine,

$AEO = 1.64\ d^2V^3$

Where, AEO =Annual energy output, KW/year,

d =Rotor diameter, meters and

V =Annual average wind speed/s

If it is required to reduce the cost of the turbine for an energy efficient one, it is necessary to reduce the size of peak demand electrical loads.
To design a wind generator, let us consider the elementary two pole dc machine in the figure2 (A).
The polarity of the induced emf for clockwise rotation, follow Lenz's law, figure (b).When angle θ (angle between magnetic axis of the stator and rotor) is zero or π, the voltage induced in the armature coil is zero. It is

assumed that, for polarities of the field poles and direction of rotation, brush b_1 always positive and brush b_2 always negative.
A full pitch armature coil of one or more turns is one that spans a pole pitch. In a two pole machine a full pitch coil spans the diameter and in a P-pole machine it spans a chord that subtends an angle of 2 π/P on the armature periphery.

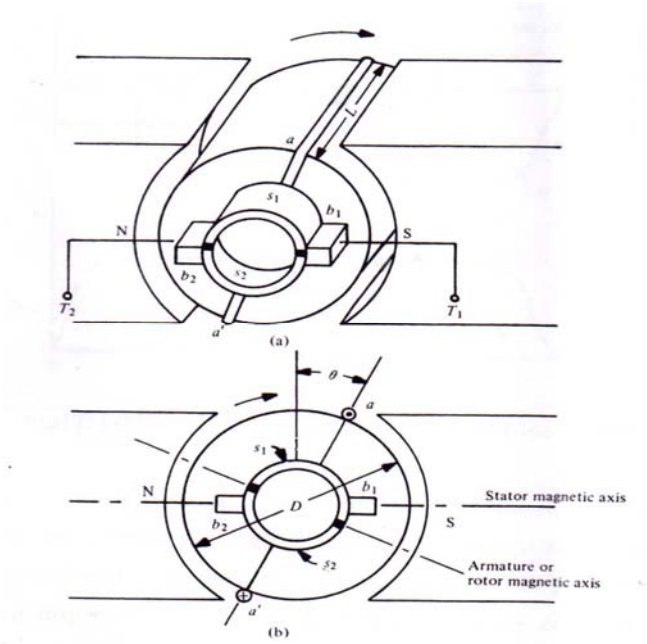

Figure2 (A): Elementary two-pole dc machine. (a) Partial view (b) Simplified view

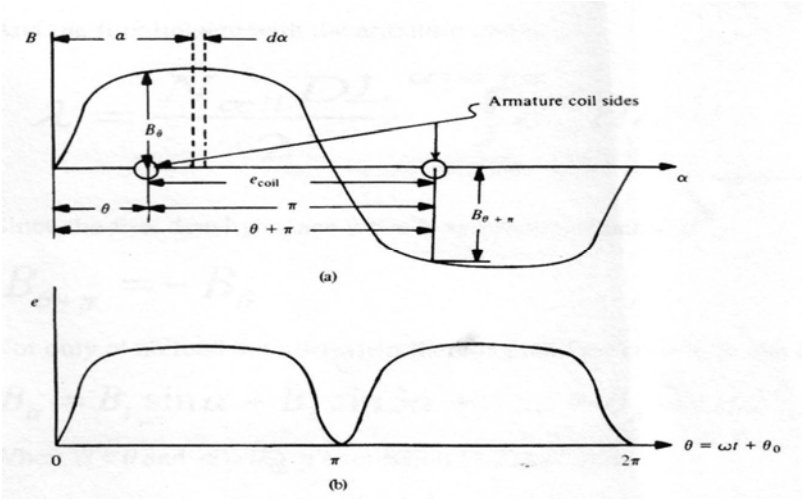

Figure2 (B): (a) Flux-density space wave (b) Rectified no-load voltage in a full-pitch coil.

Figure 2(B) shows the approximate flux density distribution curve for a dc machine at no load with the effect of the armature slots neglected. The armature current is zero and the flux is entirely due to the field current.
Average voltage induced in the coil of a generator is given by-
$E_{(coil)avg} = (2PN_{coil} \square_d n)/60$
Where $E_{(coil)avg}$ = Average voltage induced in the coil

P = Number of poles in a machine
N_{coil} = Number of coils
ϕ_d = Flux per pole
n = Speed in rpm

3. Design of wind generator

To generate 200 W , different parameters of wind generator have been calculated. The vertical axis wind rotor diameter is about 2M. Five to seven half circle or NACCA -..... profile curved thin aluminum blades are being fixed vertically at the outmost diameter of the wind rotor. The rotor rotates around the vertical axis shaft which is fitted at 20 to 30 feet height. The rotor shaft is extended to the ground platform where two gears or pulleys are arranged to increase rotor RPM at 600 from 30 -40 RPM. Sixteen poles consisting of 32 permanent magnets size of Ø28mm x 6mm are used to generate 100W- 200W power. For each magnet 100 turns, 15 gauge copper wire is used around each core material. Main components of wind generator and their measurements are given in the table below-

Sl. No.	Name of the components	Diameter (mm)	Thickness/Length (mm)	Material	Quantity
1	Permanent magnet	Ø28	3	Ferro-magnet	2x16 pcs
2	Disc for permanent magnet	Ø 300	10	Nylon fiber	2 pcs
3	Disc for copper coil	Ø 382	15	Nylon fiber	1 pc
4	Flange bush	Ø 108	30	Nylon fiber	2 pcs
5	SS shaft	Ø 20	350	SS	1 pc
6	Copper wire for coil	16 gauge			
7	Screw	Ø 6 Ø 6	12.7 25.4	SS SS	10 4
8	Cover	Ø 400	20 gauge	SS	According to body area

4. Construction of wind generator

a) The principle to construct a wind generator is, in an electrical generator, conductor cuts magnetic flux which induced e.m.f. in it.
b) In the present design two discs used for permanent magnet which are rotating and one stationary disc for copper coil or winding.
c) Copper coil disc is placed between two permanent magnets.
d) There is flange bush in the centre of the magnet disc through which the shaft will pass. The diameter of the flange bush is 108mm in one side and 32mm in another side and thickness is 30mm. It is attached to magnet disc by screw. Instead of flange bush, one can use 30 mm thick magnet disc which is costly and make the disc heavy. Another reason to use this flange bush is that, in case of any damage of the disc due to rotation, we need to change the flange bush only. Magnet disc also fixed with shaft by flange bush using screw.
e) There is one coil disc between two magnet discs which contains the winding. Shaft is passed through the center of the disc but they do not touch each other. This disc is attached with cover and makes it stationery.
f) The SS shaft is passed through the center of the discs. Magnet disc rotate on this axis. This shaft is coupled with the wind turbine to rotate the disc and make electricity.
g) Whole arranged component system is surrounded by a cover case made of SS sheet.

5. The matching procedure

The matching procedure of the wind rotor to the wind generator implies that the following three conditions should be satisfied-

1. Field energy or cut in energy is produced at $V=V_{cut\text{-}in}$
2. Tip speed ratio remain close to λ_0 for $V_{cut\text{-}in} < V < V_{rated}$
3. Rotor start turning at $V_{start} < V_{cut\text{-}in}$

For the first case, when required data of the generator and the transmission are known and even for the maximum power co-efficient of the rotor (matching procedure ensures that at V= $V_{cut\text{-}in}$ the rotor operates at C_{pmax}) this expression gives a value for $V_{cut\text{-}in}$. If this calculated value turns out to be higher than the value chosen in the calculation, the generator choice was wrong. We need to repeat the procedure. The simplest solution of this problem is to increase the area A of the rotor, in that case P_{rated} also increased and it should not exceed maximum power of the generator. If to increase A is not possible, higher value for $V_{cut\text{-}in}$ has to be accepted, implying number of operating hours per year.

In practical case for our country,

Wind velocity at which wind generator starts its maximum power output, V_{start} =2.5 m/s,

Wind velocity at which wind generator starts producing net electricity, $V_{cut\text{-}in}$ =3.0 m/s,

Average wind velocity is defined as $V_{cut\text{-}in}$ /0.7 i.e. V_{avg} =3/0.7=4.28 m/s,

Wind speed at which wind generator obtained its maximum power output, V_{rated} =1.5 X4.28=6.4 m/s,

To calculate area A of turbine blade for power P_a = 250 W and V = V_{rated} =6.4 m/s, using the equation of power P_a =0.1 AV^3 , We get A=9.53m^2 and radius R= 1.75 m.

So to generate 250 W power the radius of the turbine blade should be 1.75 m.

The starting torque of the generator depends on the pressure of the brushes on the commutator (or on the slip rings) and on the value of the field current. It can easily be measured by means of a spring balance and a rope wound the shaft of the generator.

6. Discussion

a) A wind generator for a vertical axis wind turbine of 250 W generation capacity has been designed.
b) This designed generator has been fabricated with the locally available low cost raw materials.
c) The wind generator which works at low speed of wind like our country (where average wind speed is 3.5 m/s) is costly and these generators are imported. So this development of wind generator is very much helpful for local production of wind turbines.
d) This generator is suitable for producing electricity in remote areas of Bangladesh and capable to provide electricity to five to six families.

7. Conclusion

a) Life is directly depending on use of electricity and energy crisis is a threat for economical development of Bangladesh. This type of wind turbine may be a solution of these power crisis by connecting it to the grid or using it separately in the remote areas where grid connected supply is not possible.
b) Production cost of solar energy is 4 to 5 times greater than the production cost of wind energy. So wind energy is suitable to produce and it is also environment friendly.
c) Unit cost of electricity produced by wind turbine is comparatively low hen it is produced at a capacity of over 650 MW.
d) So Government and private sectors should give emphasis on wind power generation as a effective solution of power crisis in the perspective of Bangladesh.

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Energy Saving Brick from Rice Husk Ash

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Abstract

The main objective of thesis is to develop environment friendly and energy saving brick from rice husk ash (RHA). This brick is environment friendly as no need to burn like conventional brick which pollutes the air by emitting of huge quantity of toxic elements, containing suspended particulate matters rich in carbon particles and high concentration of carbon monoxides and oxides of sulphur (SO_x) that are harmful to eye, lungs and throat. As this is not burnt in fire so there is huge saving of heat energy and it is not compressed, as a result mechanical energy can be saved. The main components of this brick are rice husk ash, lime, sand, binder. Five batch experiments have been carried out with different composition of above components to get the desired compressive strength of the brick. Compressive strength of five batches of experiment are 1.18 N/mm^2, 1.6 N/mm^2, 1.9 N/mm^2, 2 N/mm^2 and 2.1 N/mm^2 respectively. Peak load of five batches of experiment are 3126 N, 6280 N, 9722 N, 10850 N and 12883 N respectively. Strain at brick *of five batches of experiment are 1.18 %, 2%, 2.4%, 3%, 3.6% respectively. The main application of this brick is to build one storeyed low cost house.*

Keywords: Compressive strength, calcium silicate hydrate (CSH) gel, energy saving brick, environment friendly, rice husk ash (RHA).

1. Introduction

Rice is one of the major agricultural crops of Bangladesh and at least in 75 countries of the world. Production of rice from paddy yields about 9.9 million tonnes of rice husk, 35 million tonnes of clear rice annually in Bangladesh. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 % organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as rice husk ash. About 2.5 million tonnes of rice husk ash produced annually in Bangladesh. This huge amount of rice husk ash is disposed in nearby rivers of rice mills. Ash sedimentation changes the base level of the river and is one of the important reasons of flood. Numerous patents, publications, reviews and reports on rice husk beneficial utilizations have appeared during last two decades but its effective utilizations in bulk quantities has not been commercially established. In many countries rice husk has been put to use in some specific areas as renewable source of energy, development of pozzolana cementitious materials, acid resistant light weight concrete, and calcium heterosilicate bricks. Rice husk ash can utilizes in many aspects like production of Enhanced properties of RHA cement, Low cost building blocks, Refractory bricks, in the steel industry to produce of high quality flat steel, Lightweight construction materials, Silicon chips, Control of insect pests in stored food stuffs, Water purification, Vulcanizing rubber, Adsorbent for a gold-thio urea complex, Ceramics, Oil absorbent. In many countries around the world Initiatives were taken to develop lost cost building brick using Rice husk ash. The followings shed light on the research works on the utilization of rice husk and rice husk ash as a partial replacement material or stabilizing agent in building works. In [1] was carried out and extensive work on some characteristics of acha husk ash (AHA) / ordinary Portland cement concrete. Test results indicate that the compressive strength for all mixes containing AHA increases with age up to the 14 day hydration period but decrease to the 28 day hydration period while conventional concrete steadily up to 28 day hydration period. In [2] was worked on rice husk as stabilizing agent in clay bricks in which clay bricks were produced with 0% , 1%, 2%,3%,4%,5%, 10% rice husk. Some of the bricks were burnt in an electric furnace to a temperature of 1005^{o}C for about 3-4 hours. Compressive strength and absorption tests were carried out. It was concluded that the addition of the husk reduces the compressive strength of the bricks

and husk clay bricks become lighter as the percentage of husk clay increases. Followings were said [3] on the effect of rice husk and compressive strength and durability of burnt clay bricks. Test results show that rice husk has a decreasing effect on the compressive strength of the brick & increasing effect on the water absorption of the bricks. In [4] was carried out a resource work on the use of rice husk ash in concrete. Test results indicate that the most convenient and economical temperature required for the conversion into ash is 500^{o}C.Water requirement decreases as the fineness of RHA increases. The higher percentage of RHA contains the lower compressive strengths. As mentioned above huge amount of Rice husk ash produced in Bangladesh in every year, which can be utilized to develop low cost energy saving brick. A pilot plant study has been carried out to develop such brick. The main components of this brick are Rice husk Ash, Sand (Quartz), Lime ($CaCO_3$), Binder (port land cement) and Water. Five batches of experiment were performed with different composition of Rice husk Ash, Sand, Lime, Binder and Water. Main component was Rice husk ash varying 50-53 %. Other components, sand varying 7-20%, lime varying 26-34%, cement varying 0-6.5%. These components were mixed in mortar mixing machine and settled down in the aluminum block for obtaining desired shape and kept for 24 hrs for curing. The brick can be obtained either in pressing (applying compression force) or non-pressing (without applying compression force) process. But this pilot plant study was only limited to the non-pressing. As this brick was neither burnt nor pressed, obtained strength might not like conventional fired brick, so use of this brick limited to only one storeyed low cost house in rural area of Bangladesh**.**

2. Experimental

Rice husk can be utilized to produce energy efficient low cost brick. The brick can be obtained either by pressing (applying compression force) or non-pressing (without applying compression force) process. But this study was only limited to the non-pressing. As this brick was neither burnt nor pressed, obtained strength might not like conventional fired brick, so use of this brick limited to only one storeyed low cost house.

2.1. Process description

Rice husk Ash brick mainly consists of Rice husk Ash, Sand (Quartz), Lime ($CaCO_3$), Binder (port land cement) and Water. Rice husk Ash might contain coarse particle, that's why before feed to the mixture Sieving was done to remove unwanted coarse particle. Lime usually available in large lump size in market, which has less surface area, need to grind very smoothly. Lime was grinded and sent to the mixture .Sand was sieved before sending to the mixture. Appropriate amount of water was fed to the mixture for prefect mixing. After loading all materials to the mixture machine, Mixture machine was run for about 10 minutes until the prefect mixing was achieved. After mixing, materials were unloaded .Brick Block was filled with mixing materials. Then it was kept in room temperature for 24 hrs. After removing the blocks desired brick was obtained. Five batches of experiments were carried out with different composition of Rice husk Ash, Sand (Quartz), Lime ($CaCO_3$), Binder (port land cement).

2.2. Experimental Figures

Fig. 1. Mixing machine, curing aluminum blocks and RHA bricks

3. Chemistry involve in the process

When RHA is added to Portland cement, it reacts faster than fly ash in hydration process, which helps to improve the early age strength of brick, and also forms calcium silicate hydrate (CSH) gel around the cement particles which is highly dense and less porous. The formation of CSH gel in brick alters the micro structure of the brick with discontinuous pores. The pore refinement or densification reduces the permeability of brick and improves the resistance against chloride diffusion into brick.The following reactions take place during the mixing:

$$\text{Portland cement} + H_2O = CSH + Ca(OH)_2 \quad (1)$$

$$\text{Portland cement} + H_2O + RHA = CSH + \text{Unreacted silica} \quad (2)$$

There are two types of calcium silicate hydrate (CSH) gel which formed during reaction between RHA and Portland cement:

$$Ca(OH)_2 + SiO_2 = CaO.SiO_2.(H_2O) + CaO.SiO_2.2(H_2O) \quad (3)$$

4. Results

Table 1. Representation of experimental results

Components	1st Batch	2nd Batch	3rd Batch	4th Batch	5th Batch
RHA (%)	54.2	52.5	50	52	51.9
Sand (%)	19.5	17.5	15	10	7.8
Lime (%)	26.3	28	30	32	33.8
Cement (%)	0	2	5	6	6.5
Compressive strength (KN/mm^2)	$1.18x10^{-3}$	$1.6x10^{-3}$	$1.9x10^{-3}$	$2x10^{-3}$	$2.1x10^{-3}$
Peak load (N)	3126	6280	9722	10850	12883
Strain @ brick (%)	1.81	2	2.4	3	3.6

4.1. Graphical representation of results

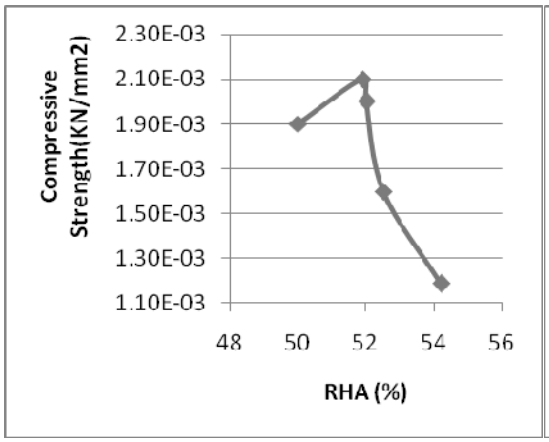

Fig. 2. Compressive Strength Vs RHA (%)

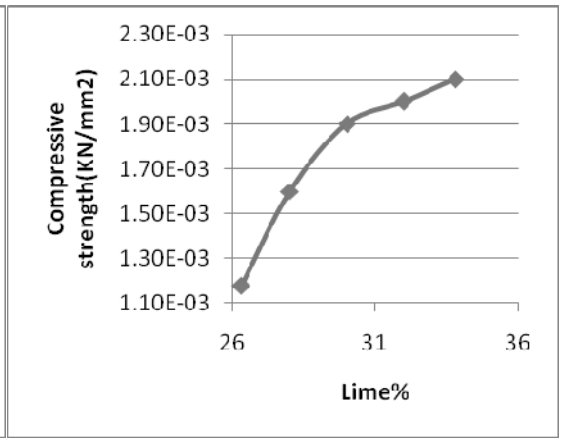

Fig. 3. Compressive Strength Vs Lime (%)

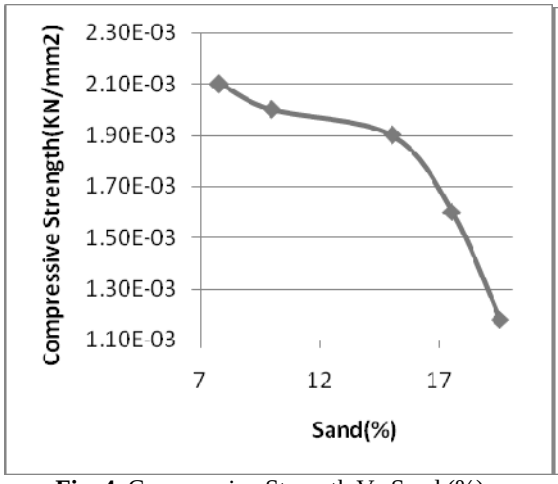

Fig. 4. Compressive Strength Vs Sand (%)

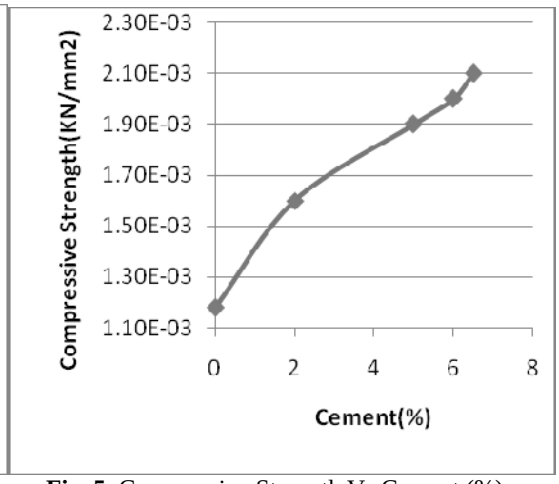

Fig. 5. Compressive Strength Vs Cement (%)

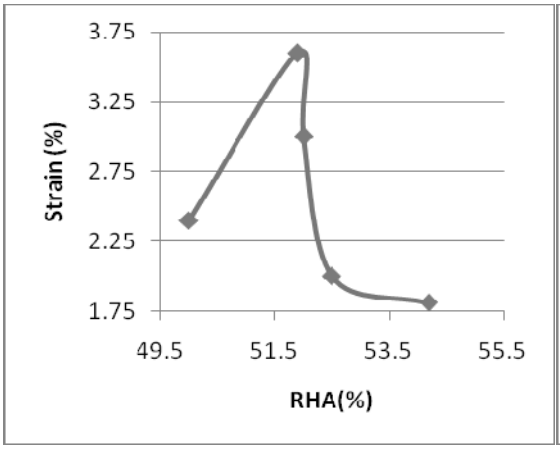

Fig. 6. Strain Vs Sand (%)

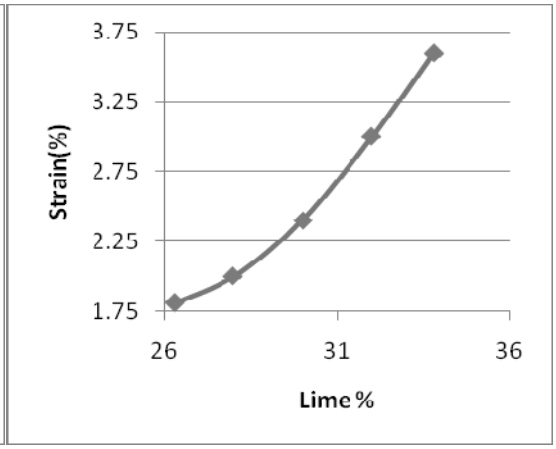

Fig. 7. Strain Vs Cement (%)

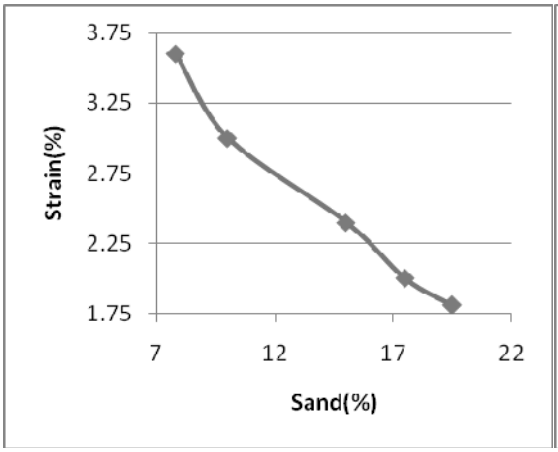

Fig. 8. Strain Vs Sand (%)

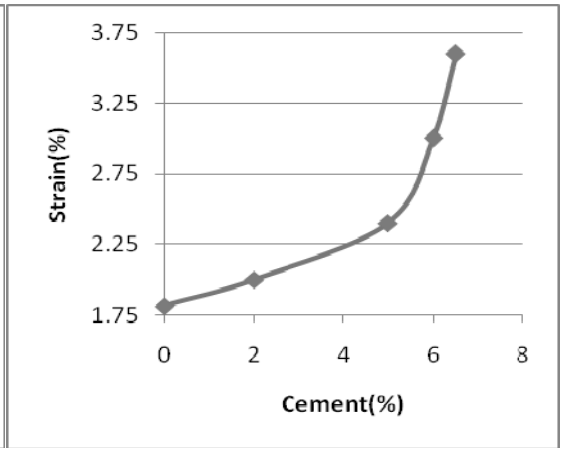

Fig. 9. Strain Vs Cement (%)

5. Result Analysis & Discussions

From the graphs, it is clear that compressive strength, peak load and strain of brick depend on the composition of brick. Binder (port land cement) plays very important role for compressive strength and pick load .From the result of first batch of experiment that compressive strength and pick load of brick is very low without binder. Because in presence of binder (Portland cement), Rice husk ash reacts with binder and forms calcium silicate hydrate (CSH) gel around the cement particles which is highly dense and less Porous, increase the strength of brick. From graph, it can be described that compressive strength and pick load increases with increase in the percentage of binder in the brick. Lime ($CaCO_3$) also plays important role for improving the strength of the brick. Compressive strength and pick load increases with increasing lime percentage. As rice husk ash is the main component of the brick, its percentage was kept around 50 %.So increase in the sand amount resulting decrease in the binder and lime amount. Also From graph, Compressive strength and pick load decreases with increasing sand percentage. Strain at brick is another important parameter of brick .From graph, it is clear that Strain at brick increases with increasing in binder and lime amount and decreases with increasing in sand amount.

6. Conclusion

Compressive strength observed from the pilot plant study for this brick is not sufficient to build high storeyed buildings. So the use of this brick should be limited to build one storeyed low cost houses. Compressive strength and peak load of the brick can be improved by increasing the amount of binder & lime. Ultimately the cost will be increased and it will not be feasible. So optimum amount of binder & lime can be increased to improve the Compressive strength of the brick. It is also important to study the behavior of this brick for long term exposure with environment. So further study can be extended to analyze the exposure behavior with different environment parameters like rain, humidity, sunlight, gaseous composition of air etc.

7. Acknowledgements

The supports from the Department of Chemical Engineering, Bangladesh University of Engineering & Technology & Pilot Plant and Process Development Centre, Bangladesh Council of Scientific and Industrial Research are gratefully acknowledged.

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Better Energy Utilization: A Solution of Power Crisis in Bangladesh

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Abstract

Bangladesh in these days encountered a severe power crisis. Due to less amount of fossil fuel, many alternative sources of energy are implemented in different forms. Although it does not assist in order to fulfill power requirement. On the other hand, proper use of existing energy can be means of power crisis solution. In this paper, an attempt has been made to unlock some way of proper management of our limited energy. Firstly, optimum uses of home appliances specially lighting, heating and cooling ones. Secondly, changing people lifestyle, in particular, early going bed and waking up from bed. Finally, early bird office time analysis is also reviewed. Taken together, a huge amount of energy can be saved. Consequently, the difference of demand and production of power is minimized by implementing the findings of the paper.

Keywords: Power, renewable energy, optimum utilization, early bird office schedule.

1. Introduction

Power is a very important factor in developing the economy and the standard of living of a country. It must be generated using the national resource of that country. Bangladesh largely depends on natural gas and hydro power stations to generate major portion of power. The country lags behind than its expected production capacity. Though many power generation units have been added to the national grid to solve the power crisis issue, it is not enough. High demand and increasing need of power have created challenge for the power stations to meet the demand. In our country, a major portion of total population still does not have the access to electricity. Only 10% of the rural households have electricity connection and there are some parts of Bangladesh which will not get the access of electricity connection from the national grid within next 30 years [1]. To solve energy crisis, we can use different form of renewable energy to generate power, optimum utilization of home appliances, change the sleeping time and also change or modified the office time. By creating new idea about power generation like foot step power generation, power generated from the speed breaker the crisis of energy also can be reduced.

1.1 Overview of power stations in Bangladesh

At present, BPDB operates 45 power stations (Including IPP) with a total installed capacity of 5823 MW. The information about power stations is shown in Table 1[2].

Table 1. Installed capacity of the different power stations in Bangladesh

Public sector		
Name of power station	Number of unit	Installed capacity (MW)
Total (East)	33	2982
Total (West)	17	737
Total (Public sector)	50	3719
Private Sector		
Total (East)	30	1799
Total (West)	8	305
Total (Private sector)	38	2104
Grand total	**88**	**5823**

From the above table it is proved that there is slightly sufficient power producing unit in Bangladesh by utilizing the existing energy.

1.2 Hypothetical demand and production curve for Bangladesh

From the rate of demand of power and production of power, a hypothetical curve for future in Bangladesh is shown in the figure 1.

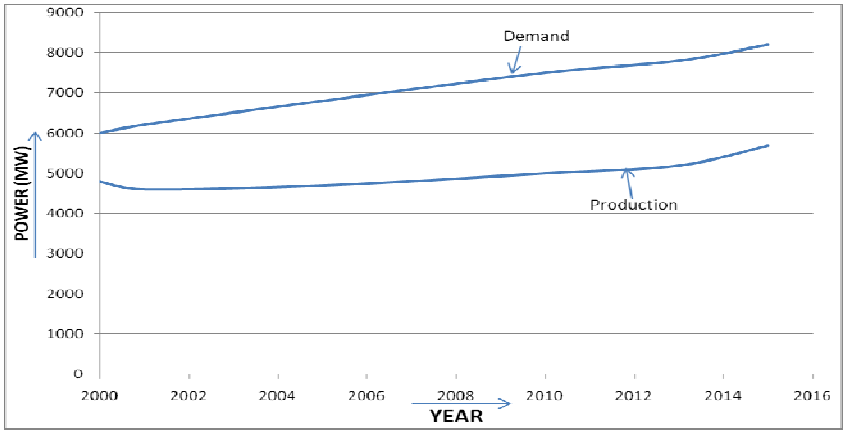

Fig.1. Yearly hypothetical demand and production curve of power

1.3 Challenge and solution of power utilization

Bangladesh lags behind than its expected production capacity. In Bangladesh, 90 million of the populations out of 140 million do not have direct access to electricity and remaining 50 million people have access but reliable and quality power is still beyond their reach [3, 4]. In order to achieve the growth rate, availability of a reasonable priced and reliable source of electricity is a prerequisite. High demand and increasing need of power have created challenge for the power stations to meet the demand. So to meet the demand all of us have to take some necessary steps.

2. Economic strategy of power consumption

For saving power some steps can be taken. Firstly, optimum uses of home appliances specially lighting, heating and cooling. Secondly, changing people lifestyle, in particular, early going bed and waking up from bed. Finally, early bird office time analysis is also reviewed.

2.1 Power consumption of different appliances

Here some home appliances with their power consumption are given in table 2 [5].

Table 2. Home appliances with power consumption

Fixture / Equipment	Wattage	Hours/day	Estimated kwhr use monthly
Cooling Equipment			
Air-conditioning Unit (0.75 HP)	727	12.0	261.72
Air-conditioning Unit (2.0 HP)	1,913	12.0	688.68
Desk Fan 10"	50	8.0	12.0
Stand Fan 16"	80	8.0	19.20
Ceiling Fan, 3-blader	140	8.0	33.60
Fan Box Type	50	8.0	12.00
Air Cooler/Humidifier	65	8.0	15.60
Entertainment Systems			
DVD/VCD Player	300	4.0	36.00
Tape Recorder (Cassette)	50	5.0	7.50
T.V. Set Color, 20"	110	5.0	16.50
T.V. Set Color, 26"	180	5.0	27.00
VHS	45	4.0	5.40
Stereo Component	380	4.0	45.60
VCD	145	4.0	17.40
Household Appliances			
Flat Iron	1,000	3-4 hrs/week	16.00
Clothes Dryer	1,600	3 hrs/week	19.20
Sewing Machine	75	3 hrs/week	0.90
Washing Machine (automatic)	585	1.5	26.33
Floor Polisher (Deluxe)	360	3 hrs/week	4.32
Hair Dryer	320	1.5	14.40
Vacuum Cleaner	400	3 hrs/week	4.80

Water Heater	3,000	8.0	720.00
Lighting Fixtures			
Ceiling Fixtures (3-lamps)	120	3.0	10.80
Fluorescent Lamp, 40 Watts	52	4.0	6.24
Compact Fluorescent Lamp	9	8.0	2.16
Fluorescent Lamp	20	8.0	4.80
	36	8.0	8.64
	40	8.0	9.60
Filament Lamp	25	8.0	6.00
	40	8.0	9.60
	60	8.0	14.40
	75	8.0	18.00
	100	8.0	24.00
Incandescent Bulb	20	4.0	2.40
	40	4.0	4.80
	100	4.0	12.00
Cooking Equipment			
Blender/Grinder/Mixer	300	0.1	0.90
Bread Toaster	600	0.1	1.80
Ranger, 4-burner	8,200	4.0	984.00
Oven (Electronic)	1,450	4 hrs/week	23.20
Microwave Oven	1,200	3 hrs/week	14.40
Turbo Broiler	1,000	1 hr/week	4.00
Rice Cooker, 1.8 liter	650	2.0	39.00
Kitchen Appliances			
Coffee Maker	600	0.5	9.00
Airport	600	4.0	72.00
Water Dispenser (Heater)	550	24.0	396.00
Water Dispenser (Cooler)	90	24.0	64.80
Chest Freezer, 8 cu. ft.	160	14.0	67.20
Chest Freezer, 10 cu. ft.	180	14.0	75.60
Refrigerator, 10 cu. ft.	170	14.0	71.40
Refrigerator, 11 cu. ft. (frost free)	150	14.0	63.00
Upright Freezer, 8 cu. ft.	60	14.0	25.20
Computers			
PC with monitor	225	8.0	54.00
Desk Jet Printer	175	4.0	21.00
Scanner	12	2.0	0.72

By using those carefully and timely switching them on/off it is possible to save a lot of power. The consumption of the power at the different specific appliances is shown in the figure 2.

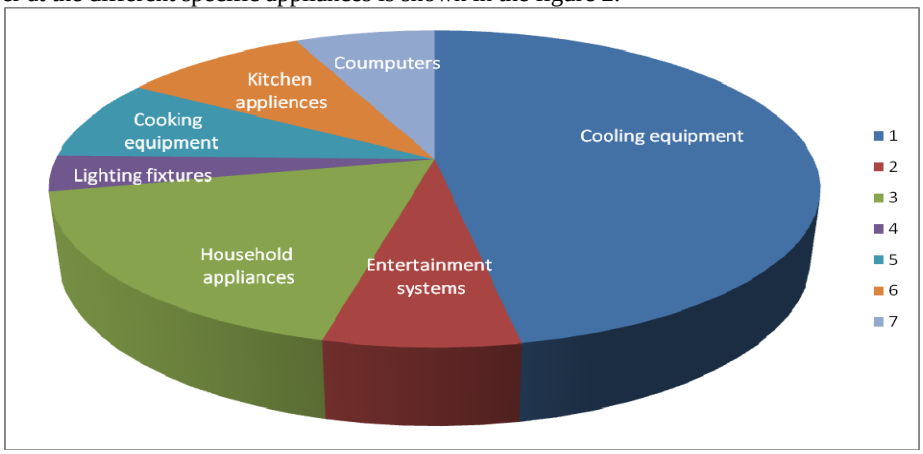

Fig. 2. Amount of power consumption at the different appliances of a middle class family

2.2 Proposed Strategy for saving power

2.2.1 Optimum use of home appliances

2.2.1.1 Light on at people staying room

In our country, it is seen that people put on all the lights in all rooms though they do not stay. This consumes much power which is unnecessary.Thus if only use light at that room where people are available or stay, saves much power like other country such as Australia.

2.2.1.2 Solar facing room design

The home sould be designed such that it will get maximum solar power.The room which needs more daylight should establish in front of sun as daining, reading room or kitchen etc.It saves the power which is used in day time.

2.2.1.3 Computer in Sleep mode

Sometimes computers are stayed on a long period though it is not in used. So if it is used only on sleep mode during the used off period, it saves much power.

2.2.1.4 Clean freeze from unnecessary things

Potato, egg or other less perishable food should out of freeze until good condition, and freezes only those items which will be consumed in very near future. Water cooling also better before 30 - 45 minutes from drinking which saves huge wastage power. Continuous power consumption is required to keep on cool of the food material. Therefore unnecessary foodstuff should be kept out from freezer.

2.2.1.5 Central A/C

In our country, in a single room individuals A/C s are used in many organizations. This consumed huge amount of power. So by using central A/C at the whole organization power is saved.

3. Life Style changing

3.1 Changing of sleeping time

In our country, it is seen that people go to the bed late night in the city and use more power in home appliances. By changing the late sleeping habit a lot of power will be saved.

3.2 Unnecessary lighting in different functions

In our country, it is seen that in marriage, birthday and in other different occasions too much lighting is done which is totally unnecessary. Also in some departmental store, hotels, restaurants, night clubs etc. the same thing is happened. By reducing high use of lighting in these sectors, it is possible to save power.

3.3 Turn off road light immediately just before sun rise

By turning off the road light immediately just before sun rise power will be saved, which is absent in country.

3.4 Early market closing

By closing the markets according to government rules, it is also possible to save power.

4. Early birds office time analysis

4.1 Daylight saving time (DST)

This is another method by which a lot of power will be saved and this is Daylight saving time (DST), is the practice of advancing clocks during the lighter months so that evenings have more daylight and mornings have less. Typically clocks are adjusted forward one hour near the start of spring and are adjusted backward in autumn. If it is done, the office can be started one hour earlier.

4. 2 Proposed Office time

From the above table we see that the average daylight time in summer is near about 13 hour 30 minute and in winter that is 10 hour 40 minute. So for winter and summer office time may be different. The time of sunrise and sunset in Dhaka for the month of June and December is given in table 3 [6].

Table 3. Rising and setting times for the Sun

Season	Date	Sunrise	Sunset	Length of day	Solar noon	Proposed office time
Summer	Jun 27, 2013	5:14 AM	6:49 PM	13h 35m 28s	89.6°	7.30 AM to 5.30 PM
	Jul 3, 2013	5:16 AM	6:49 PM	13h 33m 51s	89.2°	
Winter	Dec 1, 2013	6:24 AM	5:11 PM	10h 47m 02s	44.5°	8 AM to 5 PM
	Dec 10, 2013	6:30 AM	5:12 PM	10h 42m 33s	43.4°	

4. 3 Office time in developed countries

Many countries regulate the work week by law, such as stipulating minimum daily rest periods, annual holidays and a maximum number of working hours per week. Normally in developed countries peoples working 40 hours in a week without overtime. In most of the developed countries like USA, UK etc. working time is 9 am to 5 pm. In USA with the average man employed fulltime for 8.4 hours and woman for 7.7 hours

per working day [7]. From January 1, 2010, Australia enacted the new maximum weekly hour regulation under a new system created by the Fair Work Act 2009. Unless the additional hours are reasonable, the maximum weekly hours of work of a fulltime employee is 38 hours [8]. China enacts a 44hour normal working week and a maximum of 48 hours of work per week [9]. In some countries like UAE, China, and Australia this is more but in day and that is 8 am to 6 pm. They are thinking to come early go early from the office and use the day light as maximum as possible for their office rather than the electricity. This thinking helps to save a lot of power.

4.4 Benefits of early birds office time

Less light using, less fan and air condition required, less traffic jam etc.

5. Steps to overcome power crisis

Reducing system losses play the major role in case of power crisis in Bangladesh. At least 25% of total demand could be fulfilled by reducing system loss. Technical and non technical system loss could be removed by taking the following steps:

5.1 For reducing technical system loss

1. Disconnect the illegal connection of electricity. In that case law enforcing agencies take the initiative. There should be punishment to the charged people.
2. Connect the modern error free meter and implement the meter sealing system.
3. Whole billing system should be under computer net-work and dues should be collected properly.

5.2 For reducing non technical system loss

1. Latest technology should be implemented for the distribution of electricity. Insulated cable may used in the overhead transmission line. It is essential to modernize the distribution line, replace the old set up of the transformers, and switch gear as early as possible. Life time and maintenance of all technical equipments should be ensured properly.
2. Employees of all levels must be responsible for their respective duties. As it is a technical work all employees should have the vast idea in this field. Administration should be ensued severe punishment for the dishonest employees and power station should be close to the load center.

5. 3 Utilization of energy saving lamp

CFL or energy saving lamp can play a vital role to reduce the power crisis. CFL is a glorious energy saving lamp. Average ordinary lamp energy consumes 60 to 100W and tube light 40W. But CFL energy consumes only 9W and its intensity of lumen is higher than ordinary lamp. At present only for lighting load electricity is required more than 600MW. If 80% of the huge demand is brought into under use of CFL, then at least 300MW will be saved this is completely equivalent of set up a generating station of 300MW. To provide CFL at cheapest rate Government should provide tax free import of CFL, customer can get easily and subsidies should be given to encourage local manufacturers of CFL.

5.4 Proper load management

Load management means proper distribution and use of electricity. It could be suggested that for keeping load shedding at a minimum level Government should take the following initiatives:

i. Government should take motivational programs to enhance awareness of the consumers during peak hours. Campaign should be essential to request the consumers through electronic and print media to be rational and economical in electricity use during peak hour by switching off, unnecessary loads like extra lighting, ironing, pumps, air conditioners and welding machines etc.

ii. Industries and large commercial customers like shopping malls should use their own captive generation and Government could transfer holiday in the markets and industrial belts.

iii. Implementation of prepaid metering system will give additional facility.

5. 5 Encourage Independent Power Producers (IPP)

The Government should encourage owner of industry or factory to install their own small electricity generating plants to continue uninterrupted production during the load shedding, help them to supply adequate gas as a subsidized rate and ensure tax free imports spare parts of gas generator, and involve more power producer like Summit power in IPP [10].

5. 6 Expansion of renewable energy program

5. 6. 1 Development in solar energy program

Solar energy program has glorious opportunity in Bangladesh. Government has already been taken a solar energy development program in the Chittagong hill tracts area. This program should expand in the rural areas of the whole country to save power.

5. 6. 2 Expansion of wind energy program

For power generation the average wind speed is 5 m/sec at a height 20-30 m. The average wind speed of some costal area at a height 25 m in Bangladesh is shown in table 4[11].

Table 4. Wind speed in different places of Bangladesh

Area	Max. Speed for some time m/sec	Ave. yearly Speed m/sec
Potenga	15 (8 months)	4.2
Anwara	14 (6 months)	4.1
Teknaf	16 (7 months)	4.6
Feni (Muhuri)	15 (5 months)	4
Kutubdia	16 (9 months)	5
Kuakata	16 (9 months)	5
Char Fassion	16 (6 months)	3.8
St. Martins	20 (9 months)	5.5

From the above it is clear that there is a prospect of wind Energy Program in Bangladesh.

5. 6. 3 Enhance biogas plant for power generation

Biogas plant could be established in the remote area where there is availability of animal, plant and human wastage. For implementing this, Government should encourage IPP to set up bio-gas plant by giving technical and financial support. In that case if the wastage of dairy can be used as raw materials, there is a good prospect of biogas power plant in dairy rich area like Gazipur, Norshingdi, Narayonganj, Savar and Manikganj. There is a bright future for biogas plant in the city corporation area like Dhaka, Chittagong, Khulna, Rajshahi, Sylhet and Barishal where thousand ton of wastage are wasting every day. If these wastages can utilize properly, get power as well as we can save our environment from pollution.

5. 6. 4 Sugar Co-generation projects

Prospects of sugar Co-generation power plant there after installation of as many as 10-15 nos. of generator having 10-15 MW capacity each in the northern zone of Bangladesh where bagasses are available from the sugar mills. Cost will also be economical compared to the cost of generation of electricity by using fuel oil.

5. 6. 5 Implementation of Nuclear Power Plant

There is a huge gap between supply and demand which is increasing day by day. Since maximum power plants are gas based and proven gas reserve is reducing and no new gas reserve has been discovered yet. This huge gap cannot be met by renewable energy. In that case nuclear power may be the alternative option for generating electricity. Nuclear power could be a reality to bridge between the huge gaps between supply and demand.

6. Conclusion

Power is a great phenomena in our day to day life without whose the whole world will become dark .And also power plays a vital role in development of civilization. The advancement of a country is measured in terms of per capital consumption of electrical energy. But Bangladesh faces serious power crisis. It is quite impossible to solve over all power crisis but possible to control load demand by using CFL, transferring holiday, transfer from peak to off-peak hour only through proper planning by load management, encouraging IPP, reducing transmission loss, more utilization of renewable energy sources, modifying the office time, changing the sleeping time etc. Government should give priority to control misuse and corruption in power sector than generation of power and search alternative raw materials for the production or immediate exploration of new gas and mining of coal deposits that are essential to implement the above power generation program. Thus, we can solve this problem not only by installing new power plant or utilizing the different energy sources but also proper management by which produced energy can be utilized to overcome the power problem of Bangladesh.

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Renewable Energy for Rural Development in Bangladesh

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Abstract

Energy is one of the main prerequisites to ensure socio-economic development. The availability of energy sources and its proper utilization of energy are the prime concerns for achieving growth and progress in developing countries. Bangladesh is also facing difficulties in supplying energy to maintain its economic growth. The gap between demand and supply is gradually increasing. The situation is even worse in the rural areas where supply of energy is still very uncertain. There is also a notable discrepancy in the energy shares between urban and rural usage. The situation calls for adaptation of sustainable energy strategies that permeate energy level of the economy and can provide rural dwellers with the basic services that they need. Bangladesh has good potential for harnessing renewable energy sources such as solar, biomass, wind wave energy etc. It has been experiencing a gradual shift towards exploring renewable energy resources as a means of driving force for rural development. Few public and private organizations have started to take part to develop renewable energy technologies (RETs) projects. It is promising that the percentage of renewable energy usage in the rural area is increasing day by day with such initiatives. Renewable Energy Policy has been adopted and plans have been made to implement the policy and obtain a fare share of renewable energy at the earliest possible time. The implementation of renewable energy have brought about significant changes in the life of rural people. It has proved that development in rural areas can be much benefitted with the proper utilization of our renewable energy sources. However, in Bangladesh efficient utilization of renewable energy resources is yet to assume proper commercial dimensions and hence rational policy dissemination on renewable energy usage is essential

Keyword: Renewable energy, Rural development, Solar, Biomass, Wind, Mini-hydro, RET.

1. Introduction

For a developing country like Bangladesh uninterrupted electricity supply is of topmost priority. The scenario of power and electricity in Bangladesh in recent years with proposed solutions to improve the situation have been presented in various papers [1], [2], [3]. Bangladesh also relies on renewable energy to meet some of the power demands, especially in the rural areas. The overall status of renewable energy technologies(RET), their field of applications and prospects in this country have been shown in [4], [5], [6], [7], [8], [9]. For a sustainable renewable energy mix with respect to Bangladesh, there has been numerous researches. Different approaches to solve the power crisis in this country have been pointed out explicitly by various authors [10], [11], [12] etc.
This paper focuses on the present power scenario of Bangladesh and contribution of RETs in the rural development. It also discusses about some of the prime barriers to the implementation of RETs.

2. Current situation of power in Bangladesh

The total installed capacity was 4005 MW in FY 2000-01 which has increased to 6685 MW in FY 2010-11 (13 June, 2011) with an annual increasing rate of 6.62 percent. However, the maximum generation was 3033 MW in FY 2000-01 which has increased to 4699 MW in FY 2010-11 (13 June, 2011) with an annual increasing rate of 5.49 percent.
The following graphs shows the trend in demand and supply gap of electricity in Bangladesh.
Within the reach of the national grid Bangladesh is still reeling under 600 - 1200 MW of ‘load-shedding’. This gap in demand and supply of electricity has given rise to take renewable energy technologies (RETs) more seriously in contributing towards the deficiency.

Table 1. Electricity Scenario: At a Glance (31st December 2012)
[Bangladesh Power Development Board]

Generation Capacity	8525 MW
Maximum Generation (on 04 August 2012)	6350 MW
Per Capita Electricity Generation (including captive generation)	292kW-hr
Number of Clients (connection wise)	13.64 million
Total Beneficiaries	95.60 million
% of Population under electrification	60%

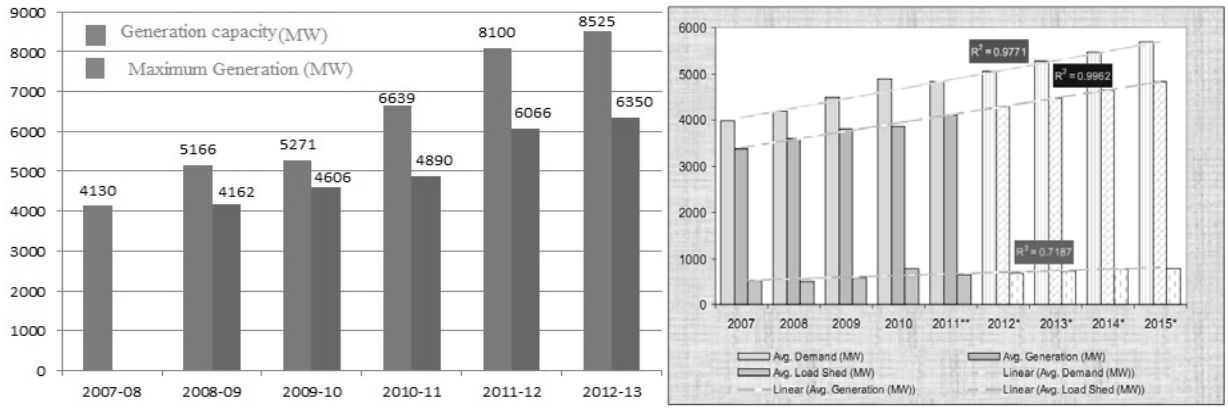

Fig. 1. Current situation and feasible future electricity demand, generation and load shedding

3. Different technologies in power generation sector

The following figures show the fuel mix of power generation in Bangladesh. It can be seen that though conventional fuels have been used steadily for the generation of electricity, renewable sources are gaining their share into the scenario.

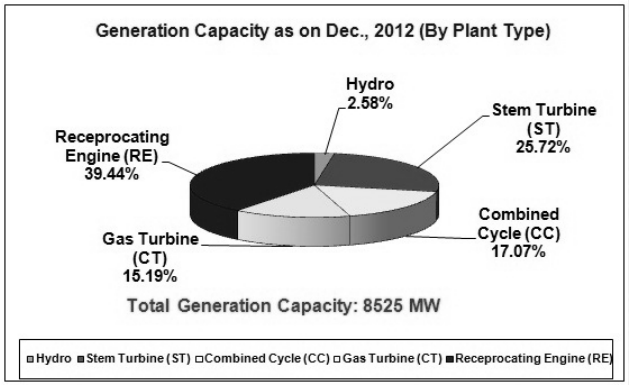

Fig. 2. Different technologies in power generation

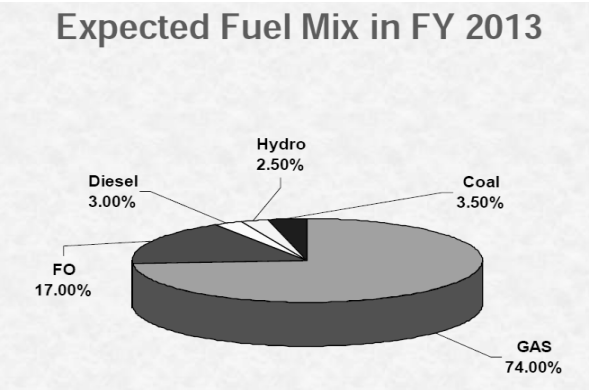

Fig. 3. Expected fuel mix in 2013

3. Renewable Energy Technologies(RETs)

Renewable energy technologies (RETs) can help Bangladesh to self-reliant in energy supplies. Some RET models have already been implemented in rural areas in Bangladesh. The following table shows installed capacity of different RETs in Bangladesh:

Table 2. Capacity of different RETs *[Infrastructure Development Company Limited (IDCOL)]*

Technology	Installed Capacity (Approximate estimation)
Solar	80 MW
Improved biomass cooker	around 300,000
Biogas	around 250,000
Wind turbine	2.8 MW
Micro-hydro	10 kW

Solar energy

Bangladesh is located between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east which is an ideal location for solar energy utilization. Here, the daily average solar radiation varies between 4 to 6.5 kWh per square meter [4]. Maximum amount of radiation is available on the month of March-April and minimum on December-January. Infrastructure development company limited (IDCOL) has supported NGOs in installation of solar home systems (SHSs) [14]. Bangladesh University of Engineering and Technology (BUET) has conducted many research works since 1980 on solar energy. Solar energy has been found to be useful in various ways to facilitate the rural people.

Solar Home System (SHS)

SHS was first implemented by Rural Electrification Board (REB) followed by various private organizations like IDCOL, Grameen Shakti etc. A typical SHS in Bangladesh consists of solar panel, storage battery, charge controller and directly connected DC appliances. SHSs are attractive for small rural business; however, these are not economically viable for only household lighting purpose.

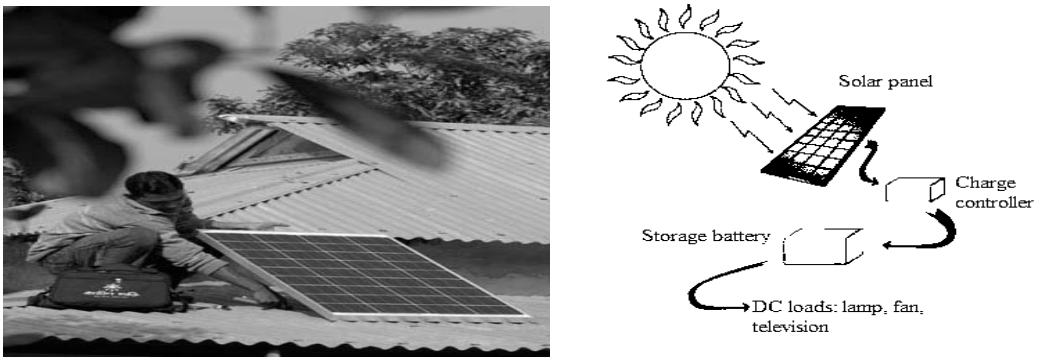

Fig. 4. Components of solar home system

Solar cookers

IDCOL, Grameen Shakti and BRAC are working on development and dissemination of solar cooker with the support from GIZ. Institute of Fuel Research and Development (IFRD) of Bangladesh Council of Scientific and Industrial Research (BCSIR) and Centre for mass Education in Science (CMES) are also engaged in promoting solar cookers. Several research projects have been conducted by BUET on solar cooker and its efficient construction. A low cost reflector type cooker can much benefit the rural mass in Bangladesh.

Solar Dryer

Different models of solar dryers have been designed and constructed with locally available raw materials. The Institute of Food Science and Technology (IFST), Bangladesh Agricultural University (BAU), BUET have been working on developing different efficient model of dryer for drying fruits, vegetables, fish etc. at an affordable price.

Solar Water Heater

Solar water heaters designed and fabricated by IFRD, BUET, Dhaka University (DU), BCSIR have been very useful. These heaters absorbs solar radiation, convert into heat and transfers the resulting heat to circulating water at a temperature below 90^{o}C.

Solar pump

Several organizations like REB, IDCOL, GIZ, Grameen Shakti, BUET, Oxfam, Bangladesh Jute Research Institute (BJRI) and many others have been working on solar pumps to provide water in the rural areas for irrigation and household uses. BUET with the support of Bangladesh Academy of Science (BAS) have established solar irrigation pumps. IDCOL also have financed many projects to set up solar irrigation pumps in different parts of the country. Some of this pumps is expected to provide irrigation facilities to more than 22.5 hectares of land benefiting as much as 22 farmers. GIZ has also been working on solar pumps to provide clean drinking water to households in the rural areas since 2010.

Solar micro grid

Solar micro grid has a great potential in solving power shortage in the countryside. IDCOL has been financing different NGOs to install solar micro grid based power system to supply electricity in remote places. Several pilot projects have been taken up already which are expected to successfully provide electricity in small villages.

Wind energy

Bangladesh has a 724 km long coast line 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. The Bangladesh Power Development Board has estimated that wind energy can contribute to 10% of the energy needs of the country.

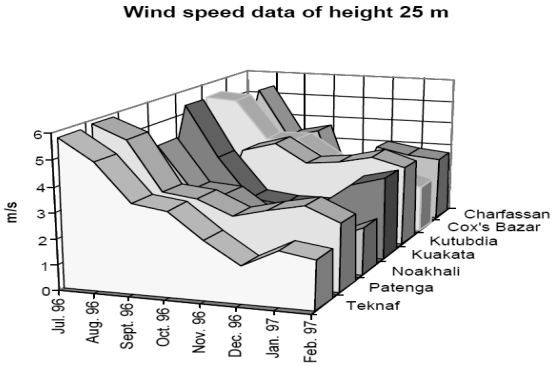

Fig. 5. Feasibility of Wind Conditions at Different Places

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. The power plant, located near the Muhuri Dam in southeastern Feni district, have four separate wind turbines of 225 kW each. It is now ready to generate electricity from wind and supply to the Muhuri Irrigation Project and the national grid, according to The Bangladesh power development board.

Beside several small wind generators have been installed by BRAC (11 small wind turbines in various coastal sites) and Grameen Shakti (two wind generators of 300 W and 1 kW at its Chakoria Shrimp Farm). Grameen Shakti has recently installed 4 small wind generators (three l.5 kW and one 10 kW) in Barguna district.

Biomass and Biogas

For an agro-based country like Bangladesh produces huge amount of waste materials. According to an estimate 29.7 billion m^3 of biogas can be obtained from the livestock of the country which is equivalent to 1.5 million tons of kerosene (which is the principal fuel in the rural areas). Converting these waste materials into energy is economically advantageous as well as helpful to solve the issue of power crisis. 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.

The Government along with several NGOs is working together for development of power production from Biogas. Several studies on biogas plants and efficient functioning have been conducted by BUET at different times. BAU, IFRD, REB, IDCOL, Grameen Shakti, BRAC, GIZ and many other organizations have successfully installed numerous biogas plants across the country. Grameen Shakti have completed 13,500 biogas plants. Recently Seed Bangla Foundation has proposed a 25 KW Biogas based Power Plant in Rajshahi. IDCOL, a Government owned Investment Company fixed a target to set up 37,669 biogas plants in Bangladesh by 2012, under its National Domestic Biogas and Manure programmers (NDBMP). It has also set a target of 25 per cent of the total target of biogas plants in the northern region which is yet to be brought under the national gas grid. Besides working in partnership with IDCOL, 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. Moreover, since May 2011, IDCOL along with its

Fig. 6. A Biogas plant

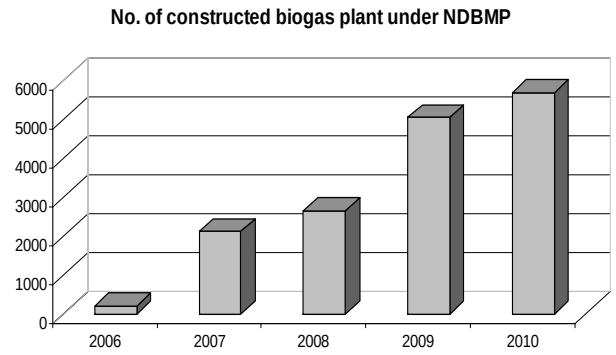

Fig. 7. Biogas plants construction in Bangladesh under NDBMP

partner organizations; has installed 18,713 biogas plants in different parts of Bangladesh. Some of these partner organizations and projects are listed below:

Table 3. Biogas Plant installation up to May, 2011 *[IDCOL Renewable Energy Project,2012]*

Partner Organization	Biogas plant completed
Grameen Shakti	10,637
Rahman Renewable Energy Co. Ltd. (RB)	896
Save our urban life - SOUL	865
Kamrul Biogas and Compost Fertilizer Research Development Co. Ltd. (KB)	850
Hossain Biogas and Compost Fertilizer Company Ltd. (HB)	609

Economic benefits derived from such biogas plants in terms of fuel and chemical fertilizer saving can have notable impact on the national economy. In future, the biogas technology is expected to be the driving force for ongoing growth of the poultry industry in Bangladesh.

Bangladesh has a huge resources of biomass fuels like crops residue, rice husks, sugarcane, vegetables, animal dung, poultry wastes etc. Different Government organization and NGOs have been working to promote biomass technology. IDCOL have financed to set up some biomass plants at different parts of the country. There has been a number of researches on fabrication of biomass plants for improved performance

Micro hydro

Hydropower is an eco-friendly clean power generation method. The scope of hydropower generation is very limited in Bangladesh because of its plain terrains except in some hilly region in the northeast and southeast parts of the country. However there are lots of canals, tributaries of main river Karnafuli, Shangu, Matamuhuri as well as tiny waterfalls having good potentials for setting up mini/micro hydropower unit in Chittagong Hill Tracts (CHT) region. A 50 kW micro-hydro plant was installed at Barkal Upazila of Rangamati district in 2005. BPDB has taken steps to install 50-70 kW Mohamaya Irrigation-cum-Hydro Power Project at Mirersorai, Chittagong and 50 kW Micro-Hydro Power Plant at Barkal Upazila of Rangamati district. Several projects are still under planning of BPDB.

4. Barriers

There are plenty of barriers of different types hindering the widespread deployment of potential RETs. Different types of barriers are: Policy barrier, Institutional barrier, Technical barrier, Market barrier, Economic, Financial and Financing Barrier, Information Barriers, Human Resource Barriers etc. Some of the barriers of various types experienced from the past are enlisted below:

- There is lack of public awareness on renewable energy technologies other than that they exist. For example, Availability of renewable energy resources is very site specific, requiring detailed analysis of the local specific conditions.
- knowledge that the life cycle costs of most renewable energy technologies are often competitive or even lowest among cost options is mostly absent.
- Lack of awareness of renewable energy in public, industry, utility, financial institutions and policy-makers.
- High initial capital costs.

- Higher perceived risks of the renewable energy technology.
- Local manufacturing and/or assembly of renewable energy technology components are currently very limited, although the knowledge, skills, expertise and facilities are available in the country.
- Lack of information about renewable energy resources, technical/economic information about RETs, equipment suppliers, and potential financiers.
- Lack of financial incentive policies to encourage renewable energy development
- Lack of standards and quality control for renewable energy equipment.
- Limited knowledge on the renewable energy market potential.
- The high upfront cost at the end user level for renewable energy is a major barrier to the increased use of renewable energy sources for the provision of modern energy services.
- No dedicated financing for renewable energy activities exists with financial institutions now. The capacity within the financial institutions and power utilities to appraise renewable energy proposals and requests for loan is limited or non-existing;
- Limited in-country capacity for renewable energy data collection and analysis.

5. Summary

There is no doubt that Renewable Energy Technologies will play a significant role in the future development scenario of the country. The conventional energy sources are failing in our country to meet the demands with the current budget. However, it is promising that the percentage of renewable energy usage in the rural area is increasing day by day with the initiative by both the Government and the private sectors. Renewable Energy Policy has been adopted and plans have been made to implement the policy and to obtain a fare share of renewable energy at the earliest possible time. The implementation of renewable energy technologies have brought about significant changes in the life of rural people. It has proved that development in rural areas can be much benefitted with the proper utilization of our renewable energy sources. But the developing countries like Bangladesh should take efforts to establish the technical reliability and social acceptability of such technologies through Demonstration / Pilot Projects. Proper guidelines and execution of plans taken so far could bring a revolutionary change in the life of the rural people as well as a positive result for the country.

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An investigation on the production of Brown gas (HHO) as an alternative automotive fuel by water electrolysis

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Abstract

The ever increasing cost of conventional fossil fuels and the associated environmental impacts of their uses have become the major concerns worldwide. Exhaust pollutants from internal combustion (IC) engines are one of the major sources that contribute to the total environmental pollutions globally. Consequently, researchers worldwide are working overtime to improve the fuel economy and emission characteristics of such engines. At the same time, they are forced to focus on the study of alternative fuels that can be used in engines without the need for a dramatic change in the vehicle design. Among different alternative fuels, brown gas (HHO, also known as hydrox gas) can be considered as a renewable, recyclable and non-polluting fuel as it contains no carbon in its molecule. The aim of this work is to design and fabricate a compact unit for generating HHO gas by water electrolysis. This HHO cell can be attached to the air intake manifold of an IC engine, so that a fuel mixture of gasoline and HHO gas is introduced inside the cylinder. Plates of stainless steel were used as both the anode and cathode in the HHO cell throughout the whole process. The electrolyte of the cell was a mixture of distilled water and potassium hydroxide (KOH). Effects of inter electrode gap, number of electrodes, solution concentration and current density on the production of HHO were investigated. Results revealed that single anode and cathode provided unsatisfactory production of HHO gas. Optimum yield of HHO was found using multi-electrode system i.e. single anode and two cathodes from a solution containing 1% KOH and 100ml of water producing 2150 cc of HHO gas when electrolysis was carried out for 15 minutes.

Keywords: Alternative fuel, Brown gas, Water electrolysis, internal combustion engines, pollution.

1. Introduction

In modern days the growing energy demands are still met mainy from fossil fuels such as coal, petroleum oils and natural gas. Fossil fuels provide energy in a cheap and concentrated form, and as a result they dominate the energy supply. However, the burning of the fossil fuels emits harmful pollutants which have negative impacts both on the environment and lives. Global warming is considered as one of the major problems the scientific community is facing today. Many theories refer to the increase of exhaust gases concentration in the atmosphere as one of the major causes of the global warming [1]. Industrial plants and automobiles are the major source of the exhaust gases. Fossil fuel uses in the transportation sector, in particular, is of great concern for the age as the world energy consumption in the transportation sector increases by an average of 1.1 percent per year [2]. Transportation activity is expected to grow significantly worldwide of the next years, with most of the increase occurring in non-OECD countries. The fast-paced growth in non-OECD transportation energy demand is a result of strong economic growth that leads to rising standards of living and corresponding increases in demand for personal and commercial travels.

The combination of issues - the increasing prices of petroleum fuels, the rise in awareness of environmental issues, concerns over energy security, stricter regulations on engine/vehicle emissions, and high growth rate of their consumptions, spurred interest in moving the world away from petroleum fuels for engine (especially vehicles) applications and toward alternative fuels and advanced vehicle technologies. This encourages researchers to seek for alternative solutions to be used in engines without the need for a dramatic change in the vehicle design. Among those using hydrogen (H_2) as an alternative fuel which enhances the engine efficiency and runs with almost zero pollution effect has been researched well in the last decade. The combination of the

molecular composition of H_2 and some of its interesting properties (such as high laminar flame speed, wide flammability range, etc.) reveals hydrogen as an attractive fuel for internal combustion engines [3]. Besides, compared with traditional fossil fuels, H_2 is a carbonless fuel whose combustion does not generate emissions such as HC, CO and CO_2. However, there are concerns regarding the viable solutions both for the generation and storage of H_2 from the commercial point of views. Other researchers have used biogas [4-5], syngas [6], producer gas [7murari] either solely or with H_2 blends successfully in gasoline engines. The use of HHO gas in gasoline engines is comparatively new. HHO gas is the mixture of H_2 and O_2 in a ratio 2:1 by volume – products of water electrolysis, which is invented since March, 1978 by Yull Brown [8]. Hence, electrolytic gas often called as "Brown's gas" or Hydrogen Rich Gas (HRG). In recent years, there are some investigations on the effects of HHO gas addition on performance of spark ignition (SI) [9] and compression ignition (CI) engine [10]. Studies indicated that the addition of HHO gas seemed to affect engine performance in the same way as if the hydrogen had been used on its now: fuel consumption reduced [11], the torque and indicate mean effective pressure (IMEP) surged, the combustion duration and cycle-to-cycle variation also declined. However, the NO_x emissions were found to be increased [12].

Water electrolysis is a technique that utilizes a direct current (dc) to split water into protons, electrons, and gaseous oxygen at the anode (positive electrode) and hydrogen at the cathode (negative electrode) in the electrolyzer. HHO gas can easily be obtained from water using a HHO fuel cell. As fresh water is available, it is possible to generate HHO gas cheaply. When dc electricity is supplied through water it separates hydrogen and oxygen molecules. Usually two metallic electrodes (as anode and cathode) are immersed in aqueous solution of catalyst. The positive current positively charges the anode which yields the electrolysis reaction of the electrolytic solution and eventually releases gaseous unseparated oxygen and hydrogen. In industrial plants the alkaline electrolysis is preferred, because corrosion is more easily controlled and cheaper construction materials can be used compared to acidic electrolysis technology. An alkaline electrolyzer immerses the two electrodes, the cathode and the anode, into an aqueous alkaline electrolyte, typically a solution of sodium or potassium hydroxide, and a voltage is applied across the electrodes. The resulting migration of ions in solution results in the production of hydrogen at the cathode and oxygen at the anode according to [13]:

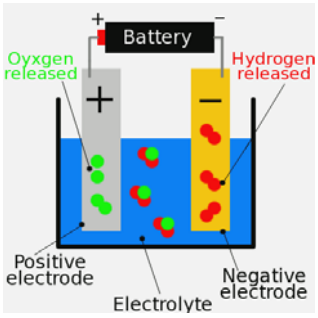

Fig. 1. Alkaline Electrolysis [14]

$2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$ Anode reaction

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ Cathode reaction

$2H_2 + O_2 \rightarrow 2H_2O$ + electric energy + heat Overall reaction

The catalysts can be NaOH, KOH or NaCl for more HHO production and an optimum molality of the catalyst is important to keep electrical resistance-conductivity balance in the cell. Hydrogen and oxygen do not form into O_2 and H_2 molecules. Rather they may remain in their monoatomic state (a single atom per molecule) and thus there are no atomic bond needed to be broken (i.e. the bonds of the H_2 and O_2 respectively) before turning back into water. Hence, HHO gas can have more energy because these bonds are never made. In this state, which is an unstable state of H_2O vapor, more energy can be achieved compared to H_2 burning with O_2 [10].This hydrogen molecule acts as a fuel and oxygen molecule helps to burn the fuel. The heating value of hydrogen is high and for the presence of oxygen the proper combustion can be assured.

The main objective of the present work is to design and fabricate of a compact unit of HHO fuel cell for HHO gas production in laboratory scale. The electrolyzer used for this project is easy to construct by using locally available materials and they are cheap. Electrodes are chosen bearing into mind that they should withstand high temperatures as well as high current flows. The used electrolyte is relatively cheaper which is not harmful for human being. Total construction procedure is simple and also it consumes less time for maintenance. The produced gas is monitored, measured, collected and sampled for elemental analysis. Finally, a theoretical analysis is done in order to assess the potentiality of using the gas as an alternative fuel for gasoline engines.

2. Experimental details

The experimental setup includes mainly the fabrication of an electrolyzer in which the electrolysis reactions would occur. The other important tasks includes material selection for electrodes, electrolyte selection, gas collection method development etc. Transparent plexiglass (having 4mm thickness) is used to make the reactor container or the eletrolyzer. The dimension of the designed electrolyzer is about 18cm×15cm×15cm (Fig.2) with a capacity of 3 liters solution. Plexiglass has some special properties other than visibility such as noncorrosive, nonconductive, nonreactive with electrolyte and it can withstand high pressure and temperature. Stainless steel is selected as electrode material as it is high corrosion resistant, non reactive with the electrolyte, good

trolyzer

conductor, and capable to withstand high temperature and voltage. Also the use of stainless sttel as electrodes can assure better HHO production rate at low cost [9-11]. The size of the electrodes used in this study is about 15cm×10cm. In this study, both the cathode and anode are made from the same stainless steel plates (Fig.2) for the cell. Since the target HHO gas is collected from cathode, the number of cathode plates are kept more than the anode. In this study, we have used two cathode and one anode plates arranging in cathode-anode-cathode order. Food grade Potassium Hydroxide (KOH) is used as electrolyte to speed up HHO production. Researchers have demonstrated that HHO gas flowrate increases in relation to mass fraction of catalyst in water. An electrolyte with increased amount of catalyst can dramatically increase current supplied from battery due to the higher reduction of total electrical resistance in the solution. Two types of electrolyte: 1 % and 0.5% KOH solution are used to perform the electrolysis process. The plate electrode and KOH(aq) are found satisfactory in relation to the electrical power consumed in the experiment. A DC battery (similar to that is used in automobiles) is used as the main power source of this experiment. The terminal voltage of the battery is 12 V and current rating is 30Amp/hr. Typically 15-18 amps current is supplied through the electrolyzer.

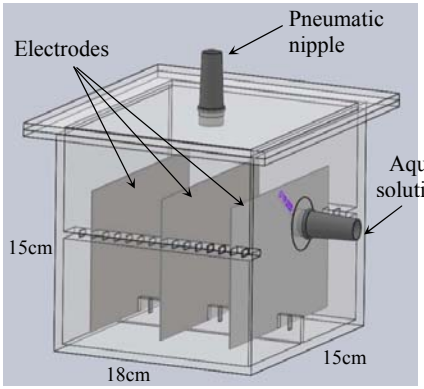

Fig. 2. Designed plexiglass electrolyzer

The generated HHO gas is collected by the water displacement method. The gas collection container initially filled with water and is placed as inverted cylinder in a reservoir of water. As the gas is created, it will displace water from the container. The volume of gas can be determined by the amount of water displaced by the gas. Electric currents are measured by an ammeter (0 to 30 amps AC/DC ammeter) and voltages are measured by a digital multimeter. The total experimental setup is presented in Fig.3.

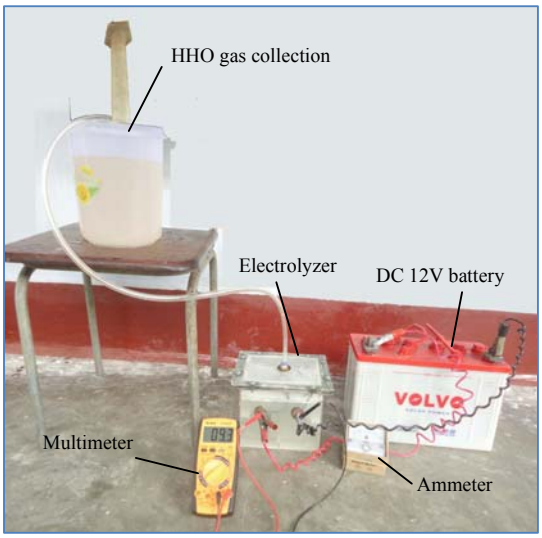

Fig.3. Total experimental setup

According to Natalia Chraplewska, Kamil Duda and Milosz Meus [15], the optimal voltage on the electrode is 1.48V, while the amount of the produced gas depends on the current strength. The volume of the produced gas for a single pair of plates - a cell can be estimated from the following equation [15],

$$V = \frac{R.I.T.t}{F.P.z} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,

V: volume of gas [m^3],

R: gas constant (≈ 8.314472$\left[\frac{J}{mol.K}\right]$),

I: current [A],

T: temperature [K],

T: time [s],

F: Faraday constant (≈ 96485.34$\left[\frac{C}{mol}\right]$),

P: ambient pressure [Pa],

z: number of excess electrons (2 for H_2, 4 for O_2).

According to (1), when connected to 14V voltage and 20A current strength in standard temperature and pressure conditions, a generator comprising 8 cells will produce 110 dm^3 of gas per hour [15]..

3. Results and discussion

As mentioned earlier, HHO gas production depends on the number of elcctrodes, strength of the electrolyte solution, inter-electrode gaps, amout of supplied current etc. During the experiment it has been observed that the regulation of the current flow into the cell is very important. It has also been experienced that this current regulation is not so easy and it requires to use another control circuit. However, this sort of current regulation control circuit has not been used in this study. Rather it has been tried to control by varying other parameters such as number of elctrodes, solution strength and inter-electrode gaps. The current flow is recorded between 7-10 amps for 2-electrodes cell and 15-18 amps for the 3-electrodes cell respectively indicating that as the number

of electrodes increases, the current flow through the cell is also increased proportionately. However, the number of electrodes are kept to three intentionally, in order to avoid the overheating of the connecting wires. Current flow rate also increases with solution concentration as it enhances the conductivity of the solution in the cell. The experiment is started with two electrodes and eventually three electrodes are used for HHO gas generation. Figure 4(a) and 4(b) presents compare the gas production as a function of time and current flow for 2-electrodes and 3-3lectrodes for 0.5% KOH solution. It can be observed that the gas production increases sharply with time, but increases slowly with current flow rate and decreases for further increase in current flow rate. As shown, the cell with 3-electrodes produce HHO gas at a faster rate than the other cell. However, the current flow rate does not show significant effect on the gas production rate when compared between the two cells. The voltage is found to vary between 8-10V during the total experiment.

The current flow is increased upto 18 amps as the solution strength increases to 1.0% KOH. Figure 5 presents the same results but for the 1.0% KOH solution. The trend for both the curves in Fig.5(a) and 5(b) is found to be similar to those obtained in Fig.4(a) and 4(b). However, HHO gas production becomes even more faster for the 1% KOH solution cell than the 0.5% KOH solution cell indicating that the solution strength has a greater impact on the gas production. According to Fig.5(a), it takes almost one-third of the time period to produce the same volume of gas for the stronger solution as compared to the weaker solution cell. According to Fig.5(b), as the current flow increases, gas production rate first increases slowly and raises to a peak at around 17 amps and then evetually starts to fall for further increased currents. It also shows that as the number of electrodes increases from two to three, the gas flow rate increases by almost three times. It can generally be observed in these figures that the 3-electrode-cell dominates the HHO gas production rate when compared with the 2-electrode-cell. For the single annode and double cathodes cell with 1% KOH electrolyte solution about 2150 ml of HHO gas has been collected in 15 minutes of time period in this etudy.

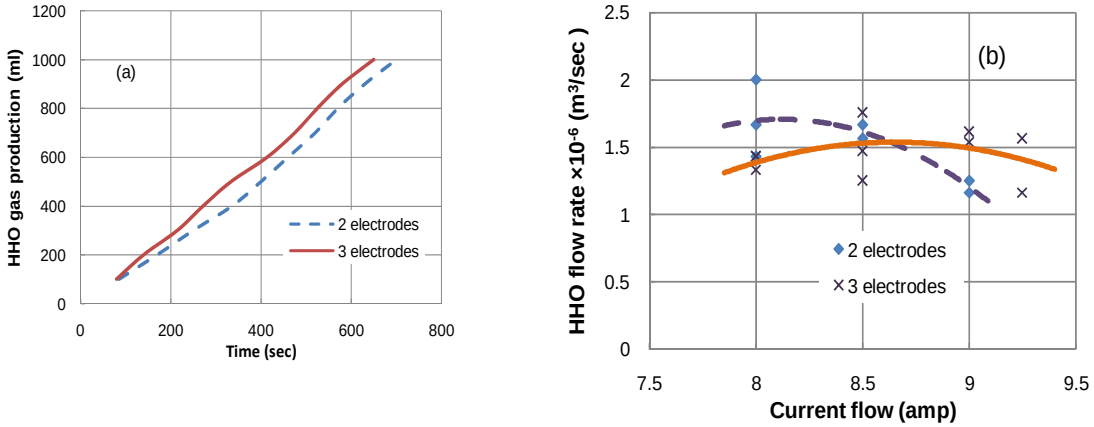

Fig.4. (a) HHO gas production (in ml) as a function of time and (b) HHO gas production rate (in m^3/s) as a function of current flow for 0.5% KOH solution.

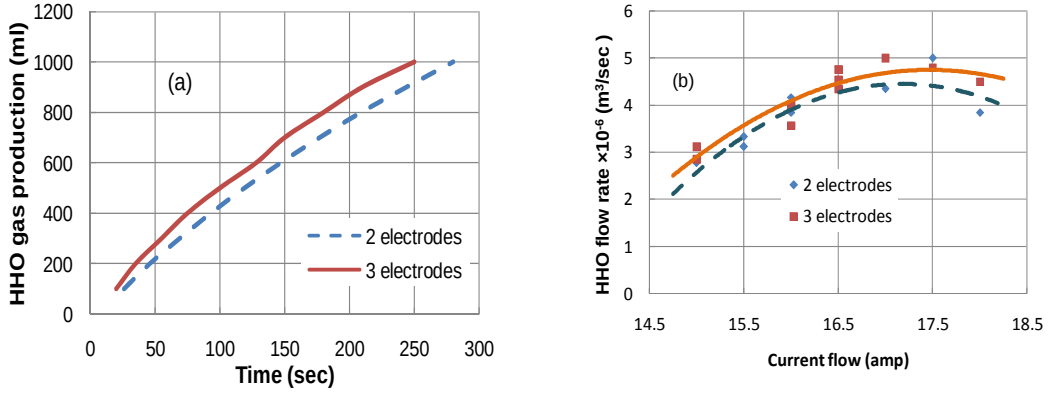

Fig.5. (a) HHO gas production (in ml) as a function of time and (b) HHO gas production rate (in m^3/s) as a function of current flow for 1.0% KOH solution.

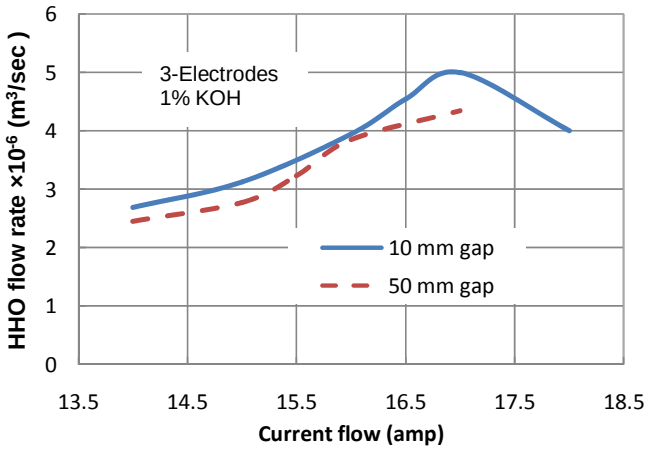

Fig.6 represents the effect of inter-electrode gaps on the gas collection rate or production rate for the 3-electrode cell with 1% KOH electrolyte solution. It can be observed from the figure that as the inter-electrode gap decreases from 50 mm to 10 mm, the current flow increases for the cell. As the current flow increases in the cell, the HHO gas production rate is also high for lower inter-electrode gap arrangements. One thing is to be noticed that at higher current flow (such as at 18 amp), the gas production rate falls as there develops a layer of unknown solid materials on the electrolyte solution (perhaps from the impurities existed in electrode materials) creating a barrier to gas flow.

Although it is planned before to do the elementary analysis, heating value, pour point and flash point determination of HHO gas, eventually they are not performed due to the unavailability of necessary laboratory facilities. However, the combustibility of the produced gas has been tested manually. The gas is fired using a torch and a substantial explosion has been experienced indicating the sudden oxidatiob reaction of the HHO gas. HHO gas is found to explode with a heavy sound (BOOM!) during the firing which proves the explosiveness property of HHO and hence it needs an extra care for handling.

4. Conclusions and Recommendations

The main aim of the project is to conduct an experimental investigation of alkaline water electrolysis for the purpose of HHO gas production. The total investigation has covered the effects of solution concentration, number of electrodes, current flow and space between the pair of electrodes on the production of HHO by alkaline water electrolysis. An electrolyzer for HHO gas generation has been successfully designed and constructed. The study has been carried out under atmospheric pressure using stainless steel electrodes and KOH as electrolyte. The current flow is measured between 7-10 amps for 2-electrodes cell and 15-18 amps for the 3-electrodes cell respectively indicating that as the number of electrodes increases, the current flow through the cell is also increased proportionately. The experimental results have showed that the performance of alkaline water electrolysis unit is dominated by operational parameters like the current flow, alkaline solution strength and the gap between the electrodes. Generally 3-electrode-cell has produced more gas than the 2-electrode- cell which indicates that the HHO gas production is directly proportion to the number of electrodes. However, it is limited to the control of the current flow through the cell for safer operation. The production rate of HHO gas has been observed to increase with increasing solution strength and current flow. It takes almost one-third of the time period requires to produce the same volume of gas for the stronger solution as compared to the weaker solution cell. Smaller gaps between the pair of electrodes increase the current flow which results in an enhanced production rates of HHO. For single anode and two cathodes, 1% KOH solution concentration provides 2150 ml of HHO gas from 15 minutes from 100ml of water. The followings can be recommended for further development:

- Problems have been experienced to maintain a uniform DC current flow through electrolyzer. So, a current flow controlling device is highly recommended in order to maintain the desired current flow. It would also provide opportunities then to increase the number of electrodes more than three (say 8-10).

- Electrolyzer container should be highly leakproof.

- A device can be recomanded that can act as a stirrer for the electrolyte solution in order to provide a uniform concentration throughout the cell.

- There should be a temperature controlling device attached with the system in order to avoid any internal damage caused by the elevated temperatures.

- A gas reservoir can be attached to the system for storing HHO gas which would be convenient to supply for any useful purpose such as engine applications.

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Modeling and Optimization of Variable Speed Wind Turbine Using Permanent Magnet Synchronous Generator

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Abstract

This paper proposes an optimized model of a Variable Speed Wind Turbine equipped with Permanent Magnet Synchronous Generator (PMSG). This model has the ability to respond to a disturbance or fault of the system from a normal operating condition to return to a state where their operation is normal again. The model has a set of six-IGBT converter-inverter connected through a DC bus. The paper presents a simulation model of a 3MW-level variable speed wind turbine with a permanent magnet synchronous generator and a full-scale converter developed in the simulation tool of PSCAD/EMTDC. Simulation results shows that the proposed model can enhance the stability of power system effectively.

Keywords: Wind Turbine, Permanent Magnet Synchronous Generator (PMSG), Modeling, Fault.

1. Introduction

In recent years the risks of shortage of fossil fuels and their effects on the climatic change have indicated the importance of renewable energies. WIND is a promising source of renewable energy. In worldwide there are now many thousands of wind turbines operating, with a total nameplate capacity of 196,630MW [1]. Both induction and synchronous generators can be used for wind turbine [2]. But the PMSG is chosen, because it offers better performance due to higher efficiency and less maintenance since it does not have rotor current and can be used without a gearbox, which also implies a reduction of the weight of the nacelle and a reduction of costs. Using the PMSG the design can be even more simplified. However, the recent advancements in power electronics and control strategies have made it possible to regulate the voltage of the PMSG in many different ways. [3, 4].

The goal of this paper is to optimize the electromagnetic energy conversion from the wind turbine and develop suitable control strategies in one hand and to stabilize the power system from fault on the other hand. Here, PWM (Pulse Width Modulator) is used to control the frequency converters. The instantaneous values of voltages are used as PWM control variables. These values of voltages are obtained from the real and reactive power through PI controllers.

2. Conversion of Wind Energy

Wind energy conversion system is quite complex. It depends on some factors like existence of various fields, (aerodynamic, mechanical and electric fields) and the factors that determine the mechanical power as wind speed, dimension and shape of the turbine. Four components are considered in describing a wind model [5] as follows:

$$V_{wind}=V_{bw}+V_{gw}+V_{rw}+V_{nw} \quad (1)$$

Where, V_{bw}, V_{gw}, V_{rw} and V_{nw} are the Base wind, Gust Wind, Ramp Wind and Noise wind components respectively (in m/s).

The kinetic energy of the wind (air mass m, wind speed v) is given by the following equations:

$$Ec = \frac{1}{2}mv^2 \quad (2)$$

Where, $m = \rho v S \Delta t$, (With S: Covered surface of the turbine and ρ: The air density)

The wind power P_w can be expressed as:

$$Pw = \frac{d}{dt}Ec \Longrightarrow Pw = \frac{1}{2}\rho S v^3 \quad (3)$$

P_m is the mechanical power that the turbine extracts from the wind, it is inferior to P_W. Because the wind speed after the turbine isn't zero (the air needs to be carried off after the turbine). Therefore, the power coefficient of the turbine C_p is defined as [6]:

$$Cp = \frac{Pm}{Pw}; \quad Cp < 1 \quad (4)$$

Therefore, the recovered power from the wind P_m (i.e. the mechanical power) is given by

$$Pm = \frac{1}{2}\rho\pi R^2 v^3 Cp \quad (5)$$

Where, R is the radius of the rotor. C_p depends on the tip speed ratio λ of the wind turbine and angle of the blades, β

$$Cp = Cp(\lambda, \beta) \qquad \text{with: } \lambda = \frac{R\omega}{v} \quad (6)$$

Where, ω is the rotation speed of the rotor. The maximum theoretical value possible for the of the power coefficient, named limit of Betz [6], is:

$$Cpmax = \frac{16}{27} = 0.593$$

The wind turbine torque on the shaft can be calculated from the power:

$$Tm = \frac{Pm}{\omega} = \frac{1}{2}\rho\pi R^2 \frac{v^3}{\omega} Cp \quad (7)$$

Introducing $\lambda = \frac{R\omega}{v}$, the equation becomes, $Tm = \frac{1}{2}\rho\pi R^3 v^2 \frac{Cp}{\lambda}$ (8)

The torque coefficient C_T is given by, $C_T = \frac{Cp}{\lambda}$

This gives: $Tm = \frac{1}{2}\rho\pi R^3 v^2 C_T$ (9)

3. Modeling of the System

A variable speed wind turbine (VSWT) with PMSG is shown in the figure.

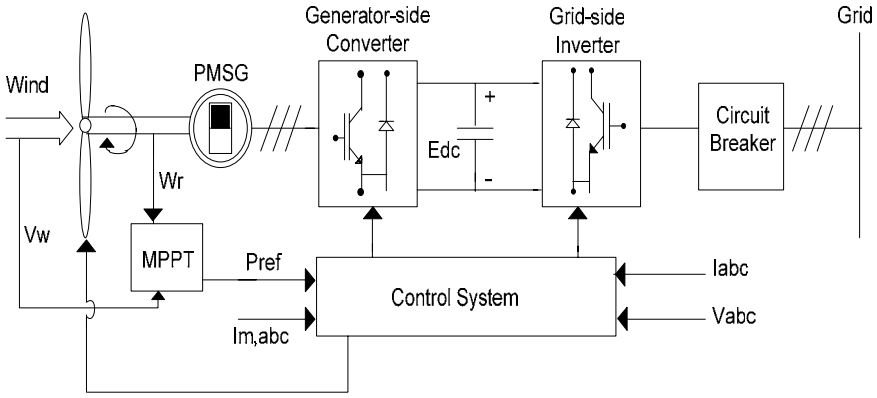

Fig.1 Electrical Scheme of VSWT-PMSG

As shown in the fig.1, a VSWT-PMSG system is modeled with a fully controlled frequency converter. The frequency converter consists of a generator side AC/DC converter, a DC link capacitor and a grid side DC/AC inverter. Each of the converter/inverter is a standard three phase two-level unit, composed of six IGBTs and anti parallel diodes.

Generator Model

The generator is based on PARK transformation. In order to get a dynamic model for the generator that easily allows us to define the generator control system, the equations of the generator are projected on a reference coordinate system rotating synchronously with the magnetic flux as shown in fig. 2.

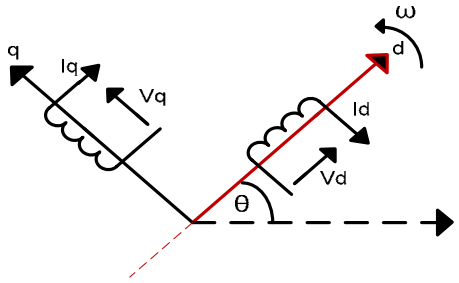

Fig.2 PARK Model for PMSG

With sinusoidal distribution of conductors and flux are linear functions of currents Id and Iq situated on the rotor. They are given by the equations [7]:

$$\begin{cases} \psi d = LdId + \psi f & (10) \\ \psi q = LqIq & (11) \end{cases}$$

Where, Ld: Stator inductance in d-axis;

Lq: Stator inductance in q-axis;

Ld and Lq are supposed independent of θ

ψf : Magnetic flux;

The wind turbine driven PMSG can be represented in the rotor reference frame as:

$$Id = \sqrt{\frac{2}{3}}\begin{bmatrix}\cos\theta & \cos\left(\theta-\frac{2\pi}{3}\right) & \cos\left(\theta+\frac{2\pi}{3}\right)\end{bmatrix}\begin{bmatrix}Ia\\Ib\\Ic\end{bmatrix} \quad (12)$$

$$Iq = \sqrt{\frac{2}{3}}\begin{bmatrix}-\sin(\theta) & -\sin\left(\theta-\frac{2\pi}{3}\right) & -\sin\left(\theta+\frac{2\pi}{3}\right)\end{bmatrix}\begin{bmatrix}Ia\\Ib\\Ic\end{bmatrix} \quad (13)$$

The equations of voltage are:

$$Va = \sqrt{\frac{2}{3}}[Vd\ cos(\theta) - Vq\ sin(\theta)] \quad (14)$$

$$Vb = \sqrt{\frac{2}{3}}\left[Vd\ cos\left(\theta-\frac{2\pi}{3}\right) - Vq\ sin\left(\theta-\frac{2\pi}{3}\right)\right] \quad (15)$$

$$Vc = \sqrt{\frac{2}{3}}\left[Vd\ cos\left(\theta+\frac{2\pi}{3}\right) - Vq\ sin(\theta+\frac{2\pi}{3})\right] \quad (16)$$

The electromagnetic torque can be expressed as:

$$\tau = \frac{3}{2}P\ [\ (L_q\text{-}L_{d)}\ I_qI_d + I_q\Psi_f\ ] \quad (17)$$

4. Control Strategies

Frequency converter and PLL

The control structure of the frequency converter at the grid side is shown in the fig. 3. Here the well known cascade control scheme with independent control of the active and reactive currents was used for the IGBT (Insulated Gate Bipolar Transistor) 2-level converter. The voltages obtained from the grid side inverter E_a, E_b, E_c, are used to calculate the Phase Locked Loop (PLL) angle for the dq/abc and abc/dq transformation. Effective

firing pulses are produced in order to control the currents for IGBT which in turn control the converter-inverter set of the system. The grid side converter maintains the DC link voltage to 1.0pu.

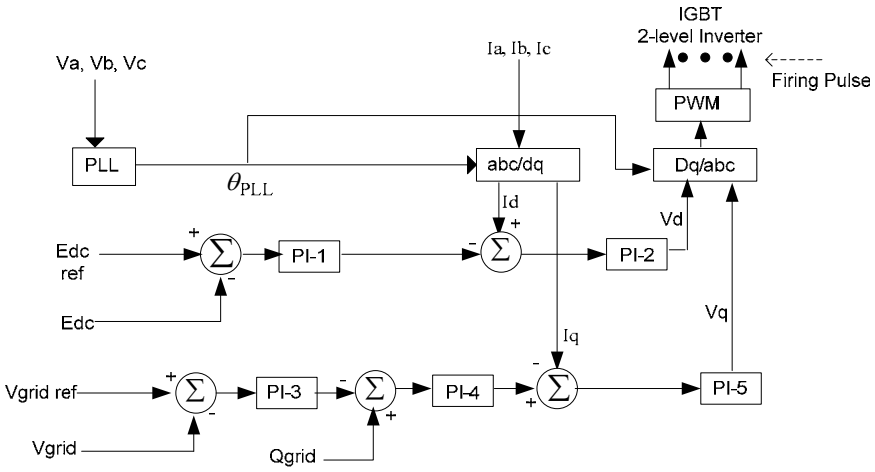

Fig.3 Control structure for the frequency converter

MPPT

The characteristic of the optimum power of a wind is strongly non linear and in the shape of "bell" [6]. For every speed of wind, the system must find the maximum power which is equivalent to the optimum rotational speed. Fig. 4 shows the characteristic curves of the wind. Every dotted line curve corresponds to a speed of wind.

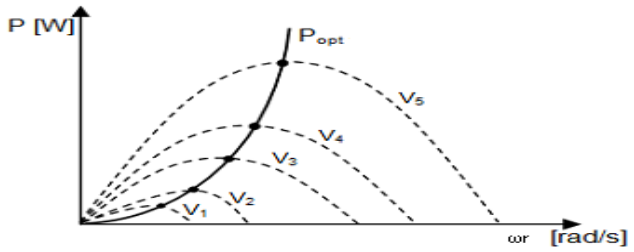

Fig.4 Characteristic curves of wind in plan power, rotational speed

An ideal wind turbine requires a perfect follow-up of this curve. To achieve this, a specific control strategy is used named Maximum Power Point Tracking (MPPT). For the MPPT operation, rotor speed is used as the controller input instead of wind speed, because the rotor speed can be measured more precisely and more easily than the wind speed. For a VSWT, generated active power depends on the power coefficient, C_p, which is related to the proportion of power extracted from the wind hitting the wind turbine blades. For each instantaneous wind speed of a VSWT, there is a specific turbine rotational speed, which corresponds to the maximum active power from the wind generator. In this way the MPPT for each wind speed, increases the energy generation in a VSWT [8].

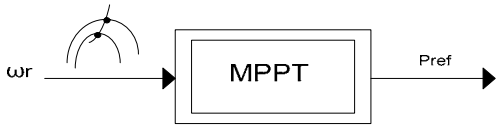

Fig.5 MPPT Searching methodology block

Circuit Breaker

The model has a circuit breaker, which responds when the fault occurs on the line that is, it isolates the faulty section from the healthy section.

5. Result and Analysis

Simulations have been done by using Power System Computer Aided Design/Electromagnetic Transient including DC (PSCAD/EMTDC) program, for 80 seconds, where a fault occurs at 35 second and clears within 0.05 second. The timing step of the simulation is chosen to be 0.001 sec. The simulation results are shown below.

Figure 6 shows the rotor speed (ω_r) variation of PMSG. It can be observed that the rotor speed fluctuates during fault, but it returns to the normal state as soon as the fault is cleared.

Figure 7 is the response of the DC link voltage after the generator side AC/DC converter. The converter maintains the DC link voltage at 1.0 pu as shown in the fig.7. Here, also, the DC bus voltage E_{DC} returns back to the normal operating condition after the fluctuations caused by the fault.

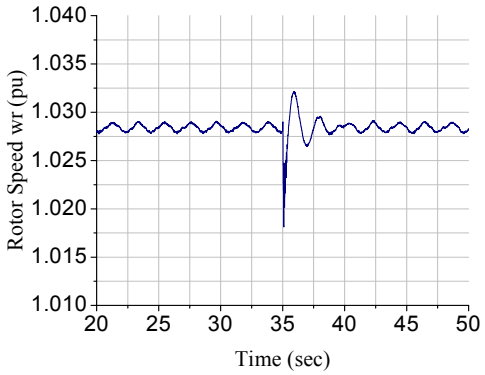

Fig.6 Rotor speed of PMSG

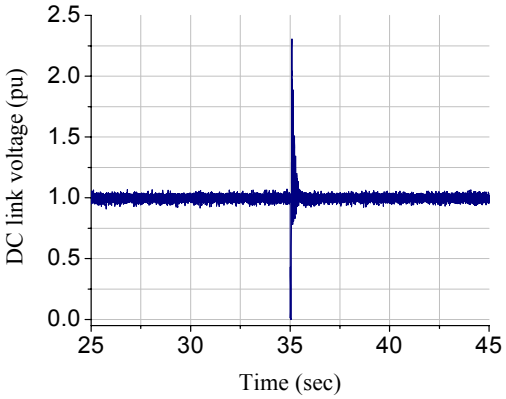

Fig.7 DC bus voltage

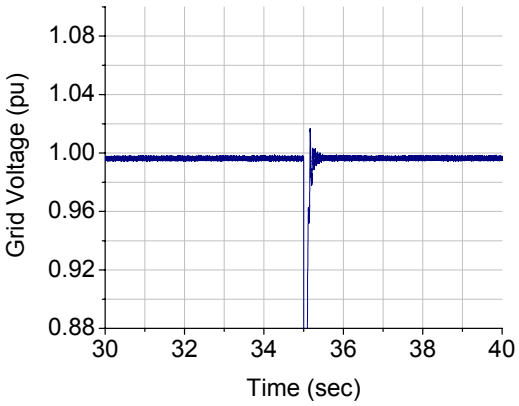

Fig.8 Voltage at the grid

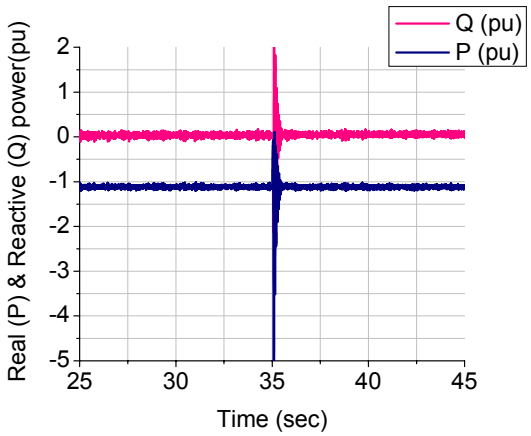

Fig.9 Real and reactive power at the grid

The grid side voltage Vg_{rid} is shown in the fig 8. As can be seen that a constant voltage is supplied to the grid by the model, again the grid voltage overcomes the fluctuations caused by the faults and went back to the normal operating condition. Similarly in fig 9, the real and reactive powers at the grid are shown. Here again the system not only supplies a constant power to the grid but also resumes to the normal sate after the occurrence of fault.

So, from all the simulation results it can be seen that the system maintains a constant voltage and power at the grid side and also it is capable of clearing faults on the line and returning back to the normal operating condition.

6. Conclusion

The paper presented a model of a VSWT driven by a PMSG. The modeling and controlling strategies for the generator rotor side frequency converter are presented. These control topologies are suitable for improving the transient analysis of the VSWT driven by PMSG, to be able to generate a constant voltage and power at the grid side and also to respond to a fault, which occurs on the system, to return back to the normal operating condition as soon as possible.

The graphs shown here proves the transient stability of the system. The model is capable of not only controlling a constant voltage and power at the grid but also resuming to the normal sate after the fault occurs, so the model is stable. Therefore the system has proved its better quality and improved reliability.

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Paper ID: ET-17

Design, Fabrication and Performance Test of an Improved Solar Water Heater

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Abstract

Solar water heater is a device or combination of equipment which works to heat water and this project of solar water heater have no requirement of utilizing other energy. Many works have been done on this topics but the major intension of the authors are to construct an improved version of the existing one (in case of performance efficiency, size and so on). In the way of this the design and construction materials have changed for the improved version. In case of design- alignment, spacing of the absorber pipe, absorbing surface analysis has emphasized more. And in case of material- heat absorption capacity, insulation nature, radiation capability etc. has emphasized more. As a result performance efficiency has increases. In case of achieving same performance, its size also reduces than previous collectors. Because of its less size it also required less material and cost reduces in that case also (though the materials used in this project are more expensive).

Keywords: Solar energy, solar water heater

1. Introduction

The form of energy- basically called electromagnetic energy is one of the basic forms of energy which comes from the sun source by electromagnetic wave or radiation is termed as solar energy. Now-a-days while more convenient energy sources like coal, gas, oil or any other fossil fuel are reducing their resources and at the same time – harming adversely to the atmosphere. In this situation, solar energy can plays a vital role on energy convenience. Its use is increasing day by day because it satisfying three "E"s (energy, economy and ecology). A solar water heater industry in South Florida was started in 1900. It is estimated that about 30000 to 50000 units were installed by 1950, but around that time their popularity began to decline due to readily available cheap energy from fossil fuel [1].

2. Solar energy as a renewable source of energy

Hence it is a matter of concern, not only for better living standard but also for very survival of the world, to device, develop and deploy all possible techniques to extract energy from renewable energy sources. The fascination of renewable energy is that it is not dwindling or reducing its intensity and it does not damage environment and rather it contributes towards a pollution free environment. Solar radiation is produced by the nuclear fusion of different elements inside the sun (basically conversion of Hydrogen and Helium nucleus). And this radiation emits in the form of sunlight, infrared rays, ultraviolet rays, cosmic rays, x-rays etc. The rate of solar emission from the sun is 4.3x109 kg/sec. The power from the sun intercepted by the earth is approximately 1.8 x 1011 MW [2]. Most of the sun's energy that makes the 93,000,000-mile journey is in the form of visible and ultraviolet light.

3. Availability of solar energy in Bangladesh

Solar energy is one of the most available and enormous sources of energy in Bangladesh, where the maximum and minimum day times are 12.5 and 10 hours respectively in the year round. The geographical position of Bangladesh is between 20º34´ and 26º38´ North latitude and longitude 90.50&90.80 E. the total potential is estimated at 22.2-28.5 x 108 MW years [3]. In Bangladesh, the solar energy that reaches 6414 sq-Km in one hour is equal to the total yearly energy consumption of Bangladesh. However the use of solar energy, as a commercially energy source as not yet received by popular acceptance in the region.

4. Prospect of solar energy in Bangladesh

Bangladesh is endorsed with an abundance of sunshine during most of the year.
The various uses of solar energy in Bangladesh are described below:

- Traditional use: Traditionally solar energy is used for drying of agriculture products, fishes, fruits, cloths and production of salt.
- Preheated water: It is used for normal cooking, cottage industries, hotels etc. Hot water (between 60ºC to 100ºC) is used in textile and paper industries.
- Distillation and Purification: Solar distillation unit is a very important device to make fresh water from salty water.
- Solar electric power: This type of system is most suitable for remote places where electricity from the grid is not available.

In addition to domestic power, solar photovoltaic (PV) cell can be used for the following purposes, such as - PV operated refrigerator , PV operated pump, Telecommunication, Military, Navigation and tower lighting, Domestic use.

5. Solar Water Heater

Water heating typically represents a high percentage of energy consumption in homes and businesses, in some cases 30% or more[4].Solar water heater is nothing but a device which utilizes harnessing energy from the sun to heat water. Solar water heating is a reliable and renewable energy technology used to heat water. Sunlight strikes and heats an "absorber" surface within a "solar collector" or an actual storage tank. Water flows through tubes attached to the absorber and picks up the heat from it. Most of the solar radiation is absorbed and converted to heat [5]. Some of this absorbed heat is conducted through the pipe to the riser tubes and then through the riser tubes walls to the water. The transfer of heat to the water rises the water temperature. Some of the heat is lost to the surroundings. The heat losses should keep as low as possible.

6. Design of the solar water heater

A) Design of the collector [6][7]

The collector overall heat loss is the sum of the top and bottom loss coefficients. Mathematically, $U = U_t + U_b + U_e$
Here, U = Overall heat transfer co-efficient, $W/m^2\text{-}^0K$
U_t = Top heat loss co-efficient, $W/m^2\text{-}^0K$
U_b = Bottom heat loss co-efficient, $W/m^2\text{-}^0K$
U_e = Edge heat loss co-efficient, $W/m^2\text{-}^0K$
The bottom loss coefficient U_b drives from the thermal conductivity K_s and the thickness L_s of the bottom insulator as: $U_b = k_s/L_s$ The top loss co-efficient U_t is evaluated by considering convection and re-radiation losses from the absorber plate in upward direction. Following the basic procedure of Hottel and Woertz, Klein
Developed an empirical equation for the top loss coefficient, U_t as (Yehet al., 2003)

$$U_t = \left[\frac{N}{\left(\frac{C}{T_m}\right)\left(\frac{T_m - T_a}{N+f}\right)^{0.252}} + \frac{1}{h_w} \right]^{-1} + \frac{\sigma (T_m^2 - T_a^2)(T_m + T_a)}{\frac{1}{\varepsilon_p + 0.0425\ N(1-\varepsilon_p)} + \frac{2N + f - 1}{\varepsilon_g} - N}$$

Where, $C = \frac{204.429(\cos\beta)^{0.252}}{L^{0.24}}$ $\qquad f = \left(\frac{9}{h_w} - \frac{30}{h_w^2}\right)\left(\frac{T_a}{316.9}\right)(1 + 0.09N) = 0.429$

$h_w = 5.7 + 3.8V$
[From Solar Energy Fundamentals and Applications by H P Garg J Prakash]
No. of glass cover, N= 1 & $\sigma = 5.67 \times 10\text{-}8$ W/m2-k4 $\qquad \varepsilon_p = 0.97, \quad \varepsilon_g = 0.07$
If the number of tubes is n, then useful heat gain is, $Q_u = n^3 q$
Now, useful heat gain, $Q_u = WC_p \Delta T$ & $\Delta T = Q_u/WC_p$
Collection efficiency can be defined as the ratio, $\eta = Q_u / (A_c I)$
Where, A_c = Collector area & I = Solar Intensity

B) Design calculation of collector plate

Amount of heat absorbed by water , $Q_l = mc_f (T_{coll.out} - T_{coll.\ in})$
Here, m= mass flow of the water 4 kg/hr

C_f = Specific heat of water =1 kcal/kg = 4.2 kJ/kg. ; $T_{coll.in}$ = 29ºC,$T_{coll.out}$ = 50 ºC
Q_1= mc_f (Tcoll.out-Tcollin) = 4*4.2*(50-29) =352.8 kJ/kg. hr
Amount of heat absorbed by the absorber plate, $Q_2 = F[\eta I_t - UL(T_{avg} - T_{amb})]$
Here, From Table 2.6:- Solar collector performance parameters (DOC 1977) Ref Books (Fundamentals & applications) H.P Garg J prakash [8][9].
UL = Heat transfer co-efficient = 6.2502 KJ/hr m^2 ^{0} K
(Considering Cu as in absorber material)
And collector efficiency factor F= 0.88 (Cu)
[Table 2.6 solar collector performance parameter (DOC 1977)] From the intensity chart of solar radiation for month of July. I =1100 kJ/hr.m^2 ; η = Absorbtivity factor = 0.7 (For black chrome paint)
Assuming, average temperature and of collector inlet and outlet , T_{ave} = 31 ^{0}C ; T_{amb} = 29 ^{0} C
Q_2 = 0.55[0.7*1100– 6.2502(31-29)] = 0.55[770 – 12.5] = 0.55*757.5
= 416.625 kJ/kg-hr.m^2
As $Q_2 > Q_1$ the design may be considered to be correct.
Specific dimension
Now the collector area = Q_2 / intensity of solar radiation. = 416.625/1100 = 0.378 m^2
Length = 0.6604 m ; Width = 0.558 m (This is available in the market)
Pipe dia. = 0.00635 m
Design Efficiency,

$$\eta = \frac{Q_u}{A_c I} = \frac{\dot{m} c_p \Delta T}{A_c I} = \frac{4 \times 4.2 \times (69 - 35) \times 1000}{0.369 \times 1100 \times 3600} = 48.65\%$$

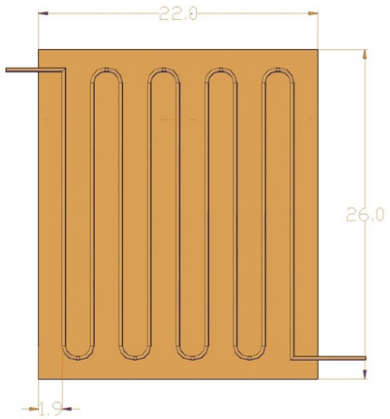

Fig.1 Design of the collector

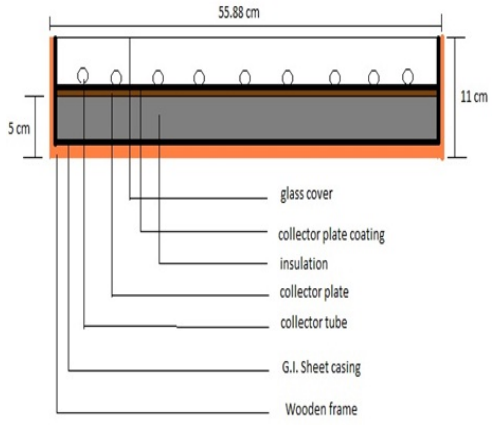

Fig.2 Cross sectional view of the collector

C) Absorber pipe

Absorber pipe absorbs the incoming solar radiation and transfer the resulting heat to the working fluid. Factors that determine the choice of absorber materials are:
High thermal conductivity, Durability, Ease of handling, Availability, Good corrosion, resistance, Compressive strength, Cost.
Thermal conductivity of various materials is investigated. Copper and aluminum are generally preferred as absorber pipe because of its extremely high thermal conductivity and resistance to corrosion. Thermal conductivity of aluminum is 204 W/m/°C and copper is 386 W/m/°C. Copper has a high thermal conductivity as compared with the aluminum for this reason copper is chosen as the absorber pipe material for this project work. Though aluminum is less costly than commonly used materials and easily available in our country but for achieving better efficiency we have used copper as absorber pipe.

D) Absorber pipe coating

The two requirements for an absorber pipe coating are:

- It should absorb a large fraction of the solar radiation falling on it.
- It should not deteriorate at the high temperature, which may be reached by the pipe.

An ideal absorber pipe surface would also be a poor radiator of heat when its temperature rose. However most common surface that is good absorber of radiation are also good radiator of heat. Black coating is a good example of commonly used coating that is a both a good absorber of radiation and a good radiator of heat. Such surfaces may absorb up to 96% of the solar radiation falling on them. The coating used in the absorber pipe must

be able to withstand the temperature encountered inside the absorber pipe. But now a days for better performance Black chrome (Chromium oxide) is used for its better thermal absorbing capacity.

E) Insulation

Insulation is necessary to reduce heat losses from the absorbing pipe and pipes of the solar water heater. For insulation, the gap between the absorber pipe and the cover pipe is vacuumed and rubber cork is used to seal the ends of the joint area.

7. Fabrication of the solar water heater

The overall design is divided into two sub-assembly components. The assembled parts are: Wooden frame & Absorber pipe with copper pipe.

A) Specified Dimension of Wooden frame

Length of the frame = 0.68 m
Width of the frame = 0.58 m

B) Specified Dimension of the Absorber pipe

Length of the Copper pipe = 0.45 m
Outer diameter of the Copper pipe = 0.635 cm
Number of Copper pipe = 9

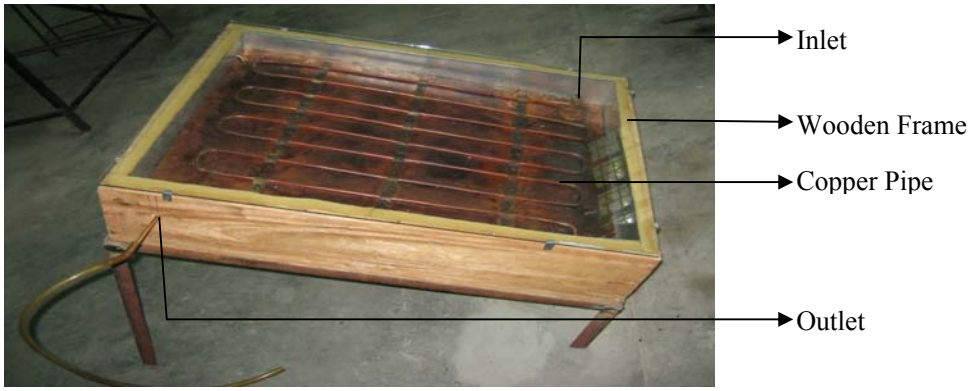

Fig.3 Photograph of our constructed solar collector

8. Performance study of the solar heater system

The performance study represents the study of collector efficiency. This includes the maximum temperature supply of water, useful heat gain collection efficiency etc. To obtain these parameters the collector inlet and outlet temperature, mass flow rates, diameter of the pipe, area of the collector are to be known.

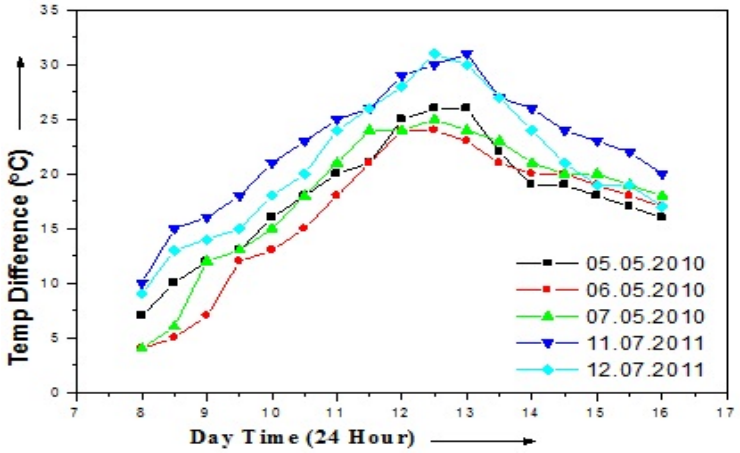

Fig.4 Temperature Difference VS Time Curve

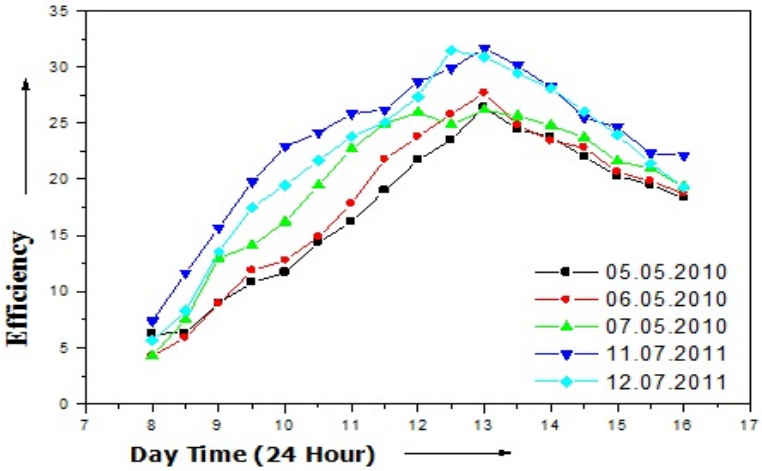

Fig.5 Efficiency Vs Day time curve

Performance of our collector in comparison with previous collector is illustrated in graphical form below- (for mass flow rate of 5kg/hr and Reading was taken in same month)

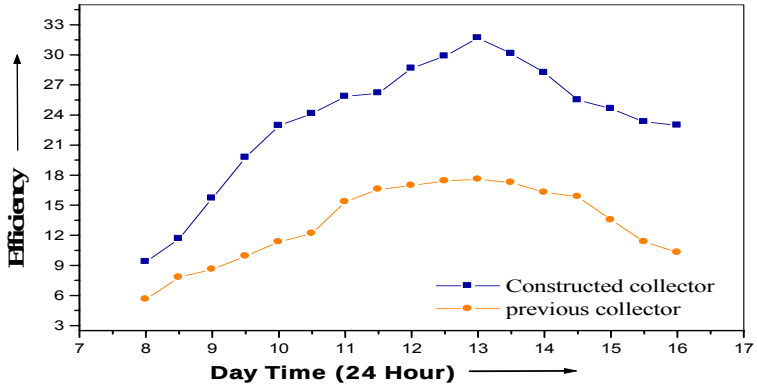

Fig.6 Efficiency VS Day time Curve

9. Result and discussion

The collector efficiency of the solar plate depends on the heat intensity. The more intense heat on absorber plate the more the efficiency. The solar radiation varies according to the position of the sun. Here 1100 W/m2 intensity of solar energy is used average one year for only Rajshahi city. The solar cell was used to measure the intensity of solar radiation. When the sky was cloudy the intensity of solar radiation was less. It was found from the experimental data that the efficiency was high at noon, it increases from 9.00 am to 12.30 pm and decreases after 1.00 pm. For mass flow rate 5 kg/hr the highest efficiency is 31.11% which was more than 14.11% for the previous collector (Reading was taken in same month).

All the figures of temperature differences vs. daytime Fig.4 shows a parabolic curve because up to a particular time of the day the temperature difference is increased and after that it starts to decrease. Again, all the figures of the efficiency v_s temperature difference Fig.5 shows a line of upward direction in rightward because efficiency always increase with the increase of temperature difference.

10. Conclusion

The main objectives of this system are to design and construct such a system which will give better performance efficiency than the existing one. The maximum temperature reached by the setup with glass as cover is 74^0C at that time the inlet temperature was 35^0C The performance of collector maximum efficiency 31.11% which is less than our design efficiency; due to some losses were occurred. Again the fluctuation of solar radiation intensity affects the performance of the system. But also the project improves than the previous one which could increase the temperature up to 68^0C and could utilize the energy up to 23.43% performance efficiency.

11. Recommendation

The solar water heater was made according to the design. But it would be much better if the more number of Copper pipes can be used. If the number of Cu pipe will increase, the absorber area will be increased so that higher efficiency can be achieved. But the number of pipes should not be increased as much so that the construction cost will high. For increasing the number of pipes, the space between the pipes should not be shorter. There must be a minimum distance between the pipes otherwise heat absorbing capacity of the pipes may be decrease. If a cover pipe with fluorescent tube with proper vacuum formation is used then the amount of heat absorbed can be increased and as a result the heater will give a better performance. In the present heater no reflector is used. But the use of a reflector such as mirror can trap more sun radiation which will increase the heat gaining capacity. A storage unit can be arranged with the heater to store hot water.

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Design, Fabrication and Performance Study of a Plastic Waste to Oil Converter

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Abstract

Pyrolysis is one of the most important thermo chemical energy conversion methods for renewable energy sources. In this paper the conversion of waste Plastic/Polythene into pyrolytic oil by air tight reactor has been taken into consideration. The raw and crack plastic particle was pyrolized in an electrically heated 7.5 cm diameter and 18 cm high air tight reactor with nitrogen as a carrier gas. The reactor was heated by using electric heater. The parameters varied were running time and feed particle size. The different temperatures were found to influence the product significantly. The maximum liquid yield was 66 wt% at 350^{0}C for a feed size of 3 cm^2 at a Nitrogen gas flow rate of 2 liter/min with a running time of 40 minutes. The pyrolysis oil obtained at these optimum process conditions was analyzed for some of its properties as an alternative liquid fuel.

Keywords: Pyrolysis, Plastic, Pyrolytic oil, Thermal decomposition.

1. Introduction

Energy is defined as the ability to produce change or do work and that work can be divided into several main tasks. Energy is the main way for growth of economical development. From the present point of view we can see that a country economically successful if it utilize its own reserve of renewable and nonrenewable source of energy. Energy from Waste offers a Pyrolysis technology, which has the ability to produce a clean, high calorific value fuel gas from a wide variety of waste and biomass streams. Pyrolysis for energy conversion from carbonaceous wastes is defined as the thermal degradation of organic matter either in total absence of air or with a lack of a stochiomtrically needed amount of oxygen to the extent where gasification does not occur [1].
In this thesis waste plastic is taken into consideration. Because every year a great amount of plastic is manufacture as the same amount plastic waste is produced. Plastic has great negative impacts on environment. Plastic is mainly made from petroleum, it is estimated that 7% of the world's annual oil production is used to produce and manufacture plastic [2]. In Bangladesh the amount plastic waste is terrific. Table 1 shows the annual production of petroleum, plastic and rubber with their values in Bangladesh.

2. Materials

A Plastic material is any of a wide range of synthetic or semi-synthetic organic solids used in the manufacture of industrial products. Plastic are typically polymers of high molecular mass, and may contain other substances to improve performance and reduce production cost. Monomers of plastic are either natural of synthetic organic compounds [4]. The word plastic is derived from the Greek word "Plastikos" meanings capable of being shaped or molded.
There are mainly two types of plastics: Thermoplastic and Thermosetting polymers.
Thermoplastics are the plastics that do not undergo chemical change in their composition when heated and can be molded again and again. Examples include polypopylne, polystyrene, polyvinyl chloride and polytetrafluooethylene (PTFE) [5]. Thermosets can melt and take shape once; after they have solidified, they stay solid. In the thermosetting process, a chemical reaction occurs that is irreversible.
Polythylene is classified into several different categories based mostly on its density and branching. The mechanical properties of PE depend significantly on variables such as the extent and type of branching, the crystal structure and the molecular weight [6]. Such as- Ultra high molecular weight polyethylene (UHMWPE), High density polyethylene (HDPE), Linear low density polyethylene (LLDPE), Medium density polyethylene (MDPE), Low density polyethylene (LDPE) etc.

Table 1. Production of Selected Industrial Items (Value in 000 taka) [3]

Code and Items	Units	2007-08		2008-09		2009-2010	
		Quantity	Value	Quantity	Value	Quantity	Value
354 Petroleum products:							
Naphtha		134561	1488615	79666	1010953	15847	-
L.P.G.	M.Ton	9987	376690	6278	240622	-	-
M.S.		42868	3687962	28802	2483739	2186565	-
H.O.B.C.		34655	2965988	20715	1807964	3162502	-
356 Rubber products 3569 Rubber footwear	Doz. Pair	345618	49962	347165	50223	332752	-
357 Misc. plastic products 3579 PVC products	M.Ton	12761	692409	14848	816640	19015	-

Environmental impact of plastic waste

Due to their insolubility in water and relative chemical inertness, pure plastics generally have low toxicity. Some plastic products contain a variety of additives, some of which can be toxic. For example, plasticizers like adipates and phthalates are often added to brittle plastics like polyvinyl chloride to make them pliable enough for use in food packaging, toys, and many other items. Traces of these compounds can leach out of the product. Owing to concerns over the effects of such lactates, the European Union has restricted the use of DEHP (di-2-ethylhexyl phthalate) and other phthalates in some applications. Some compounds leaching from polystyrene food containers have been proposed to interfere with hormone functions and are suspected human carcinogens. Whereas the finished plastic may be non-toxic, the monomers used in the manufacture of the parent polymers may be toxic. In some cases, small amounts of those chemicals can remain trapped in the product unless suitable processing is employed. For example, the World Health Organization's International Agency for Research on Cancer (IARC) has recognized that vinyl chloride, the precursor to PVC, as a human carcinogen [7]. Beside this

- Plastic are durable and degrade very slowly.
- Burning plastic can release toxic fumes and large amount of CO_2.
- The harmful chemical pollutants are responsible for the depletion of the Ozone layer.
- Plastic trash is polluting the oceans and washing up on beaches.
- Reducing fertility of soil.

3. Method

The low density plastic was first collected from dustbin and then washed properly in water. Then the washed plastic/polythene was crashed in small particle. The plastic was crashed in size of $0.5cm^2 – 3cm^2$. So the average particle size is 3 cm^2. Then the plastic was died on sun ray. The gross calorific value of the solid crushed plastic is 38718.96 kj/kg (9218.8 kcal/kg).

Heating value or calorific value of a fuel is the magnitude of the heat of reaction at constant volume at a standard temperature (usually 25^0C) for the complete combustion of unit mass of fuel. Complete combustion means that all carbon is converted into CO_2, all hydrogen is converted into H_2O and any sulfur present is converted into SO_2 [8].The heating value of plastic is calculated by

Calorific Value = $\Delta TW / m$

Here, ΔT= Temperature difference, W= Water equivalent, m = Mass of water.

Heating Value calculation

Initial Temperature = 34˚C

Final Temperature = 37.9˚C

C_v = {(37.9- 34) × 2426 cal/˚C} / 0.001 kg

= 39737.88 kj/kg.

Design and fabrication

The schematic diagram of the experimental set-up is presented in Figure.1.The experimental unit consists of five major components are

1. Air tight reactor chamber,
2. Condenser,
3. Thermometer,
4. Nitrogen gas flow meter and
5. An electric heater.

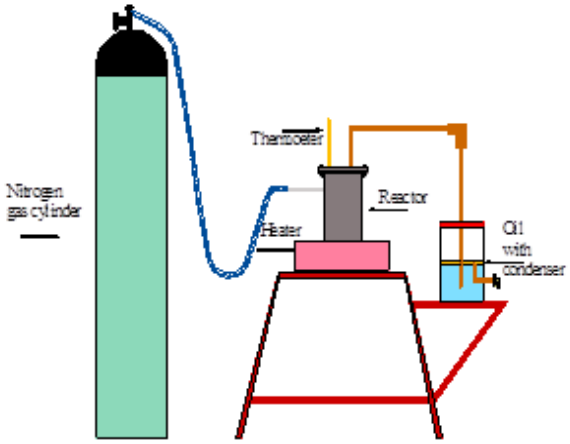

Figure 1. Schematic arrangements of plastic to oil convert

Electric heater heated the reactor, which is full with well cracked waste plastic particle. Stainless steel nut-bolt, gasket paper and liquid gasket shield is used make it air tight. The produce gas is passes from reactor to water container through a copper pipe. The gas is escape in the water and condensed. The liquid is stored as a layer on the surface of the water. The oil is collected by a tap using gravitational force. The nitrogen gas is used as a carrier gas and it also produce an inert environment within the reactor.

Limitations of this system

1. The range of the thermometer is 360˚C.
2. To avoid the leakage stainless steels nut bolt is used.
3. The thermometer must be fixed with the flange.
4. Gasket sheet with liquid gasket cement must be used.
5. Prevention of the leakage is the main challenge in this setup.
6. For tire waste feed material the condensing system is not enough.

4. Experimental results

Three common products oil, char and gases were recovered after each run of plastic waste oil pyrolysis. Higher percentage of liquid collection makes this plastic waste potential for liquid fuel extraction. The liquid appear brownish with a strong acrid smell. The liquid was not harmful for human skins, leaving temporary yellowish brown marks, which can be removed by detergent.

No phase separation was found to take place and the color of the liquid products does not depend on the color of the feed materials. There were some permanents gases produced during the pyolytic conversion. The gases had small acid smell and it was free to the atmosphere. The char was black in color and not sticky. It was not like powder but not wetted. There was no bad or acrid smell in the char.

Physical Properties and Chemical Composition Analysis

The physical characteristics of the plastic waste derived pyrolysis oil are shown in Table 2. The energy content of the oil is 39737 kJ/kg. The oil is found to be heavier than water with a density of 751.75 g/m^3 at 30^{0}C.

Table 2. Physical characteristics for plastic waste oil

Properties	Values
Flash point (˚C)	36
Density (kg/m^3)	751.92
GCV (kJ/kg)	39737.88
Fire point (˚C)	40
Viscosity (centipoises)	8.6

Fourier Transform Infra-Red (FT-IR)

The plastic pyrolysis oil and pyrolysis aqueous fraction were analyzed by Fourier Transform Infra-Red (FT-IR) spectroscopic technique. Pyrolysis oil consists of mainly alkanes, alkenes, aromatic rings and phenols [9]. The FT-IR spectrum represents the functional group compositional analysis of plastic derived pyrolysis oil. The presence of hydrocarbon groups C–H; C=C indicate that the liquid has a potential to be used as fuel. Due to absence of functional groups of O-H; C=O; C-O and aromatic compounds the plastic waste oil is not acidic. The presence of hydrocarbon groups in plastic waste oil C-H; C=C; and alcohols indicate that the liquid has a potential to be used. The FT-IR fractional groups and the indicated compound of the liquid product are presented in Table 3.

Table 3. FT-IR fractional groups and the indicated compounds of the pyrolysis oil

Frequency range (cm^{-1})	Functional groups	Class of compound
3050-2800	C-H stretching	Alkanes
1490-1325	C-H bending	Alkan
1020–845	C=C stretching	Alkenes

5. Discussion

Effect of reactor temperature on product yields

Figure 2 shows the variation of percentage mass of liquid, char and gases at different reactor bed temperature for plastic waste pyrolysis with particle size 3.00 cm^2, running time 40 minutes. From this figure it is found that the maximum liquid product yield was obtained at a reactor bed temperature of 350^oC and this was 66 wt% of plastic waste feed. With the decrease of reactor temperature at 300^oC, the liquid product was decreasing (50 wt% of plastic waste feed) while with the increase of bed temperature at 400^oC the liquid product yield was constant (66 wt% of plastic waste feed). With the increase of reactor bed temperature, the solid char yield was decreasing over the temperature range of 150 to 350^oC. For the feed particle size of 3.00 cm^2, at a bed temperature of 150^oC yielded the maximum percentage of char, 90 wt% of plastic waste feed. At a higher temperature of 400^oC, the solid char production was lower, it was found to be 8 wt% of plastic waste feed. Figure 2 also shows that as the reactor bed temperature was increased the gaseous product yield increased. A fixed bed temperature of 400^oC yielded the maximum percentage of gas yield of 25 wt% of plastic waste feed.

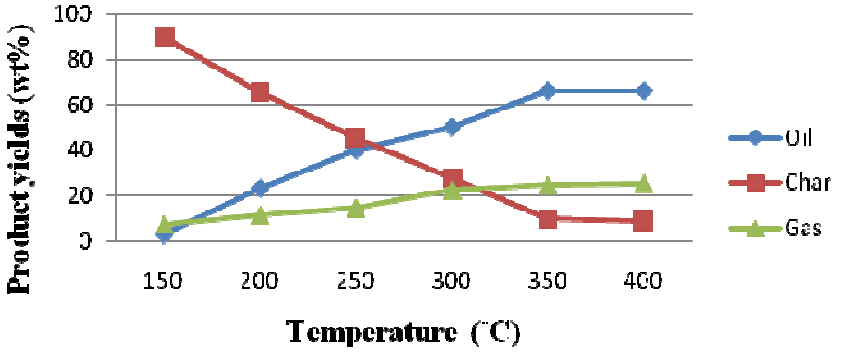

Figure 2. Effect of temperature on product yields for feed size 3 cm^2 and running time 40 minutes.

The reason behind the product distribution was that the lower temperature was not sufficiently high enough for the pyrolysis devolatization reaction to take place completely rendering reduced amount of liquid and gaseous products. Again the higher temperature was causing secondary cracking reaction of the vapors yielding more gas at the cost of the liquid product yield. However, the intermediate temperature was sufficient enough for complete pyrolysis reaction to take place and at the same time this temperature was not high enough for secondary reaction rendering maximum quantity of liquid product with less amount of char residue and gaseous products.

Effect of feed size on product yields

Figure 3 represents the percentage yields of liquid, solid char and gaseous products for different feed size of plastic waste at optimum temperature of 350^oC and running time 40 minutes. It was observed that the

percentage yield of liquid product was maximum 66 wt% of plastic waste feed for particle size of 3.00 cm^2 with a solid char product of 9 wt% waste. The particle size of 13 cm^2 produced a percentage yield of liquid product of 64 wt% of dry plastic waste feed with a solid char product of 11 wt%. The large particle size of 32 cm^2 produced percentage yield of liquid and char products 65 wt% and 10 wt% respectively. Figure 3 represents that the particle size has not significant effect on the product distribution for plastic waste pyrolysis. This may be due to the fact that the thickness of plastic waste feed is same at all the portions.

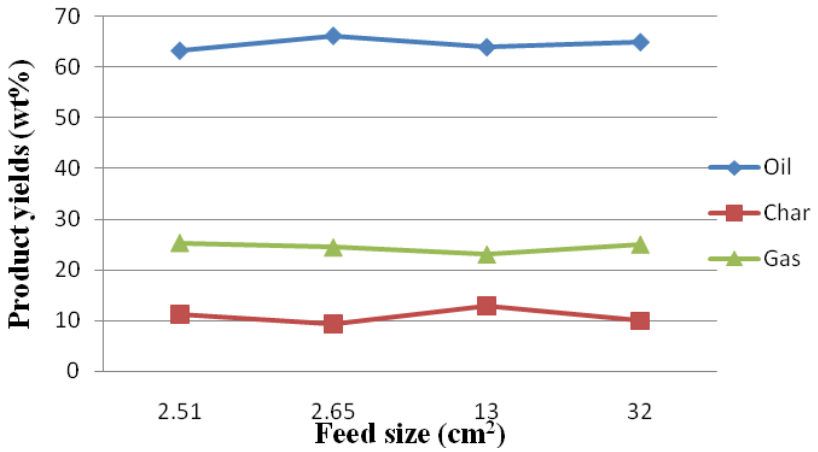

Figure 3. Effect of feed size on product yields for temperature 350°C and running time 40 minutes.

Effect of running time on product yields

Figure 4 shows the variation of product yields with respect to running time at optimum reactor temperature 350°C for feed particle of size 3.00 cm^2. The maximum liquid product was 66 wt% of plastic waste feed while the solid char product was 10 wt% for running time 40 minutes.

It is observed that for running time less than of 40 minutes the liquid yield is reduced due to incomplete pyrolysis reaction of feed. For the running time above 40 minute the liquid yield is almost constant with slight increase in gases and decrease in char yields. Thus it may be concluded that the pyrolysis of solid feed plastic particle is completed within 40 minute of running time.

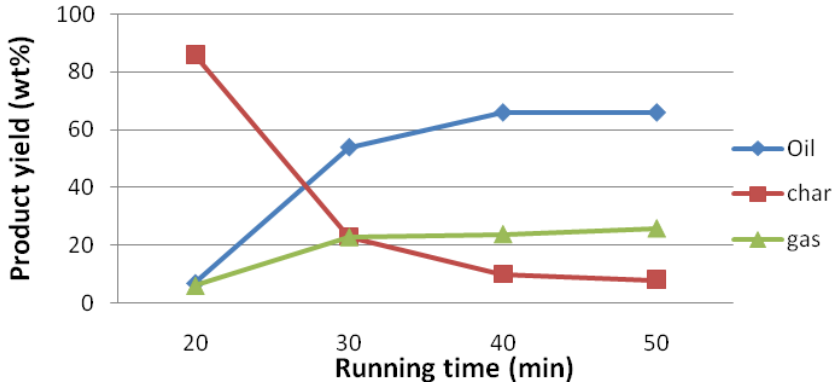

Figure 4. Effect of running time on product yields for feed size 3 cm^2 and temperature 350°C.

Figure 4 also represent that the char drop rapidly at 30 minutes and then slowly. This is because the pyrolysis devolatization reaction rapidly takes place at this time. So maximum liquid oil was convert from plastic at this time.

6. Conclusions

This report investigated the design of plastic to oil converter and produce oil and performance study of the oil and comparison with others. The results of this report may be summarized as follows:

- Plastic oil is produced from plastic waste by pyrolysis process.

- Maximum 66 wt% productions were found from 150g plastic waste at 350˚C.
- The higher temperature and longer running time contributes to secondary reactions results in more gaseous products with the expense of liquid while char yields remain almost constant.
- The fuel properties of pyrolysis liquids such as density, flash point, fire point and GCV are found almost comparable to petroleum fuels.
- The FT-IR spectrum shows that the liquids are dominant with pronounced functional groups which indicate the presence of alkenes. The liquid has a good potential to be used as fuel.

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Modeling and Controlling of Directly Driven Wind Turbine with Permanent Magnet Synchronous Generator

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Abstract

This paper proposes a dynamic simulation of a directly driven wind turbine generation system having an effective control strategy with permanent magnet synchronous generator (PMSG). This control strategy allows the PMSG to operate for different wind speed in order to optimize the generated power from the wind turbine and also to maintain a constant grid side voltage. For the dynamic analysis of PMSG, two-level IGBT converter-inverter set has been used associated with the Maximum Power Point Tracking (MPPT). All the elements have been modeled and the equations explaining their behavior have been introduced. The simulation model of PMSG and the proposed control strategies are presented by the engineering software PSCAD/EMTDC. The comparative results show that directly driven PMSG perform better performance than Induction Generator (IG).

Keywords: Wind Turbine, Permanent Magnet Synchronous Generator (PMSG), Modeling.

1. Introduction

In recent years the world consumption of energy has increased enormously due to the massive industrialization which has been intensified rapidly in some geographical areas of the world remarkably in the countries of Asia. So renewable energy sources, such as the wind energy has attracted the attention as a clean and non-polluting energy source. Worldwide there are now over two hundred thousand wind turbines operating, with a total nameplate capacity of 282,482 MW as of end 2012 [1]. The realization of a wind turbine may depend on the optimum design of the system and the control strategies of the different possible parameters that can operate efficiently under extreme variations in wind conditions. The general goal of this paper is to model a variable–speed wind turbine and optimize the electromechanical energy conversion of the wind turbines; developing suitable strategies of control [2]. This paper describes the operation and control of such a variable speed wind generator named PMSG.

Megawatt class wind turbines equipped with PMSG have been announced by Siemens Power Generation and GE energy. In this concept, the PMSG can be directly driven (gearless) and is connected to the AC power grid through the power converter [3, 4]. In PMSG, the excitation is provided by permanent magnets instead of field windings. Permanent magnet machines are characterized as having large air gaps, which reduce flux linkage even in machines with multi-magnetic poles [5, 6]. This paper presents an effective control strategy for the operation of a directly-driven permanent-magnet synchronous-generator-based variable-speed wind turbine. This generator is connected to the power network by means of a fully controlled frequency converter, which consists of a pulse width-modulation (PWM) rectifier, an intermediate DC circuit, and a PWM inverter, Phase Locked Loop (PLL) etc. The control strategy for the generator-side converter with maximum power point tracking (MPPT) is also presented here. In this paper, a comparison of some parameters between Induction Generator (IG) without Static Compensator (STATCOM) and PMSG has been introduced. It is shown that the proposed model of PMSG maintains a constant output voltage and power, which, in case of IG is not possible without using STATCOM.

2. Modeling and Description of the system

The model system shown in Fig.1 has been used for the simulation analysis of variable speed wind turbine (VSWT)-PMSG analysis. The proposed model is derived from the analytical representation of the main components: (I)Dynamic wind turbine model, (II) Directly-driven PMSG, (III)AC/DC converter and (IV)the Grid Model.

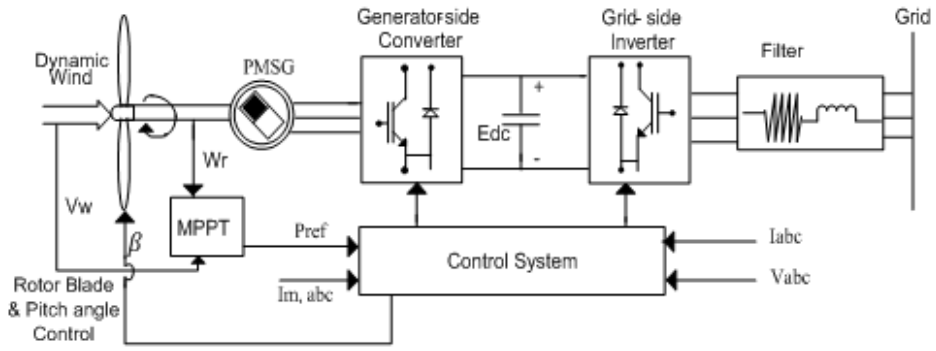

Fig.1 Power system model with direct-drive PMSG

In the fig.1, a VSWT-PMSG system is modeled with a fully controlled frequency converter. The frequency converter consists of a generator side AC/DC converter, a DC link capacitor and a grid side DC/AC inverter. Each of the converter/inverter is a standard three phase two-level unit, composed of six insulated gate bipolar transistor (IGBT) and anti parallel diodes. The control system also consists of MPPT, PLL, pitch controller etc.

2.1 Wind Turbine Model

The model of wind turbine rotor is complicated. According to the blade element theory [7], modeling of blade and shaft needs complicated and lengthy computations. Moreover, it also needs detailed and accurate information about rotor geometry. Therefore, considering only the electrical behavior of the system, a simplified method of modeling of the wind turbine blade and shaft is normally used [8]. The mathematical relation for the mechanical power extraction from the wind can be expressed as follows [7]:

$$Pm = \frac{1}{2}\rho\pi R^2 Vw^3 Cp(\lambda, \beta) \quad (1)$$

Where, P_m is the mechanical power that the turbine extracts from the wind, ρ is the air density (Kg/m^3), R is the blade radius (m) and C_P is the power coefficient which is a function of both, tip speed ratio, λ, and blade pitch angle, β(deg). λ and C_P are expressed as[9]:

$$\lambda = \frac{\omega R}{Vw} \quad (2)$$

Where, ω is the wind turbine angular speed (rad/s), V_W is the wind speed (m/s).

The power coefficient, C_P is, [9]

$$C_P = \frac{1}{2}(\Gamma - 0.022\beta^2 - 5.6)e^{-0.17\Gamma} \quad (3)$$

Since, C_P is expressed in feet and mile, Γ is corrected as,

$$\Gamma = \frac{R}{\lambda} \cdot \frac{3600}{1609} \quad (4)$$

The torque coefficient, C_T, is given by,

$$C_T = \frac{Cp(\lambda)}{\lambda} \quad (5)$$

The wind turbine torque is expressed as,

$$Tm = \frac{1}{2}\rho\pi R^3 Vw^2 C_T(\lambda) \quad (6)$$

2.2 Generator Model

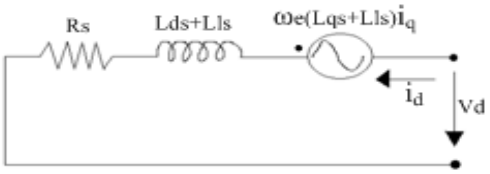

Fig.2 d-axis equivalent circuit of PMSG

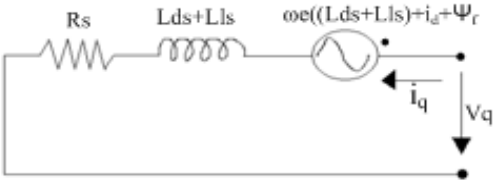

Fig.3 q-axis equivalent circuit of PMSG

Fig.2 and fig.3 shows the d-axis and q-axis equivalent circuit of PMSG. It has been considered that the PMSG is a system which produces electricity from the mechanical energy obtained from the wind. The dynamic model of PMSG is derived from the two-phase synchronous reference frame, in which, the q-axis is 90° ahead of the d-axis with respect to the direction of rotation. The synchronization between the d-q rotating reference frame and the abc three phase frame is maintained by utilizing a PLL.

The equations required to model the PMSG are:

$$\frac{did}{dt} = \frac{1}{Lds+Lls}(-Rs\ id + \omega e(Lqs + Lls)iq + Vd) \quad (7)$$

$$\frac{diq}{dt} = \frac{1}{Lqs+Lls}(-Rs\ iq + \omega e((Lds + Lls)id + \psi f) + Vq) \quad (8)$$

The wind turbine driven PMSG can be represented in the rotor reference frame as:

$$V_d = -R_S i_d - L_d \frac{did}{dt} + \omega L_q i_q \quad (9)$$

$$V_q = -R_S i_q - L_q \frac{diq}{dt} - \omega L_d i_d + \omega \psi_f \quad (10)$$

Where, d and q refer to the physical quantities that have been transformed into the d-q synchronous rotating reference frame, R_S is the stator resistance, L_d and L_q are the inductances of the generator on the d and q axis, ωe is the electrical rotating speed of the generator, Ψ_f is the magnetic flux.

$$\omega e = p \times \omega g \quad (11)$$

Where, p is the number of pole pairs of the generator. The electromagnetic torque equation is given by,

$$Te = 1.5p(Lds - Lls)idiq + iq\psi_f \quad (12)$$

2.3 Pitch Controller

The range of rotor speed variation is, in general, approximately 5 to 16 rpm [9]. If the reference optimum power, P_{opt}, is greater than the rated power of the PMSG, then a specific controller is used to control the rotational speed, named pitch controller. Therefore, the reference optimum power will not exceed the rated power of the PMSG. The pitch servo is modeled with a first order delay system with a time constant, Td, of 2.0 sec. Because the pitch actuation system cannot, in general, respond instantly, a rate limiter with the value of 10°/s is added. The minimum and maximum blade pitch settings are 0° and 90° respectively [10].

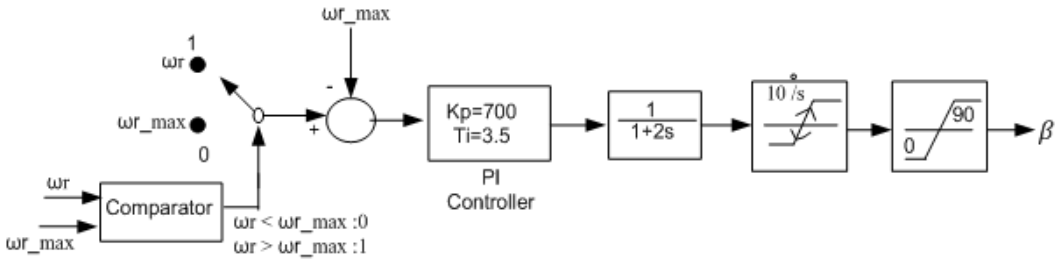

Fig.4 Pitch controller

3. Control Strategies

3.1 Grid side frequency inverter

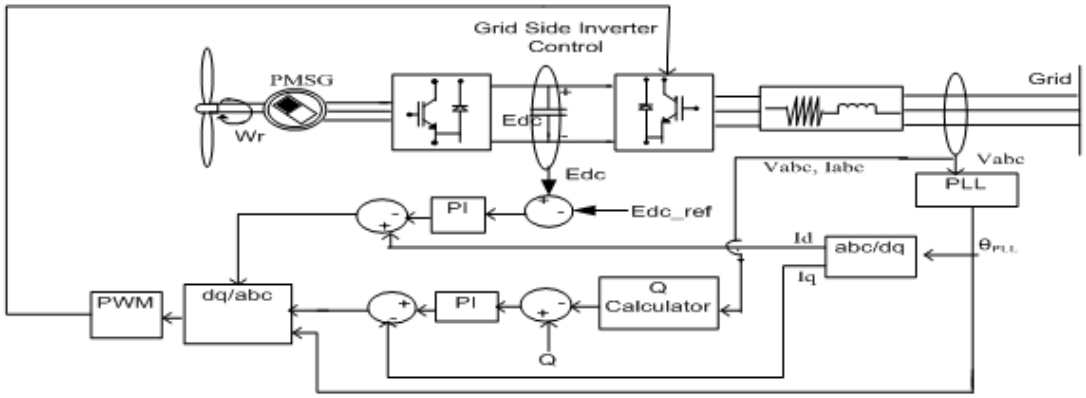

Fig.5 Control structure for the grid side frequency inverter

In this model, the back to back converter-inverter set is composed of six IGBT connected with a common DC link. An advantage of this system is that, the DC link capacitor decouples the converter and inverter and a separate control on each of them can be used. The control structure for the grid side frequency inverter is shown in the fig.5. The voltage obtained from the grid is used as the input of PLL. The output of PLL, i.e. θ_{PLL} is used for dq/abc and abc/dq transformations. The d-q components of currents and voltages are used by the PWM, which produces effective firing pulses in order to control the IGBT two-level converter-inverter set. Similar control topology has been used for the generator side converter.

3.2 MPPT

In order to obtain the maximum amount of energy from the wind, the wind turbine must have a specific rotation speed to maintain the optimum tip-speed ratio. The purpose of the MPPT is to maintain the tip-speed ratio of the wind turbine as close as possible to the optimal tip-speed ratio. Fig. 6 shows the characteristic curves of the wind. Every dotted line curve corresponds to a speed of wind.

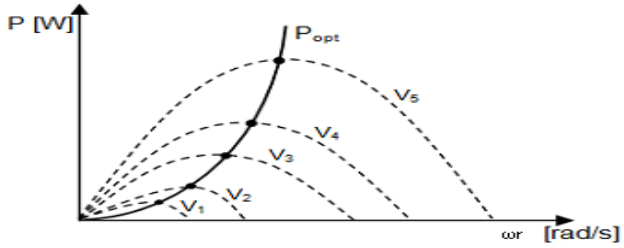

Fig.6 Characteristic curves of wind in plan power, rotational speed

An ideal wind turbine requires a perfect follow-up of this curve. For the MPPT operation, rotor speed is used as the controller input instead of wind speed, because the rotor speed can be measured more precisely and more easily than the wind speed. For a VSWT, generated active power depends on the power coefficient, C_p, which is related to the proportion of power extracted from the wind hitting the wind turbine blades. For each instantaneous wind speed of a VSWT, there is a specific turbine rotational speed, which corresponds to the maximum active power from the wind generator. In this way the MPPT for each wind speed, increases the energy generation in a VSWT [9].

4. Simulation result and comparison to IG without STATCOM

Simulations have been done by using Power System Computer Aided Design/Electromagnetic Transient including DC (PSCAD/EMTDC) program [11], for 80 seconds. The timing step of the simulation is chosen to be 0.001 sec. The rotor speed, grid side voltage and output power for PMSG are compared with that of the IG without STATCOM. The simulation results are shown below.

Fig 8 shows the variable wind speed data used in the simulation of both PMSG and IG without STATCOM. It appears from fig.9 that IG has apparently a better response of rotor speed than that of PMSG. But actually IG rotor has no control over the output power and voltage, since it cannot change its speed, which PMSG can. So the PMSG provides a control of output power and voltage as shown in the next figures.

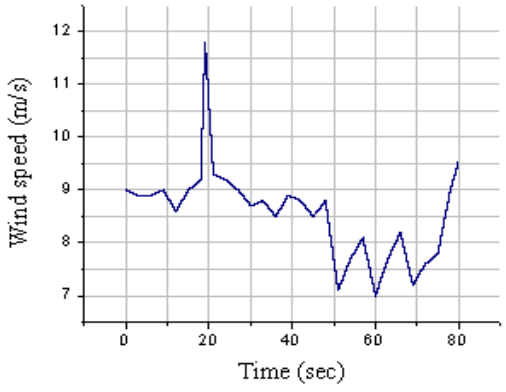

Fig.8 Wind speed data

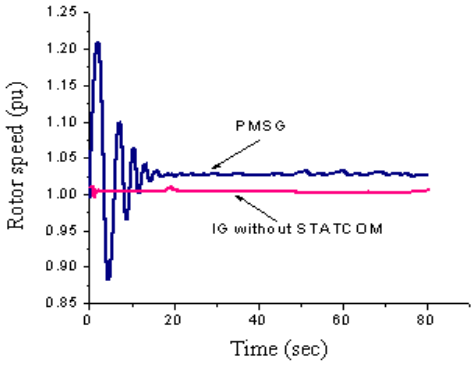

Fig.9 Rotor speed of VSWT-PMSG

Fig.10 shows the real power, P, available at the grid side. For PMSG, in spite of varying wind speed, the real power at the grid maintains a constant value, whereas, in case of IG without STATCOM, the power at the grid side fluctuates with the wind speed, as stated above. Similar result can be observed in fig.11, in case of reactive power, Q, at the grid side. It shows, though the wind speed is dynamic, but the proposed control strategy allows a constant grid-side reactive power, which can not be obtained with an IG without STATCOM.

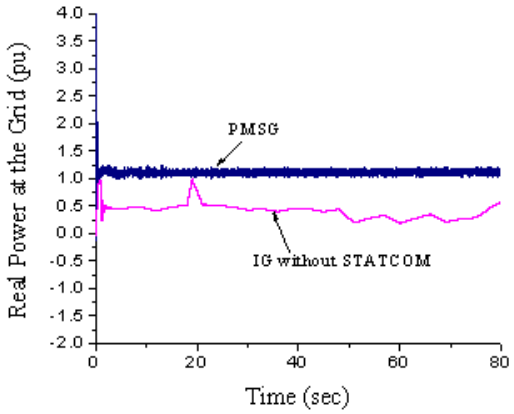

Fig.10 Real power at the grid side

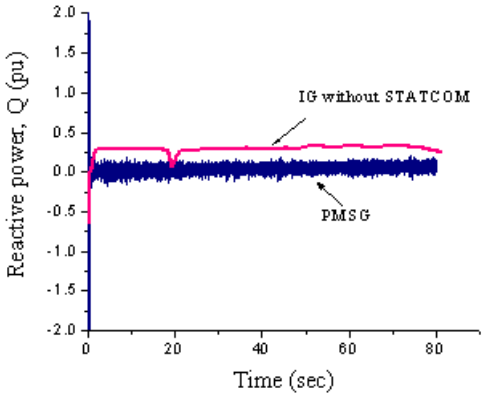

Fig.11 Reactive power at the grid side

Fig.12 shows the grid side voltage. For an IG without STATCOM, the grid side voltage is fluctuating in nature, whereas, the proposed model of PMSG is able to maintain a constant voltage at the grid side in spite of the dynamic nature of wind.

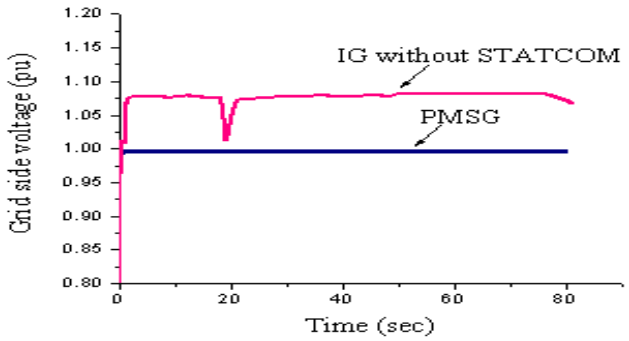

Fig.12 Grid Side Voltage

Fig.10, 11 and 12 indicates the stated parameters for both IG and PMSG, simulated for the same wind speed. For IG the output powers (real and reactive) and the grid side voltage fluctuate with the wind speed. If it is to be controlled, i.e. to supply a constant voltage and power at the grid with the IG, then some special control systems like STATCOM must be used. But it can be observed from these figures that the proposed model with PMSG is able to supply constant power and voltage at the grid side without using STATCOM.

5. Conclusion

This paper presented the model of a VSWT driven by a PMSG. The modeling and control strategies for the generator and grid side frequency inverter are presented. These control topologies are suitable for improving the dynamic analysis of the VSWT driven by PMSG.

Since wind is fluctuating in nature; the output power and terminal voltage of wind generator also fluctuate randomly, as seen from the figures in case of IG without STATCOM. The proposed control system can smooth the wind generator output power. Moreover, it can also maintain constant voltage magnitude at wind farm terminal. The graphs shown here proves the dynamic stability of the system. Therefore the proposed system has better quality and improved reliability.

6. References

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Prospects of Bagasse Gasification Technology for Electricity Generation in Sugar Industries in Bangladesh

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Abstract

Bangladesh is facing severe power crisis all over the country. This acute electricity crisis along with the conventional fuel crisis is affecting every sector of the country and economy is being crippled. Bagasse gasification in the sugar industries in Bangladesh could be an alternative option for electricity generation. Bagasse is the fiber left over after the juice has been squeezed out of sugarcane stalks and accounts 25% of sugar cane production. Bagasse, being a by-product of sugar production as well as of biomass origin seems to be a suitable candidate for sustainable energy production. There are 15 sugar mills in Bangladesh and sugar cane production in the fiscal year 2010-2011 was about 4.67 million tonnes and bagasse production was around 1.167 million tonnes. The potential of power generation from bagasse by gasification is around 100MWe in Bangladesh over the year. In this regards, in sugar industries, bagasse gasification for power generation for its own consumption could be an alternative option in Bangladesh and the surplus could be exported to the national grid. In this paper the prospects of bagasse gasification for power generation and the technological aspects of the gasification process as well as environmental effects have been studied.

Keywords: Bagasse, sustainable energy, gasification, sugar industry, power generation

1. Introduction

The present electricity access to people is approximately 49% in Bangladesh [1]. The major part of this electricity is delivered from natural gas. The reserve of this natural gas however is currently under threat. Government is therefore becoming desperate to think of alternatives of natural gas. In the recent years the government is allowing to produce electricity from heavy fuel oil (i.e. furnace oil) which is imported at a high rate. The installed capacity in Bangladesh as increased by roughly 3,415MW between 2009-2012 and is now about 8,535MW (December 2012) [2]. Over 70% of total primary energy consumption is covered by biomass, mainly agricultural waste and wood. Only about 6% of the entire population has access to natural gas, primarily in urban areas. Biomass fuels, such as wood, cow dung and agricultural residues are collected mainly from the local environment and have become a traded commodity as cooking fuel [3].

Biomass provides a clean renewable energy source that could dramatically improve our environment; economy and energy security [4].Biomass can be converted into gaseous and liquid fuels [5]. In Bangladesh, researchers evaluated the rate of biomass energy potential for electricity generation produced from agricultural residues. They found that the assessment of available biomass supply can vary in the range of biomass energy consumption [6].Bangladesh has strong potential for biomass gasification based electricity. More common biomass resources available in the country are rice husk, crop residue, wood, jute stick, animal waste, municipal waste, sugarcane bagasse etc. This technology can be disseminated on a larger scale for electricity generation. Bangladesh has a 15 sugar mills and most of them are situated in the north-west region where they face severe electricity crisis for production. Sugarcane is one of the largest biomass resources that can be crop residues base for electric energy. Residues from the sugarcane can be divided into three main parts: juice, fiber residues (bagasse) and sugarcane agriculture residues (tops and leaves). Sugarcane bagasse and sugarcane tops and leaves can be utilized as principal feedstock for electricity production. Some sugar factories were fitted with biomass gasifier-combined cycle systems, which can produce about 15–30 kWh per ton of sugarcane [7].

2. Bagasse in Bangladesh

Bangladesh is an agricultural country and it's economy largely depends on agriculture. About 70% people earn their livelihood by agriculture and agro-based industry. Total area of Bangladesh is about 147570 km², where the total agricultural land is about 90500km² which is 62.8% of the total area. Total arable land is 79700km²

and is 55.3% of the total area [8]. Crop residues represent the non-edible plant parts which are left in the field after harvest and/or remain as byproducts after crop processing e.g. extraction or milling [9]. Crop residues are generated by agriculture production. Agricultural residues contribute significantly to the biomass sector of Bangladesh. The quantities of residues have been estimated by applying a residual factor from several studies for different agricultural crops. Straws are typically produced around 50% of the total crops production whereas rice husk produce 20% of paddy production and bagasse are produced 36% of the total sugarcane production [10].Sugarcane harvested in the year of 2011 was 116175 hector and the sugarcane production was 4.67million tones [11]. So, bagasse production counted around 1.68 million tones.

3. Characteristics of Bagasse

Proximate analysis gives information about feedstock suitability in terms of moisture content, volatile matter content and fixed carbon content. Chemical compositions of the bagasse are identified by the determination of elemental contents in the sample such as Carbon, Nitrogen, Sulfur and Hydrogen. Table 1 shows the proximate and ultimate analysis of bagasse [12].

Table 1: Proximate analysis of sugarcane bagasse

Proximate analysis	
Contents	wt%
Moisture	9.51
Volatile Matter	74.98
Fixed Carbon	13.57
Ash	1.94
Ultimate analysis	
Elements	wt%
C	43.77
H	6.83
N	-
S	-
O	47.46
Bulk density	177.65 kg/m^3
Calorific value	16.81 MJ/kg

The higher heating value (HHV) indicates the energy content of a given biomass. The typical HHV of agricultural residue ranges between 15 MJ/kg and 17 MJ/kg. Feedstock needs suitable sized 15~75 mm and dried before loading.

4. Gasification overview

Biomass gasification is a thermo-chemical conversion process in which a solid biomass fuel e.g. wood, husk, bagasse is converted into a combustible gas. In a biomass gasifier, biomass is burned in a limited amount of air. The amount of air supplied is less than the amount of air required for complete burning. This converts the biomass (which consists of carbon, hydrogen, oxygen, etc) into an inflammable mixture of gases known as producer gas/ wood gas. The producer gas consists of carbon monoxide (CO), hydrogen (H_2), and methane (CH_4), along with carbon dioxide (CO_2) and nitrogen (N_2). The nitrogen is not combustible; however, it does occupy volume & dilutes the syngas as it enters & burns in an engine. A generalized reaction describing biomass gasification is as follows [13]:

Biomass + air (or H_2O) → CO, CO_2, H_2O, H_2, CH_4 and N + tars + particulates

Gasifiers can differ in either their system construction or bio-fuels used, but generally not in the chemical reactions. Regardless of gasifier type, the bio-fuels must undergo drying, pyrolysis, oxidation, and reduction steps to convert the fuel from a solid phase into a gas phase. The gasification reaction mechanism is shown in figure 1. Classification of biomass gasifiers based on the density factor (ratio of dense biomass phase to total reactor volume) is a simple and effective method of classification. The gasifiers can be classified into a) dense phase gasifiers b) lean phase gasifiers. In lean phase gasifiers e.g. fluidized bed, the biomass occupies very little reactor volume i.e. 0.05 -0.2. Most of the gasifiers employed for decentralized applications in developing countries are dense phase reactors, mostly fixed bed reactors, they have typical density factor of 0.3 -.08 [9].

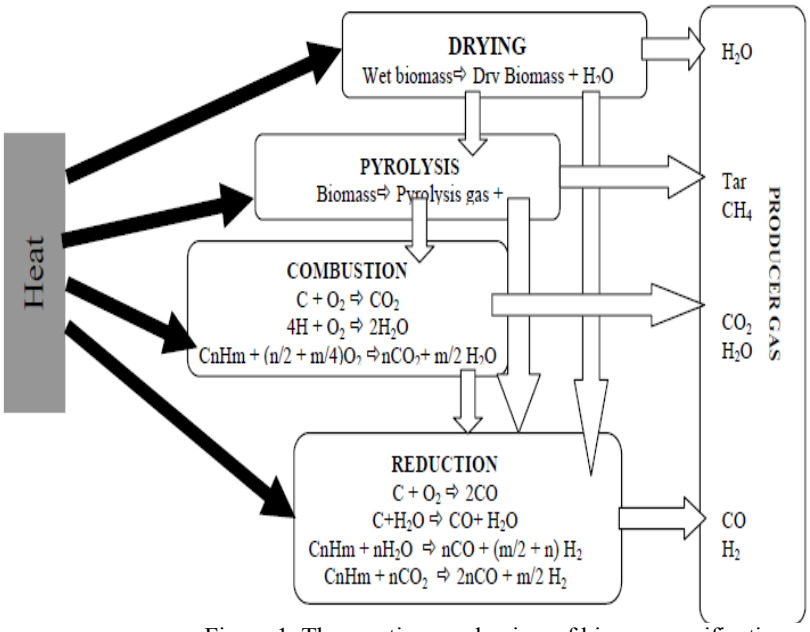

Figure 1. The reaction mechanism of biomass gasification process [14].

Fixed bed gasifier

Fixed bed gasifiers typically have a grate to support the feed material and maintain a stationary reaction zone. They are relatively easy to design and operate, and are therefore useful for small and medium scale power and thermal energy uses. The two primary types of fixed bed gasifiers are updraft and downdraft.

In a downdraft gasifier, air is introduced into a downward flowing packed bed or solid fuel stream and gas is drawn off at the bottom. The air/oxygen and fuel enter the reaction zone from above decomposing the combustion gases and burning most of the tars. Downdraft gasifier is suitable for bagasse gasification for small scale power generation for its simplicity and cost effectiveness.

In an updraft gasifier, the fuel is also fed at the top of the gasifier but the airflow is in the upward direction. As the fuel flows downward through the vessel it dries, pyrolyzes, gasifies and combusts. The main use of updraft gasifiers has been with direct use of the gas in a closely coupled boiler or furnace. Because the gas leaves this gasifier at relatively low temperatures, the process has a high thermal efficiency and, as a result, wet MSW containing 50% moisture can be gasified without any pre-drying of the waste.

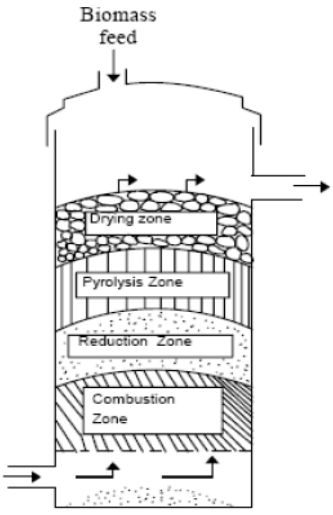

Figure 2: Updraft gasifier

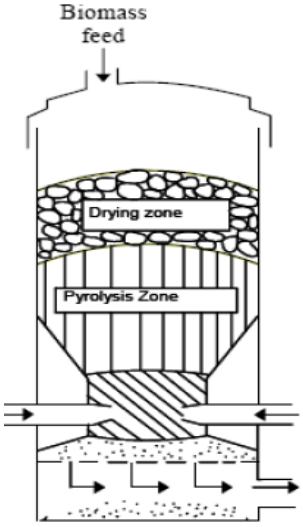

Figure 3: Downdraft gasifier

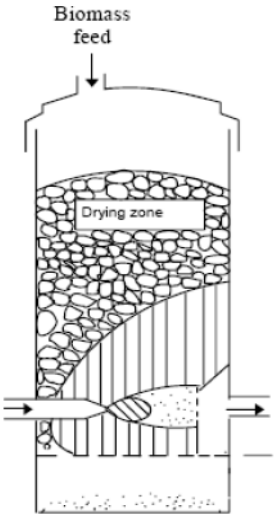

Figure 4: Cross draft gasifier

Fluidized bed gasifier

Fluidized beds are an attractive proposition for the gasification of biomass. In a fluidized bed boiler, a stream of gas (typically air or steam) is passed upward through a bed of solid fuel and material (such as coarse sand or limestone). The gas acts as the fluidizing medium and also provides the oxidant for combustion and tar cracking. Waste is introduced either on top of the bed through a feed chute or into the bed through an auger. Fluidized-beds have the advantage of extremely good mixing and high heat transfer, resulting in very uniform bed conditions and efficient reactions. Fluidized bed technology is more suitable for generators with capacities greater than 10 MW because it can be used with different fuels, requires relatively compact combustion chambers and allows for good operational control. The two main types of fluidized beds for power generation are bubbling and circulating fluidized beds.

In a Bubbling Fluidized Bed (BFB), the gas velocity must be high enough so that the solid particles, comprising the bed material, are lifted, thus expanding the bed and causing it to bubble like a liquid. As waste is introduced into the bed, most of the organics vaporize pyrolytically and are partially combusted in the bed. Typical desired operating temperatures range from 900° to 1000 °C.

A circulating fluidized bed (CFB) is differentiated from a bubbling fluid bed in that there is no distinct separation between the dense solids zone and the dilute solids zone. The capacity to process different feedstock with varying compositions and moisture contents is a major advantage in such systems

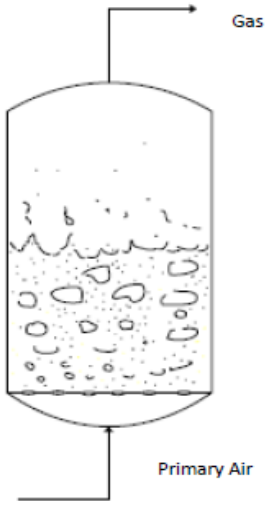

Figure 5: Bubbling fluidized bed

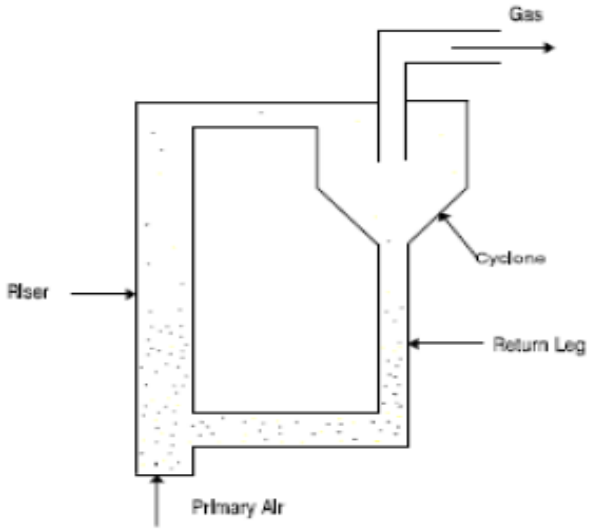

Figure 6: Circulating fluidized bed

Figure 2, figure 3 and figure 4 show the different type fixed bed gasifier whereas figure 5 and figure 6 present the fluidized bed gasifier [15]. Downdraft gasifier system can be chosen for developing countries perspective due to their simplicity in construction and cost competitive. Down draft gasifier produces very small amount of tar and with little treatment it can directly use to the internal combustion engine. Also, the technologies of these systems are quite matured in the world. Based on the above comparative discussions, however, a downdraft gasifier is better than an updraft gasifier system in many aspects. This gasifier has some unique advantages like suitability to small scale production (50-150kW), minimum operating labor required, exhaust type (particularly % of tar content), and easy as well as less maintenance required [15].

5. Power generation potential from bagasse in Bangladesh

Electricity generation from bagasse depends on the availability of raw materials and technology for conversion of bagasse to electricity. Gasification converts a traditional, low quality fuel to a modern day energy carrier i.e. combustible gas. Such conversion occurs at relatively high efficiencies and results in total convenience and process control. The process can be applied over a very wide range of output ratings (a few kilowatts to tens of megawatts) with only a small variation in overall efficiency and investment. Gasifiers with individual units being capable of supporting power generation at upto 500-800 kWe level; larger outputs need paralleling of more than one unit. Complete power generation systems including gasifiers, gensets, fuel handling sub-systems and grid paralleling sub-systems, as needed and effluent treatment.

Bangladesh, having about 15 sugar mills, produced around 1.68 million tons of bagasse in the year 2011 which is sufficient to produce power with minimum investment. In the north-western region, which is starved for energy, the sugar mills would be a great energy resource. This is also an advantage as all the 15 sugar-producing units were installed in the region. Gasification process is equally applicable for electricity generation and a variety of thermal applications. Raw material availability is also a concern for larger plants. The process is equally applicable for stand-alone utility and grid feeding. Almost all environmental pollution associated with biomass use can be eliminated. Various researcher shows that the downdraft gasifier is suitable for small scale bagasse gasification base power plant [15, 16]. For gasification based power plant consumption of bagasse is 2kg per kWh electricity generation [17]. On the basis of the bagasse available in Bangladesh and assuming a small fraction (~50% availability) of bagasse is available for generation in sugar industries, the possible power potential is about 50 MW.

6. Conclusion

In response to meeting the energy demand from sustainable sources, green energy technology implementation is essential. Bangladesh has a good potential form power generation from bagasse gasification and the current study indicates in 2011 the total potential of power generation from bagasse gasification has estimated around 50 MWe. There are seasonal, geographical distribution and other variations in the availability of this potential. This could help the sugar industries to be self sufficient of power generation and be able to expedite the sugar production as well. Establishment of bagasse based power plants in sugar industries will be led to an enormous change in the sugar production and rest of power to be supplied to national grid and to the local communities.

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Paper ID: ET-24

Development of a Novel Water Treatment Technique Using Solar Still Cum Sand Filter

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Abstract

Water is a basic need for human being for physiological processes. The supply of pure drinking water is a serious problem for most parts of the world .In coastal areas, there is a much scarcity of pure water because of high salinity in water. Develop a tubular solar still (TSS) by using ceramic media along with a sand filter (SF) for water purification. In the raw water salinity was found to be around 1550mg/L. In the treated water from TSS and TSS-SF, salinity was found to be around 0 mg/L and 400 mg/L respectively, though the influent raw water salinity was 1550 mg/L. In the influent raw water the total dissolved solids (TDS) and total coliform (TC) was 2880 mg/L and 220 no/L respectively. The salinity, total dissolved solids (TDS) and total coliform (TC) of the treated water from TSS-SF was within the permissible limit. So, the treated water is safe for drinking purposes.

Keywords: Solar desalination, water purification, salinity, Water treatment, potable water.

1. Introduction

Water treatment technologies have evolved over the past few centuries to protect public health from pathogens and chemicals. As more than a billion people on this earth have no access to potable water that is free of pathogens, technologies that are cost effective and suitable for developing countries must be considered [6]. Sustainable operation of these treatment processes taking into consideration locally available materials and ease of maintenance need to be considered. Now-a-days water desalination is an essential process in those areas where ground water is fully contaminated by salinity and surface water is highly polluted. So, this study has been introduced to develop the water treatment technique by installing tubular solar still using ceramic media along with sand filter to provide enough, pure and safe water supply specially in coastal regions. Water is one of the abundant resources on earth but only about 3 % of it is potable and remaining 97% is saline water which is lying in the sea. According to [4] 60-90% and according to Food and Agriculture Organization (2006), 69% of all freshwater sources are used for agricultural irrigation. Desalination (also spelled desalinization) is the process of creating fresh water by removing saline (salt) from bodies of salt water. There are varying degrees of salinity in water, which affects the difficulty and expense of treatment, and the level of saline is typically measured in parts per million (ppm). The U.S. Geological Survey provides an outline of what constitutes saline water: 1,000 ppm – 3,000 ppm is low salinity, 3,000 ppm – 10,000 ppm is moderate salinity, and 10,000 ppm – 35,000 ppm is high salinity [7]. Water that contains saline levels less than 1,000 ppm is generally considered fresh water, and is safe to drink and use for household and agricultural purposes. Groundwater has been used for various purposes such as drinking, domestic purposes, irrigation, and industrialization and so on. So, water level is lowering day by day. In coastal areas, there is a much scarcity of pure water because of high salinity in water. Again, surface water is being contaminated by various kinds of organisms and compounds. By using ceramic filter we can get a better quality and quantity of water. Generally, groundwater is clear, colorless with very little or no suspended solids and it is free from disease producing micro-organisms which normally present in surface water [1]. For these reasons groundwater is the main source of water supply in urban and rural areas of many developing countries but in some areas groundwater is contaminated with arsenic, and excessive dissolved iron. Besides, in coastal areas groundwater contains high level of salinity. Solar desalination is the process that removes excess salts and other organic compounds from the water. It is the process for water purification where solar energy is used as input energy, raw water is evaporated from the storage channel of solar still and finally accumulated into the outlet. Nevertheless, sand filtration reduces the number of micro-organisms and other physicochemical compounds present in the water. The main objective of this study is to develop a novel water treatment technique using solar still cum sand filter which would increase the production of treated water and retain the salinity within a permissible level.

2. Methodology

Develop a tubular solar still (TSS) by using ceramic media along with a sand filter (SF) for water purification. To monitor of the treated water quality and quantity is developed in the treatment unit. The observation of the workability of ceramic media for enhancing the capacity of TSS.To provides some Proposals for the modification of TSS-SF for its long-term sustainability. To identity the operation & maintenance problems of the developed TSS-SF.The laboratory investigation was carried out on the top roof of the Civil Engineering Department of Khulna University of Engineering and Technology (KUET) is shown in figure-1 and Structural components of a TSS-SF unit is shown in figure-2. A low cost Tubular Solar Still cum Sand Filter (TSS-SF) was designed and constructed. It was constructed of tubular frame covered with a transparent normal polythene paper and a black rectangular tray used as channel for storing saline water along with sand filter. The sand filter consists of a circular filter box and an outlet. The influent raw water quality in both TSS and SF was remained same. The effluent treated waters from these treatment operations were blended together and stored in a container. The schematic diagram of the TSS-SF unit is shown in figure below:

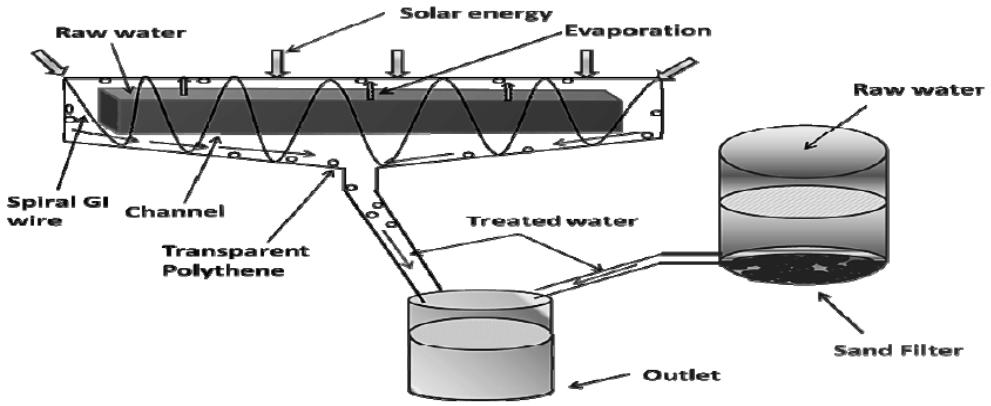

Fig.1. Schematic diagram of TSS-SF unit

Structural components of a TSS-SF unit

Black rectangular tray

Sand filter

Tubular Solar Still (TSS) Ceramic Filter

Fig.2. Structural components of a TSS-SF unit

3. Results and Discussion

A sample of 15 litres water was taken into the solar still and made its salinity artificially about 1550 mg/L for winter and summer 2100mg/L by adding sodium chloride. At the same time, the same quality of 2 litres water was taken into the sand filter in each day. When the influent raw water of TSS was finished, then it was again filled up. The output of treated water from the TSS-SF unit was collected from 19th December, 2012 to 19th January, 2013 shown in Table 1 and Table 2 respectively. Each 30 days total output from the period 19th December, 2012 to 19th January, 2013 for winter and summer 6th march to 2 April shown in Table 3 and Table 4 respectively. Graphically, Variation of value of water quality parameters between raw, TSS, SF and TSS-SF water in winter season is shown in figure-3, 4,5,6,7 and figure-8.Again, Graphically Variation of value of water quality parameters between raw, TSS, SF and TSS-SF water in Summer season is shown in figure-9,10,11,12,13 and figure-14.

Table1: The value of water quality parameters of Raw water

Water quality parameters	Value
Chloride conc.(mg/L)	1550
TS(mg/L)	3540
TDS (mg/L)	2880
TC (No./100ml)	22
FC (No./100ml)	2
DO (mg/L)	7.87
Color(Pt-Co.unit)	73
pH	6.54

Table2: The value of water quality parameters of treated water

Water quality parameters	Tubular solar still (TSS)	Sand filter (SF)	Tubular solar still cum sand filter (TSS-SF)
Chloride conc.(mg/L)	0	1481	400
TS(mg/L)	0	1850	900
TDS (mg/L)	0	1745	850
TC (No./100ml)	0	0	0
FC (No./100ml)	0	0	0
DO (mg/L)	7.82	7.95	7.6
Color(Pt-Co.unit)	0	3	0
pH	7.4	8.3	7.8

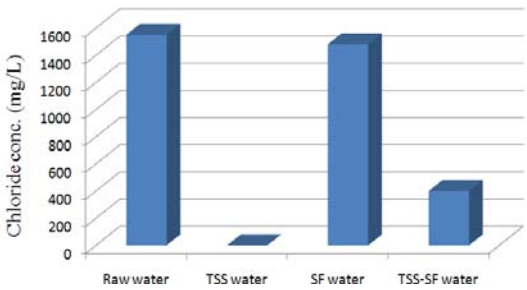

Fig.3. Variation of salinity

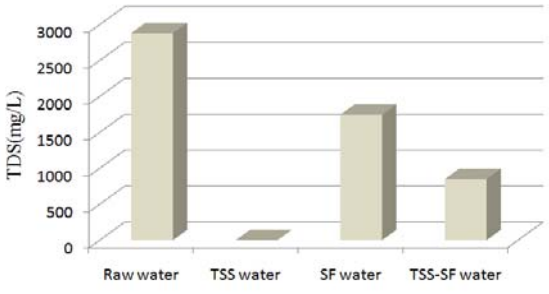

Fig.4. Variation of total dissolved solids(TDS)

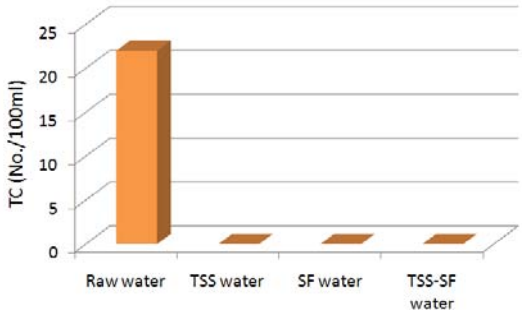

Fig.5. Variation of total coliform(TC)

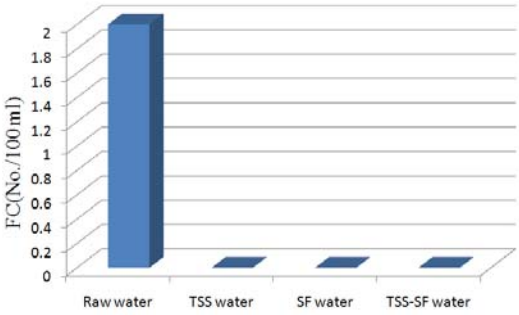

Fig.6. Variation of faecal coliform(FC)

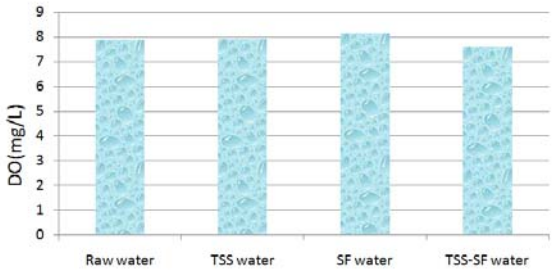

Fig.7. Variation of dissolve oxygen(DO)

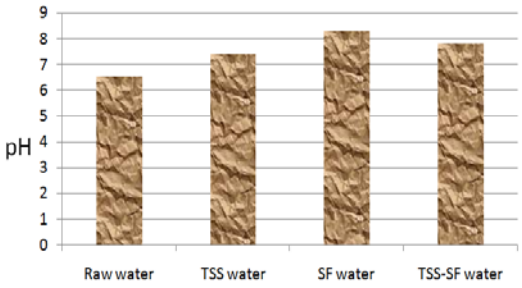

Fig.8. Variation of pH

Table3: The value of water quality parameters of Raw water

Water quality parameters	Value
Chloride conc.(mg/L)	2100
TS(mg/L)	3540
TDS (mg/L)	3500
TC (No./100ml)	21
FC (No./100ml)	2
DO (mg/L)	8.77
Color(Pt-Co.unit)	60
pH	7.94

Table4: The value of water quality parameters of treated water

Water quality parameters	Tubular solar still (TSS)	Sand filter (SF)	Tubular solar still cum sand filter (TSS-SF)
Chloride conc.(mg/L)	0	1983	400
TS(mg/L)	0	1813.2	868
TDS (mg/L)	0	1813	868
TC (No./100ml)	0	0	0
FC (No./100ml)	0	0	0
DO (mg/L)	7.96	8.16	7.98
Color(Pt-Co.unit)	0	0	0
pH	7.6	7.82	7.73

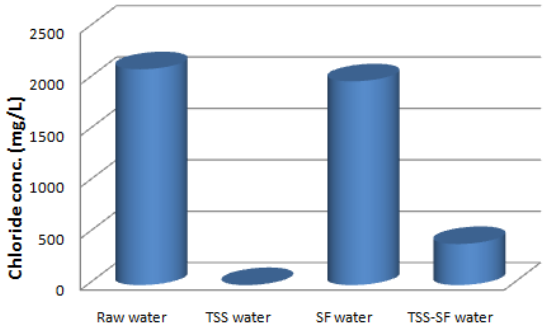

Fig.9. Variation of salinity

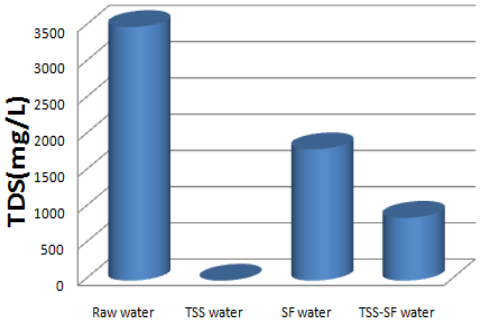

Fig.10. Variation of total dissolved solids(TDS)

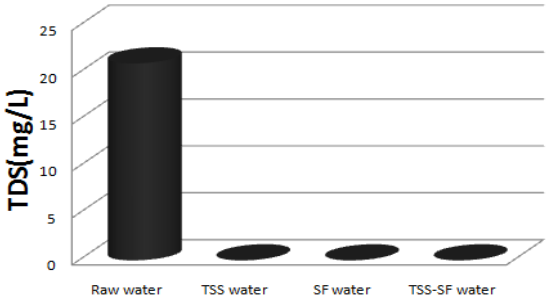

Fig.11. Variation of total coliform(TC)

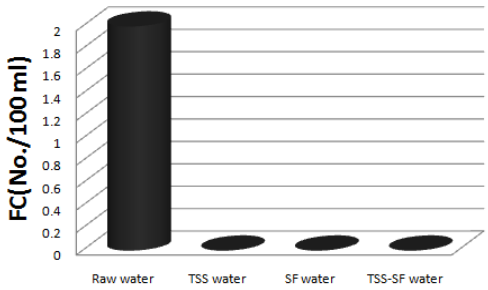

Fig.12. Variation of faecal coliform(FC)

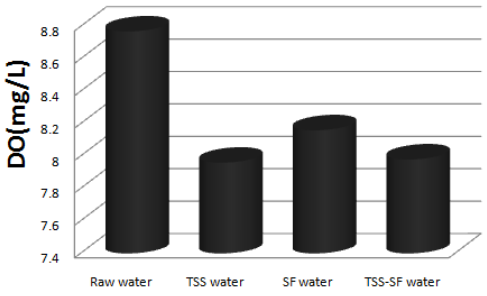

Fig.13. Variation of dissolve oxygen(DO)

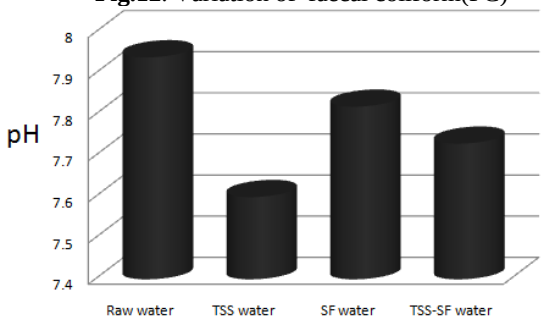

Fig.14. Variation of pH

The construction cost of TSS was 500 Tk (BDT) and including it, the cost of storage channel and tubular frame was 250 Tk (BDT) and 120 Tk (BDT) respectively. The storage channel was made of good quality cartoon paper with high durable polythene so its construction cost was semi-high relative to the TSS. The construction cost of SF was 900 Tk (BDT). By adding the operational cost, the total cost of TSS-SF unit was 1750 Tk (BDT). The TSS-SF unit was placed strongly on a safe place so that high wind velocity could not do any harm to it. The TSS-SF was operated very carefully and maintained continuously.

The raw water salinity was found to be around 1550 mg/L. In the treated water from TSS and TSS-SF, salinity was found to be around 0 mg/L and 400 mg/L respectively, though the influent raw water salinity was 1550 mg/L. In the influent raw water the total dissolved solids (TDS) and total coliform (TC) was 2880 mg/L and 22 No/100mL, respectively. The TDS value of treated water from TSS and TSS-SF was found 0 mg/L and 850 mg/L, respectively. The TC value of treated water was found to be 0 No/100mL.

4. Conclusions

Today, the world demand for potable water is increasing continuously due to industrial development, intensified agriculture, improvement of standard of life and increase of the world population. The world demand for potable water is increasing continuously due to industrial development day by day, intensified agriculture, improvement of standard of life and increase of the world population. The supply of pure drinking water is a serious problem for most parts of the world. In dry season, this problem becomes very acute. But in dry season, the productivity of TSS-SF unit is higher. The TSS-SF unit is suitable for producing potable water from mostly available saline water in the coastal belt of Bangladesh. Though desalination is a slow process, but in the TSS-SF unit the production rate is larger than desalination process and production cost of distilled water is very small. The construction of the TSS-SF unit is very simple and one can use this technology easily in the house. Water from desalination is not bound by many of the conditions that plague traditional fresh water development. The increase in the public awareness of the environmental problems associated with fresh water sources coupled with the new, more stringent drinking water quality regulations make development of new traditional water resources more difficult and costly. Unlike traditional water supplies, alternative desalted water supplies are not vulnerable to weather. So, it is concluded that the application of TSS-SF technique can fulfill the demand of potable water in coastal areas of many developing countries like Bangladesh.

5. Acknowledgement

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Design and Fabrication of Solar Agricultural Water Pumping System and Cost Comparison with a Diesel Pump

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Abstract

Bangladesh is an agricultural country. Most of our economy depends on agriculture. Irrigation system of water is very important factor for cultivation. But every year irrigation system is collapsed due to shortage of energy source. So an alternative source of energy is very essential for our economy. Also Bangladesh is an under developed country. In many regions of our country where the energy like diesel, octane, petrol etc. are not available or so expensive. So, solar energy is very effective in these places. Solar energy is a renewable energy that comes from sun's heat energy. Our main aim focuses to run a water pump by using solar energy. Our water pumping system consists of a solar panel, charge controller, DC centrifugal pump and a battery. Solar panel converts this light energy into electrical energy. Then DC power from solar panel is passed through the digital solar charge controller. A 12V dc battery is charged through the charge controller. Then a 10W dc centrifugal pump is connected to battery output. Finally pump supply water to the reservoir or agricultural land. We also made a comparison between solar water pump and diesel pump based on cost.

***Keywords**: Agriculture, Energy, Solar panel, Pump, Cost*

1. Introduction

There are two sources of energy such as renewable and nonrenewable source. A nowadays nonrenewable source of energy is mostly used such as fossil fuel. However, the amount of fossil fuel is limited on earth .using of fossil fuel already has created environmental pollution which causes global warming effect. The exhaust gas have been produced during combustion of fossil fuel contain CO_2, CO and other harmful gas. These gases are results greenhouse effect. Sources of renewable energy such as solar energy, wind energy, tidal energy and so on. All of them, solar energy is more efficient compared to others.

For investigations the performance of solar pump, many researchers designed and analyzed various systems. Solar water pumping system was first made in 1979. Solar pumping technology continues to improve. In the early 1980s the typical solar energy to hydraulic (pumped water) energy efficiency was around 2% with the photovoltaic array being 6-8% efficient and the motor pump set typically 25% efficient. Today, an efficient solar pump has an average daily solar energy to hydraulic efficiency of more than 4%. Photovoltaic modules of the mono crystalline type now have efficiencies in excess of 12% and more efficient motor and pump sets are available. A good sub-system (that is the motor, pump and any power conditioning) should have an average daily energy throughput efficiency of 30-40%.

There are various activities in rural Bangladesh which totally depend on the use of solar energy if these could be performed more quickly and efficiently by using simple devices, it would increase productivity without making and demand on commercial energy sources. In Bangladesh research and development work to harness solar energy in the form of heat has been going on for many years at Dhaka University, Bangladesh Agriculture University, BUET, Solar Park of Dhaka College and BCSIR Laboratories. There are more than 10,000 solar powered water bore pumps

in use around the world today. They are widely used on farms and outback stations in Australia to supply bore water to livestock. In developing countries they are used extensively to pump water from wells and rivers to villages for domestic consumption irrigation of crops.

A typical solar powered pumping system consists of a solar panel array that powers an electric motor, which drives a bore pump. The water is often pumped from the ground or stream into a storage tank that provides a gravity feed. No energy storage is needed for these systems. PV powered pumping systems are a cost-effective alternative to wind systems.

2. Objectives of the project

1. To design and fabricate a solar agricultural water pumping system
2. To make a cost comparison of solar pump with diesel pump

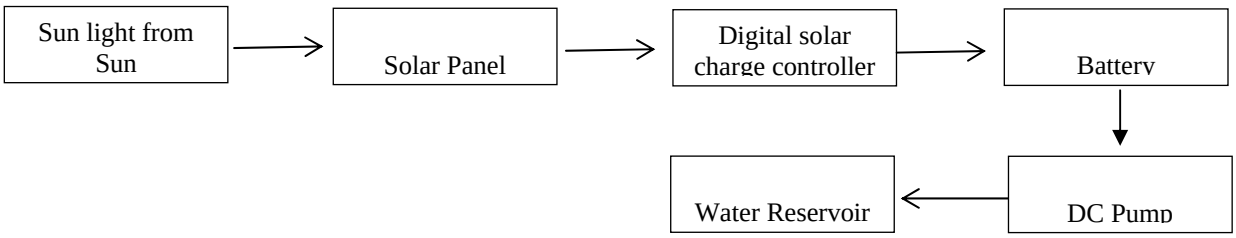
3. Descriptions

A Solar panel is devices which receives sun light and then convert into electrical energy. My project is to run a water pump by solar electricity for agricultural irrigation. Every year Bangladeshi farmers face a great problem during irrigation due to power crisis. Farmers cannot continue irrigation properly. As a result, the production of paddy decreases a great amount which affect our gross economy .Solar energy may be a solution of this problem. Solar electricity from solar panel can be used as alternative energy to continue irrigation. A number of attempts have been made by scientists to utilize solar energy for irrigation water pumping. It is mainly a problem of conversion of heat energy available from the sun, to mechanical energy. Some ingenious methods have been devised to utilize the available energy at low temperatures. This paper reviews past efforts to develop solar thermal water pumping systems which employ either conventional pumps or unconventional pumps, and emphasizes how the system modifications were made to suit different pumping conditions and requirements. Photovoltaic (PV) modules (i.e. solar electric panels) produce electricity from sunlight using silicon cells with no moving parts.

4. Methodology

This chapter explains detail about the methodology of the whole system and flow of step that used in solar agricultural water pumping system. This chapter also describes further more about the planning of the whole project. This project is based on solar energy. Solar energy is available and unlimited around the world. In this project solar energy is converted into electrical energy that is used to run a dc pump for collecting water from underground level. This water is supplied to crops land for irrigation. Sunlight is incident on solar panel which supply dc current. A solar charge controller is used after solar panel to regulate current and voltage. A battery is also used to restore electricity to supply current. Then current is passed by wire to dc pump. DC pump is settled to the ground level. DC pump collect water and store to reserve tank. A float switch is used to stop the motor when the tank is full of water. Then water is passed to narrow canal to crops land.

4.1 Flow chart



5. Importance

In developed country solar electricity is widely used for various purposes, for example: solar water heating, solar power plant, solar powered car, solar powered air conditioner, solar water pump, solar boat etc. In Bangladesh solar electricity is not so popular compared to developed country. But some institute and organization such as **Grameen Shakti**, **BRAC** try to spread out the using of solar electricity. Bangladesh power development board can not generate sufficient electricity for supplying electricity throughout the country especially rural areas and hill tract areas. In the "boro" season PDB cannot supply sufficient electricity. So a solar agricultural water pumping system may be a good system for irrigation.

6. Advantages of solar pump set

i. No fuel cost-uses abundantly available free sun light.
ii. No conventional grid electricity required.
iii. Highly reliable and durable-free performance.
iv. Easy to operate and maintain.
v. Eco-friendly.
vi. Saving of conventional diesel.

7. Application of solar pump set

i. Livestock Watering: Cattle-Sheep-Poultry-Exotics
ii. In addition to these, SWT System have been used for pumping in
iii. Irrigation both small-scale traditional and drip
iv. Orchard and tree nursery watering
v. Fish ponds
vi. Pollution monitoring and remediation wells
vii. Wildlife water supply

8. Limitations and scope

Bangladesh power development board can not generate sufficient power. As a result BPDB is unable to transmit electricity to hill track area as well as north Bengal rural areas. So farmers of rural areas depend on river, canal or pond water. Otherwise they depend on shallow machine which run by fossil fuel. As a result the production cost of paddy is very high. When river or canal is dried up, farmers cannot irrigate to their land. So the production rate of paddy decreases. Solar water pumping system will be very effective for irrigation. But solar water pumping system must be cheaper than any other irrigation system. This system must be made within low cost as much as possible. Solar panel is very expensive. If farmers of a village make a organization together to contribute a solar water pumping system, then this pumping system will be cheaper.

9. Experimental set up

Solar irrigation pumping system is very easy to install. It is free from environmental pollution. There is no maintenance cost for the system .It's initial setup cost is quite large, but if we connect several solar panels with several pump in series than the cost will be less in respect of long term service, because a solar pump can run continuously without any need of electricity. So a large amount of crops produced in terms of conventional diesel pump & there is no fuel cost. The system consists of a solar panel, a digital solar charge controller, a 12V dc battery & a dc pump.

10. Digital Solar charge controller

Solar charge controller is designed to protect 12V lead-acid or gel-cell battery from being overcharged by solar panel, which prevents discharge of battery during night time. This controller reduces overall system maintenance and prolongs your battery life. It will continuously display the charging current or battery voltage in charging proceeding from LCD digital meter. It also automatically indicates the battery condition from LED bar-graph. This controller is designed to work with all kinds of 12volts solar panels for indoor use.

Features:

i. Digital voltage and current : Continuous display for battery and solar panels
ii. Battery type selected: select the gel-cell or lead-acid battery by selector switch
iii. Protection of battery: Protect batteries from solar over charged and maintains battery in fully charged state.
iv. Safety circuit protection: short circuit and reverse polarity protection
v. Reverse leakage protection: protect batteries from solar power discharge
vi. Over temperature protection: over temperature protection and auto resume

10.1 A 12V Lead-Acid battery

An alternative to large storage capacities is to install a battery backup system in conjunction with the solar system. Battery Backup systems are required by some on-demand pump systems where water must be available 24 hours per day 7 days per week but battery systems involve more initial cost and require more maintenance than direct solar systems. The higher cost and increased maintenance can be avoided in most applications by proper direct solar system sizing.

10.2 DC pump

The pump, driven by a 12volt dc motor, draws water from wells or rivers, then pours water into the reservoir or storage tank, or directly to irrigation systems and fountain systems. Based on the requirements and installation conditions, different types of pumps can be used. In solar pumping system, selection of pump is essential, which directly affects the economy and stability of the whole system. Submersible pumps which have widely application and speed-regulating range, are common in solar pumping systems, and it also can increase daily working time and water now rate of the solar pumping system. If the users require low head and high water flow, can choose self-priming pump, while they require high head and low water flow can be chosen volume delivery pumps.

Fig 1: Experimental set up

11. Data collection and analysis

11.1 Data collection method

i. At first solar panel was stetted at highest pick point of the sun in the roof
ii. A solar charge controller was connected to the panel through the connector plug
iii. After that a 10 watt dc pump was connected from the output of the controller
iv. We have measured voltage and current through the multi-meter at various conditions for various span of the day
v. After getting all the data, we measured power and plotted various graphs

11.2 Data analysis by graph

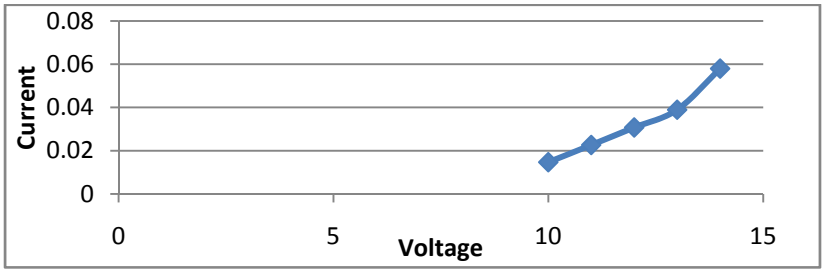


Fig 2: Current vs. Voltage at load condition (dated 26-09-12)

Result: Current increases rapidly with the change of voltage

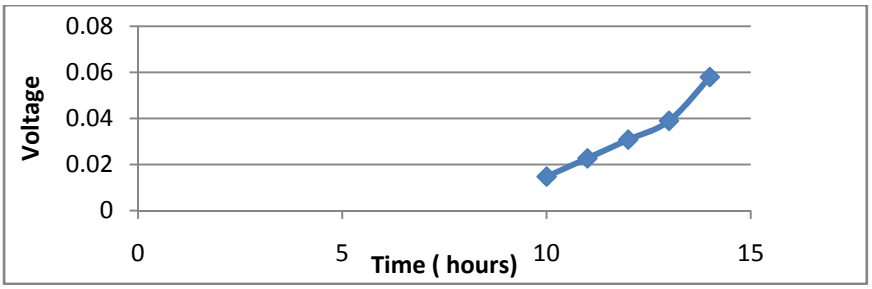


Fig 3: Battery charge rate (dated at 25-09-12)

Result: Voltage increases rapidly with the change of time

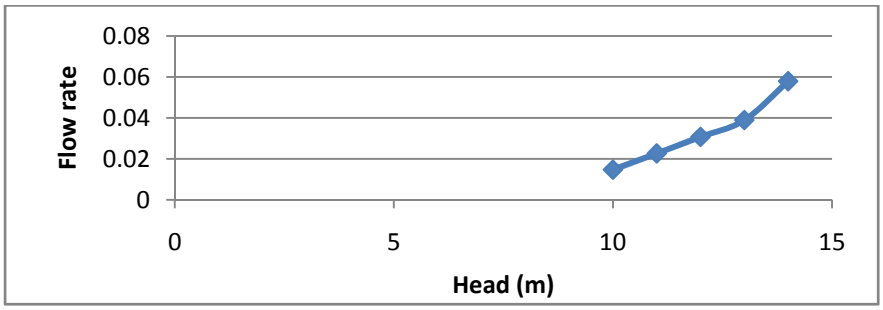


Fig 4: Head vs. flow rate (dated at 26-09-12)

Result: Flow rate increases rapidly with respect to head

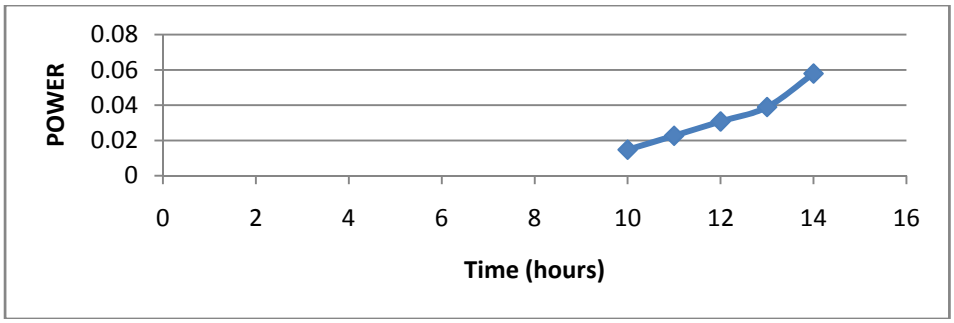


Fig 5: Power vs. time (dated at 26-09-12)

Result: Power is produced with a short of time

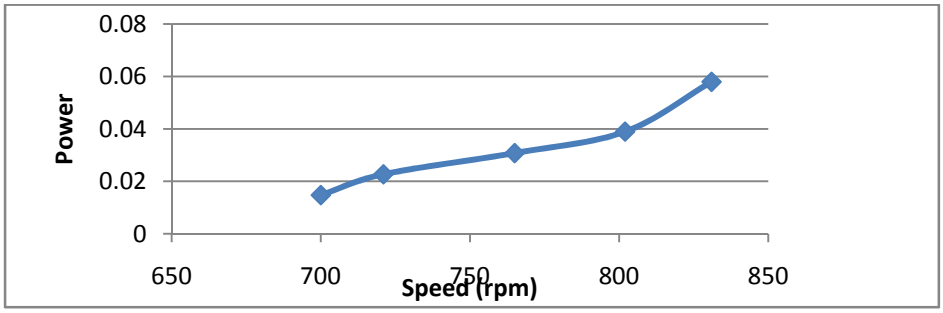


Fig 6: impeller speed vs. power (dated at 26-09-12)

Result: Power is produced slowly with respect to impeller speed

12. Cost analysis

12.1 Sizing of solar pumps

The hydraulic energy required (kWh/day)
= volume required (m^3/day) x head (m) x water density x gravity/ (3.5 x 10^6)
= 0.002725 x volume (m^3/day) x head (m)
The solar array power required (kwp) = Hydraulic energy required/Av. Daily solar irradiation
Where, F = array mismatch factor = 0.85 on average
And E = daily subsystem efficiency 0.25 – 0.40 typically

12.2 Estimating Solar Electric (PV) System Size: Area of Solar Panel

On average (as a genera] "rule of thumb") modern photovoltaic (PV) solar panels will produce 8 - 10 watts per square foot of solar panel area For example, a roof area of 20 feet by 10 feet is 200 square-feet (20 ft x I0 ft). This would produce, roughly, 9 watts per sq-foot, or 200 sq-ft x 9 watt/sq-ft = 1,800 watts (1.8 kW) of electric power.

12.3 Converting Power (watts or kW) to Energy (kWh)

One kilowatt-hour (1 kWh) means an energy source supplies 1,000 watts (**1** kW) of energy for one hour. Generally, a solar energy system "Virri" 11 provide output for about 5 hours per day. So, if you have a 1,8 kW system size and it produces for 5 hours a day, 365 days a year: This solar energy system will produce 3,285 kWh in a year (1.8 kW x 5 hours x 365 days).

If the PV panels are shaded for part of the day, the output would be reduced in accordance to the shading percentage. For example, if the PV panels receive 4 hours of direct sun shine a day (versus the standard 5 hours), the panels are shaded 1 divided by 5 = 20% of the time (80% of assumed direct sun shine hours received). In this case, the output of a 200 square-foot PV panel system would be 3,285 kWh per year x 80% =- 2,628 kWh per year.

13. Cost calculation

For solar pump

Let assume, area of land = .03 acre =.03 x 4048.327m^2 = 121.44 m^2
So, capacity of water required for one time irrigation = 121.44 x.03 m^3 =3.6432 m^3 =3643.2L
Flow rate = .032 L/s for 2m head
Time required for one time irrigation = 31.625 hr = 15.8 hr /day
Cost:

Solar panel – Tk.1700	(20W @85/W)
DC pump – Tk. 500	(10 W)
Charge controller –Tk.1000	
Battery - Tk. 1100	(12V)
Total: Tk. 4300	for .03 acre land

So, for 1 acre, total cost = Tk. 4300 x 33.3 = Tk. 143190
We know, solar pump sustain 20 years (on an average)
So, cost of irrigation for 1 acre land for one season =143190/40 =Tk.3579.75
For diesel pump:

Specification of diesel pump

Type: Centrifugal pump
Max^m Suction Head = 60-70 ft
Speed = 1400 rpm

Cost:

Diesel cost for 1 acre for one season = Tk. 4575
Lub. Oil cost for 1 acre for one season = Tk.240
Diesel pump cost for 1 acre for one season =Tk. 300
Maintenances cost for same criteria = Tk. 154

So, cost of irrigation of 1 acre land for one season by diesel pump = Tk.5269.

Saving

So, savings by solar pump =Tk. (5269 – 3579.75) = Tk.1689.25/acre for one season

7. Conclusion

Solar energy is one of the effective renewable energy. Day after day the amount of fossil fuel is decreasing but on the other side solar energy is free and unlimited. It has no environmental pollution. In our country, there are a lot of scopes to use solar energy. For this reason, I have completed this project. In our country solar water pump used in agriculture will be a very good step. Bangladesh is under developed country. In many regions of our country where the energy like diesel, octane, petrol etc are not available. So, solar energy is very effective in these places. Although solar panel is expensive but it has no fuel cost. If the government of Bangladesh helps farmers, then it will be superior. After all, I can say that my project will be very helpful to our country's economy. The main purpose of this my project is to reduce cost and to make it as a general mass use. From the cost analysis of the project, I compared the total irrigation cost of solar pump with diesel pump and finally found that total cost of solar pump is cheaper than the other one. So, if we utilize the solar pump in our agricultural area, it will be helpful to our country's economy.

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Study of Pyrolysis Products-Oil-Bitumene Rocks Western Kazakhstan

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Abstract

The investigations of the pyrolysis products oil-bitumene rocks (OBR) of different fields in Western Kazakhstan by gas-liquid chromatography (flame ionization detector) and IR spectroscopy. It was found that pyrolysis products comprise mainly masut 370-500 and diesel 200-370.

Keywords: Oil and bitumen rocks, pyrolysis, IR-spectroscopy, the mechanism of thermical destruction, depolymerization

Introduction

Currently, the following questions are particularly acute environmental improvements oil-producing regions, as contaminated soil, spills and accidental releases of oil, barn oil, sediments remaining after oil extraction or waste sewage occupy vast areas and harmful to the environment because they are not processed and this problem becomes more threatening. [1]. Kazakhstan has huge reserves oil-bitumene rocks (OBR) (950-1000 million tons), containing in the structure of natural bitumen [1]. The Republic of Kazakhstan pays great attention to the construction of modern highways that meet international standards, but for long term use in the spring and summer and especially in autumn and winter periods in multiple alternating temperature changes from -40 ° C to + 40 ° C and in heating Road cover 90-100 ° C, roads wear out quickly, which requires annual renewal of the top layer - the asphalt. Earlier thermomechanical studies have shown that the bitumen softens at 0 ° C, becomes viscous-fluid state at 20 ° C and 100% degradation is reached at 40 ° C, the area of rubbery deformation is absent [2].
Oil-bitumene rocks, and especially isolated from their natural bitumens are used as binders for the production of modified road-building materials, sporting and flooring, sealants, mastics, etc. In the industry of building materials bitumen is widely used for construction and repair of road and airfield pavements and foundations, floors, industrial buildings, soil stabilization, protection against corrosion of metal and concrete, the manufacture of roofing, hydro, thermal and vapor barrier, materials and products, the protection of radioactive radiation, in the manufacture of paints [3-8].

Experiment

The objects of study were the various oil-bitumene rocks of western Kazakhstan. Samples of various OBR after pyrolysis without air:
F-1, a dark brown solid residue; № 2, a dark solid residue;
F-3, the bottom layer - the thin, transparent, F-3, the upper layer - a dark oily liquid.
F-4 - a clear liquid.
F-5, the bottom layer - the thin, transparent, F-5, the top layer - a dark oily liquid.
OBR No. 4 - 1st distillation, the bottom layer - brown liquid;
OBR No. 4 - 1st distillation upper layer - light-brown oil.

Gas-liquid chromatography. Currently, of particular interest is the study of the qualitative and quantitative composition of the products of pyrolysis oil-bitumene rocks modern rapid methods, including gas-liquid chromatography. The investigations of the pyrolysis products *oil-bitumene* species by gas-liquid

chromatography (flame ionization detector). In this work, we used a gas chromatograph "Crystal Suite 4000" production (Yoshkar-Ola, Mari-El). Assay conditions: packed column, length 1 m Sorbent - "Chromaton NDMCS» c 5% OV-101; Carrier gas - helium gas flow rate of 30 ml / min hydrogen - 30 ml / min air - 300 ml / min; flame ionization detector (FID). Temperatures Detector - about 270; Evaporator - about 270; Column - initial temperature of 40, and 2 minutes in the isothermal mode, and then heating the 4 o / min to 260 of Volume of the sample injection - 3 l. The calculation was performed by the method of simulation of distillation ASTM-89.

IR spectroscopy. For information about the processes by mixing oil-bitumene rocks with polymeric binders were held infrared spectroscopic studies of the respective samples. Infrared absorption spectra of bitumen, OBR and polymer compositions were obtained on an automatic dual-beam spectrometer UR-20 in the absorption interval of 400-4000 cm^{-1}.

Pyrolysis held various fields neftebituminoznyh rocks of western Kazakhstan and the method of gas-liquid chromatography investigated liquid and solid products of decomposition. Previously there have been studied methods modified OBR electron paramagnetic resonance (PMR) [5]. The pyrolysis process comprises heating OBR without access of air, which leads not only to *oil-bitumene* distillation fraction to flow but of complex chemical reactions at high temperature pyrolysis at 580-600 0C. As a result, the pyrolysis gas produced (not caught) liquids and solids are removed, and almost all of the volatile products. To carry out distillation was used iron retort. Liquid and solid pyrolysis products OBR was dissolved in benzene.

Results and discussion

Therefore, the actual problem has both theoretical and practical interest is the modification of bitumen with various polymers, which give the set of physico-mechanical and operational parameters, as well as durability. By infrared spectroscopy (IR) was used as the primary method of genetic-typing typical oilbitumene rocks and assess qualitative and quantitative relations of their component hydrocarbon and heteroatomic components. Of particular concern is the problem of creating highly flexible organic corrosion inhibitors of road-building materials, roofing systems, sealants, and other products based on natural bitumen by modifying their various additives and analysis of the products of pyrolysis. The additives used polymeric binders, rubber, waste production, and polyesters. Polyester was prepared from phthalic anhydride and glycerol. Degree of polycondensation of synthetic resin glyptal determined by acid value and saponification number. For information about the processes occurring in mixing *oil-bitumene rocks* with polymer binders were held infrared spectroscopic studies of relevant samples. The research methods of pyrolysis products NBP gas-liquid chromatography (flame ionization detector). Figures 1 and 2, respectively, are the IR spectra of natural bitumen extracted from the NBP and the modified polyester synthesized by us from phthalic anhydride and glycerol. Very intense pp at 1375-1376,3 and 1453,9-1457,7, 1486.4 cm^{-1} in the oil fractions are stretching and bending vibrations of the CH2 and CH3 groups in paraffin and tsikloparafinovyh hydrocarbons. In the spectra of all the components is clearly visible pp at 726.8 cm^{-1}, which corresponds to the bending vibrations of CH 2 groups in free paraffinic chains. The presence of polyester characterized by the appearance of the absorption band is much more intense in the 1721.5 cm^{-1} (Fig. 2), indicating the presence of oxygen-containing compounds. Simultaneously observed in the modified bitumen low intensity pp at 1453.9 and 1282.6 cm^{-1}, which disappear in the original bitumen. The modified bitumen reduced intensity pp at 1125.6 and 1070.1, as well as 776.4 and 705 cm^{-1}.

Pyrolysis of various deposits held oil-bitumene rocks (OBR) in Western Kazakhstan and by gas-liquid chromatography investigated liquid and solid products of decomposition. It was found that the pyrolysis products contain mainly masut 370-500 and diesel 200-370.

Fig. 1 and 2 show the chromatograms and the content of the pyrolysis products OBR number 4 of the lower and upper layers, respectively. From Figure 1 it follows that in the products of pyrolysis gasoline fraction and no tar. The pyrolysis products are diesel and fuel oil fraction. Diesel 200-370 is present in an amount of 65.18%, and oil 370-500 - in an amount of 34.82%.

From Fig. 2 shows that the top of the content of the gasoline fraction pyrolysate minor - 0.12%, diesel fuel - 41.75% oil - 58.13%. From a comparison of data content of diesel fuel and fuel oil NBP number 4 in the top and bottom fractions (Fig. 1 and Fig. Two, respectively) that during the transition from the bottom to the top of the diesel fuel fraction falls to 23.43%, and amount of fuel oil increased by 23.31%. Apparently, the depolymerization reactions occur and degradation oil-bitumene rocks.

Of particular interest are the IR spectroscopic studies of the OBR.

Figures 3 and 4 respectively shows the IR spectra of natural bitumen derived from OBR modified polyester synthesized Center of phthalic anhydride and glycerin. A comparison of the IR spectra show that the samples of

bitumen in the 400-2200 cm-1 absorption band (pp) are observed at 425 and 426.9, 471.2 and 485.3, 537.5 and 559.5 , 618.9 and 646.8, 705 and 726.8, 882, 911.8 and 925.7, 986.1, 1032.3 and 1042.2, 1070.1, 113.5 and 1125.6, 1218 , 8, 1236, 1282.6 and 1376.3 1375, 1453.9 and 1457.7, 1486.4, 1557.9, 1581.7, 1598.3, 1641.6, 1699.3, 1721.5, 1958.1, 2108.2 and 2149.6 cm^{-1}. Very intense pp at 1375-1376,3 and 1453,9-1457,7, 1486.4 cm^{-1} in the oil fractions are stretching and bending vibrations of the CH2 and CH3 groups in paraffinic hydrocarbons and cycloparaffinic. In the spectra of all the components is clearly visible pp at 726.8 cm^{-1}, which corresponds to the bending vibrations of CH2 groups in free paraffinic chains. The presence of polyester characterized by the appearance of the absorption band considerably higher intensity of 1721.5 cm^{-1} (Fig. 4), indicating the presence of oxygenated compounds. At the same time in a modified bitumen there is less intensity pp at 1453.9 and 1282.6 cm^{-1}, which disappear in the original bitumen. Slightly less than in the modified bitumen intensity pp at 1125.6 and 1070.1, and at 776.4 and 705 cm^{-1}. In the 2200-4000 cm-1 are absorption bands at 2726.9, 2860.1 and 2860.6, 2923.7, and 2924, 2950.7 and 2951, 3071.9, 3434.7 and 3434.9 cm^{-1}. It is known [8], which is low in intensity and broad 3434.7 and 3434.9 cm^{-1} may pertain to stretching vibrations of OH and CH. The strongest in the medium-wave part of the spectrum ap 1453,9-1457,7 cm^{-1}, she, like pp 3071 cm^{-1} belongs to the methylene groups. In the initial bitumen missing pp at 3071.9 cm^{-1}. Changing polymer content of the resulting composition results in compositions of various consistencies, from mastic to a solid material.

Conclusions

1. It is considered that the pyrolysis oil-bitumene rocks (OBR) without air accompanied by preferential formation of diesel fuel and fuel oil 200-370 370-500 that can be applied in the petrochemical industry.
2. It was showed that in rock oil-bitumene rocks (OBR) No. 4 in the upper part of pyrolysate gasoline - 0.12%, whereas in the lower part of the gasoline fraction is absent.
3. It was found that oil-bitumene breed F-5 in the upper part of pyrolysate gasoline - 0.03%, whereas in the lower part of the gasoline fraction is absent.
4. The possibility of using oil-bitumene rocks for diesel fuel and heating oil and gasoline in small quantities.

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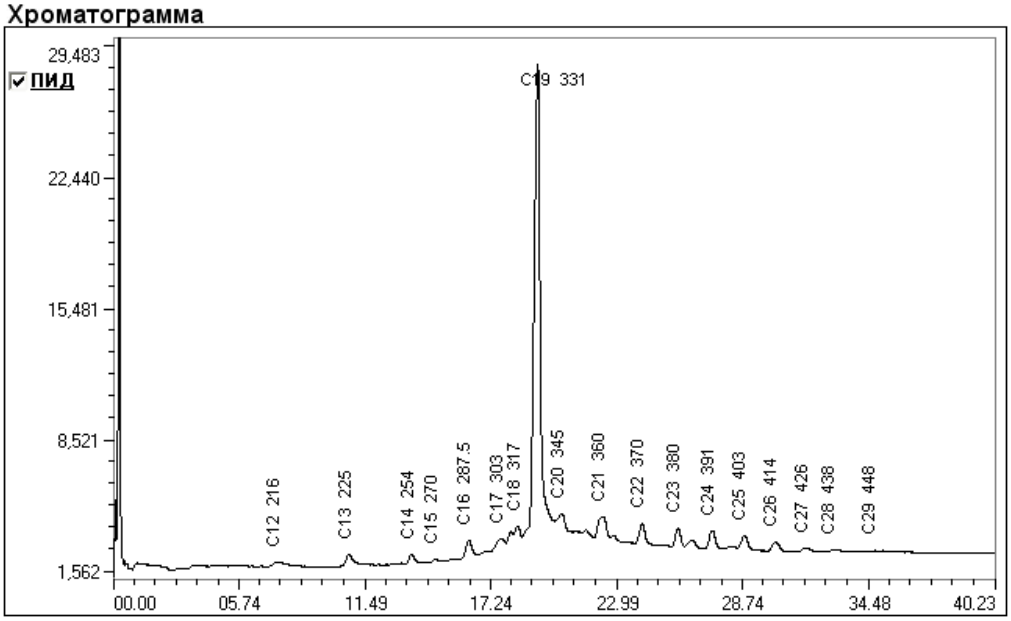

Пики

№	Время, мин	Компонент	Площадь,%
1	7,51	C12 216	0,5610
2	10,77	C13 225	1,0024
3	13,61	C14 254	0,4063
4	14,73	C15 270	0,3564
5	16,21	C16 287.5	1,8317
6	17,67	C17 303	2,9573
7	18,44	C18 317	4,7592
8	19,36	C19 331	34,3398
9	20,45	C20 345	9,6762
10	22,31	C21 360	9,6574
11	24,11	C22 370	9,2102
12	25,75	C23 380	6,8562
13	27,30	C24 391	6,8165
14	28,77	C25 403	4,8157
15	30,19	C26 414	2,7352
16	31,58	C27 426	1,5503
17	32,83	C28 438	1,2985
18	34,70	C29 448	1,1698
			100,0000

Группы

№	Группа	Детектор	Концентрация, % об.
1	бензин-200	ПИД	0,000000
2	дизель топ-200-370	ПИД	65,179222
3	мазут-370-500	ПИД	34,820778
4	гудрон выше- 500	ПИД	0,000000

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Fig. 1. "The chromatogram OBR No. 4 (bottom layer)"

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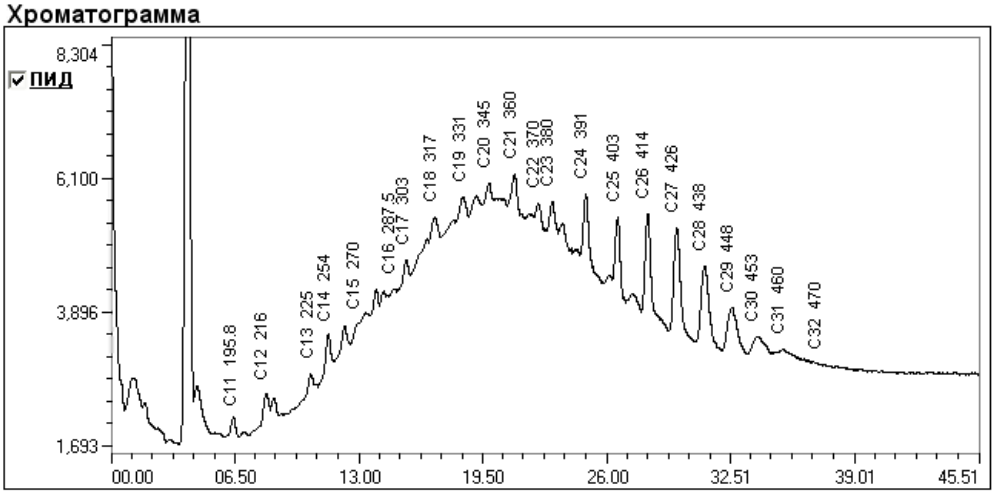

Пики

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2	8,10	C12 216	0,8014
3	10,47	C13 225	0,9833
4	11,36	C14 254	2,5874
5	12,89	C15 270	2,5538
6	14,77	C16 287.5	3,2289
7	15,47	C17 303	3,4481
8	16,97	C18 317	6,7151
9	18,47	C19 331	6,7127
10	19,78	C20 345	8,1542
11	21,15	C21 360	8,1506
12	22,38	C22 370	8,7435
13	23,11	C23 380	10,5871
14	24,88	C24 391	8,2703
15	26,54	C25 403	7,0532
16	28,11	C26 414	6,7822
17	29,63	C27 426	5,3233
18	31,10	C28 438	3,7812
19	32,53	C29 448	2,6182
20	33,84	C30 453	1,6541
21	35,18	C31 460	1,2163
22	37,09	C32 470	0,5282
			100,0000

Группы

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2	дизель топ-200-370	ПИД	41,749981
3	мазут-370-500	ПИД	58,129494
4	гудрон выше- 500	ПИД	0,000000

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Fig. 2. "The chromatogram OBR No. 4 (top layer)"

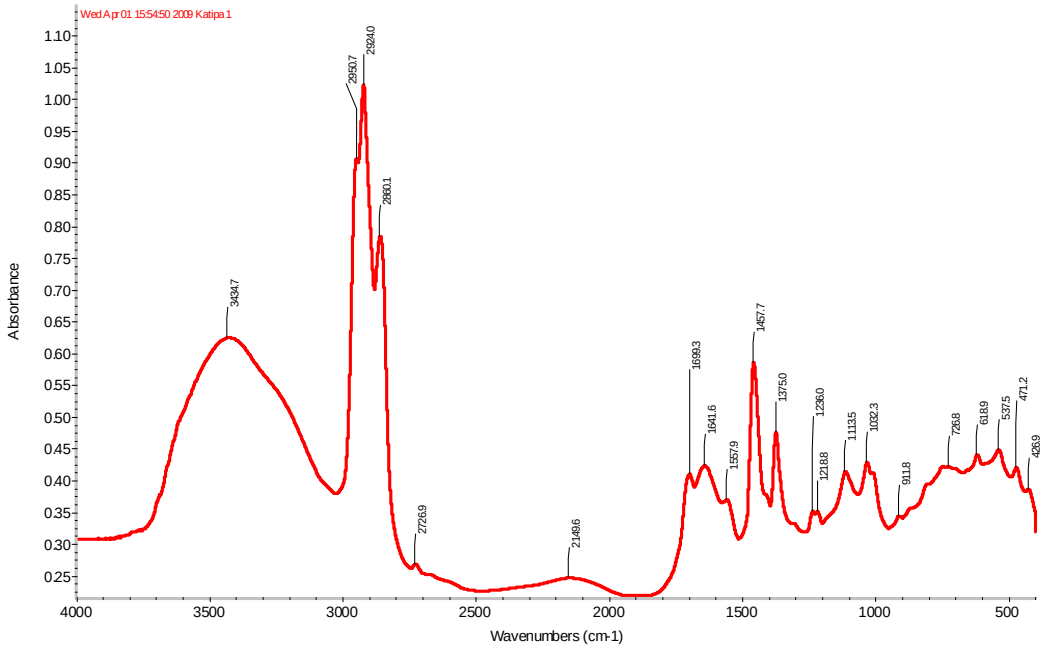

Fig. 3. - IR spectra of bitumen extracted from the OBR

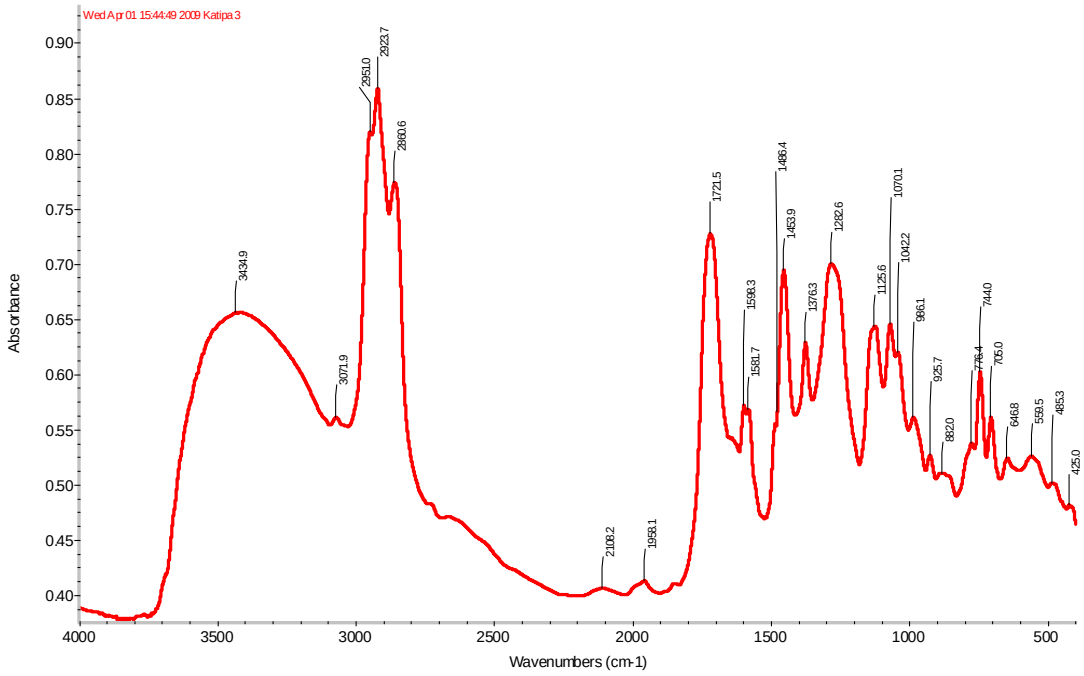

Fig. 4. - IR spectra of the reaction product of bitumen with polyester

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Hybrid Energy Modeling for Auto Vehicles

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Abstract

Hybrid electric technology has become the latest milestone in the automotive industry. This paper presents an auto rickshaw based hybrid energy storage system that operates in an environmentally friendly way. The proposed auto rickshaw consists of a Solar panel, a Plug in Battery charger, a Maximum Power Point Tracking (M.P.P.T) circuit, battery module, Power controller, Control circuitry, Instrumentation system and a DC series excitation motor. The battery is fully charged by battery charger and the PV panel is trying to keep the state of full charged battery by continuous trickle charging. The charge sustaining capability enables the vehicle to accelerate faster, enhance the cruising capability, driving range, the battery life-span, and reduce road accident. The proposed vehicle model is analyzed by the Advanced Vehicle Simulator (ADVISOR) software. Finally, the use of hybrid energy can effectively improve the vehicle performance and efficiency.

Keywords: Hybrid energy, solar panel, MPPT, auto vehicle, ADVISOR.

1. Introduction

The first ever HEV was built in 1898, and there were several automotive companies who were selling HEV s in the early 1900s [1]. But the production of HEVs did not proceed due to the requirement for a smooth coordination between the engine and the motor, which was not possible due to the use of only mechanical controls and the poor efficiency compare to the combustion engine vehicle. Motorization was increasing day by day with the development of industrialization and urbanization.

The oil crisis of the 70s and the growing threat of global warming, excessive fossil fuel dependence, and increasing the fuel prices which have accelerated the development of Hybrid Electric Vehicles (HEV) into the political spotlight. Hybrids have been looked at as a possible solution to resolve consumption and pollution problems without having to reduce performance or range compared to a normal car. Therefore, serious research on hybrid cars began in the late 70s [2]. Electric drives are becoming very popular in the control of hybrid vehicles. The revolution in the design of automobile's electrical system creates a very large and diverse market for a practical 48V electrical system, new electrical functions, alternative electrical sources and necessity of power electronic controls and interfaces [3],[4]. Many automobile industries developed hybrid vehicles namely Honda Insight, Honda Civic, Toyota Prius, Volkswagen, Venturi Astrolab, Chevrolet Volt etc. The hybrid vehicles still have the disadvantage of a too high price. Also this type of hybrid vehicles (a four seated middle class car) does not really fulfill the needs of the Bangladeshi society and does not meet the requirements of a typical Bangladeshi city either. Conventional auto rickshaws are suited to the Bangladeshi environment. They are small and narrow, allowing maneuverability on congested roads. So, conventional auto rickshaw was converted to the hybrid energy storage system and it will be suitable in the development country.

Bangladesh is situated between $20^0$34' and $26^0$38' North Latitude and $88^0$01' and $92^0$41' East Longitude and the climate is tropical [5]. It gets abundant sunlight year round. The monthly average solar insolation at different Locations of Bangladesh is given in Table 1[6]. The Table 1 showed that the monthly average solar insulation is the highest in Rajshahi and the lowest in Sylhet. The daily average of bright sunshine hours at Dhaka city is given in Table 2 and showed that the daily sunlight hours in Bangladesh to range from 10 to 7 hours [7]. Maximum amount of radiation is available on the month of March-April and minimum on December-January [6].

The total solar energy reaching in Bangladesh is 180×10^9 Mwhr/year which is 105 times the energy generated as electricity [5]. So, the solar resource in Bangladesh is rich and suitable form of renewable energy for urban region because of availability of plenty of sunshine. In effective operation, keeping the produced energy by this green source and the designed stand-alone system can operate economically. The vehicle is emission, noise and maintenance free. The oil prices all over the world are increasing day by day. In this system, our country does

not depend on foreign oil. At night time charging of EVs will help to balance the load and improve the power plant efficiency.

Table 1. Monthly Average Solar Insolation (KWh/m^2) at Different Locations of Bangladesh

Month	Dhaka	Rajshahi	Sylhet	Bogra	Barisal	Jessore
January	4.03	3.96	4.00	4.01	4.17	4.25
February	4.78	4.47	4.63	4.69	4.81	4.85
March	5.33	5.88	5.20	5.68	5.30	4.50
April	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
June	4.80	5.25	4.53	5.26	4.39	5.12
July	4.41	4.79	4.14	4.34	4.20	4.81
August	4.82	5.16	4.56	4.84	4.42	4.93
September	4.41	4.96	4.07	4.67	4.48	4.57
October	4.61	4.88	4.61	4.65	4.71	4.68
November	4.27	4.42	4.32	4.35	4.35	4.24
December	3.92	3.82	3.85	3.87	3.95	3.97
Average	4.73	5.00	4.54	4.85	4.71	4.85

Source: Mondal, M. A. H., 2005, p.29

Table 2: Daily Average of Bright Sunshine Hours at Dhaka City

Month	Daily Mean	Maximum	Minimum
January	8.7	9.9	7.5
February	9.1	10.7	7.7
March	8.8	10.1	7.5
April	8.9	10.2	7.8
May	8.2	9.7	5.7
June	4.9	7.3	3.8
July	5.1	6.7	2.6
August	5.8	7.1	4.1
September	6	8.5	4.8
October	7.6	9.2	6.5
November	8.6	9.9	7
December	8.9	10.2	7.4
Average	7.55	9.13	6.03

Source: Bashar, REEIN, 2010a

With the factors of pollution, increased traffic in mind, drive range, charging cost, battery life and power crisis the best way to revamp the auto rickshaw is to develop a more efficient design that will be powered by a nonpolluting hybrid energy source, which can be achieved with an electric drive train since there are zero pollutants at the tailpipe. A hybrid energy source would make it a better solution compared to the current alternative-fuel-powered rickshaws and auto rickshaw.

In this paper, hybrid energy for auto vehicles is presented and comparison between electric vehicle and hybrid energy auto vehicles was done using a realistic driving cycle. The main purpose of this study is to evaluate the solar energy based auto vehicles for zero environmental pollution and to propose an efficient model for increasing the driving range, driving speed, minimize the charging time, enhance battery life and reduce the charging cost. The proposed vehicle model is analyzed by the Advanced Vehicle Simulator (ADVISOR) software. For designing and parameters analysis the data are collected from local markets and international markets through internet and the solar panel estimation data is calculated with respect to Dhaka city.

2. Conventional Auto Rickshaw

Auto rickshaws are three-wheeled vehicles that are widely used in many Asian countries as taxis or Easy bike for people. The existing electric three-wheelers are popularly known as Borak, E-Bike, Easy Bike, City Bike, etc. are now being used in 17 districts in Bangladesh. It has only battery powered electric vehicle. The battery is fully discharged in the evening. At night, the battery is charging 9 to 10 hours. At new condition, it covered 110km to 140km per day in a single charge with the top speed approximates 40 to 45 km/ph. The vehicle speed depends on the battery charge. The slope and bad road condition discharge the battery charge rapidly and

reduces the drive range. At night, the driver turn on the head light and it reduces the drive range. Because of this, most of the drivers drive the vehicle without “turns on” the head light due to increase their drive range and the prolong road accident is happened. The battery efficiency is decreasing constantly. After one year, it covered around 60km to 70km in night time charging and at launch time 2 to 3 hours charging it covered around 30km to 40km. For this reason, battery charging cost is high. Sometimes the battery is failure less than one year.

3. Model Configuration

The electric three wheelers can be characterized by its tin/iron body supported by three small wheels (one in front and two at the back), with a seat for the driver with a passenger in the front and two bench seating four or five passenger in the rear. It has an open design: no doors for the driver or passengers, allowing immediate pick-ups and drop-offs. The redesign auto vehicles do not want to change any part of the aforementioned characteristics. Only redesign its energy storage system. It is reflect on the rickshaw. The proposed vehicle will be well-suited with the old one and easily used by the drivers and comfortable for the passengers. The proposed vehicle model is shown in fig.1.

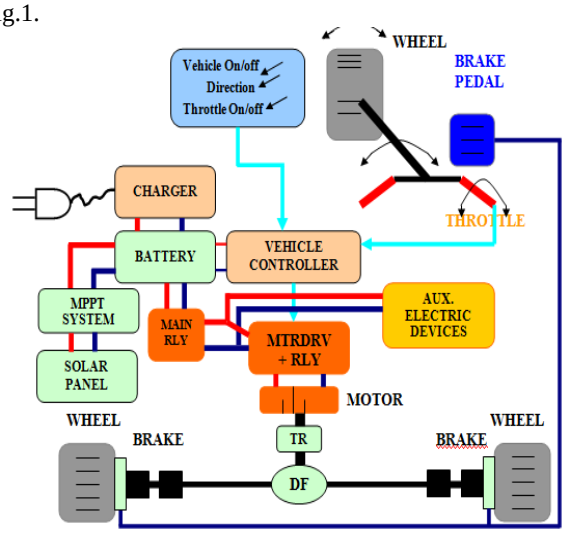


Fig. 1. Auto Vehicle Model

The proposed vehicle is more efficient to use all over the places in Bangladeshi environment. This vehicle is also small, narrow and environmental friendly. The vehicle top speed is 50km/h and usually carries one to five passengers with a driver. It covers a small distance 160 to 180 km per day in a single charge. The prototype system consists of a Solar panel, a Plug in Battery charger, a Maximum Power Point Tracking (M.P.P.T) circuit, rechargeable battery module, Power controller, Control circuitry, Instrumentation system and DC series excitation motor. At night, the battery module is charging at 5 to 6 hours by the Plug in system and at day, the PV panel is trickle charging the battery. When the vehicle is slowing down, the motor becomes a generator and provides energy to the batteries. So, the large current discharging of battery is avoided, enhance the cruising capability and the driving range. Thus, the battery life-span is extended. When the battery is charging by the plug in system, the control circuitry cut off the M.P.P.T circuit, which is sensed by the instrumentation system. The M.P.P.T control circuit not only takes maximum power from the solar panel but also monitor the condition of the battery.

The energy stored in the Vehicle's rechargeable battery module. The battery module supplies power to the motor by the power controller. The power controller is a device, which controls the amount of power supplied to the electric drive motor(s) based on the position of the accelerator through the control circuitry. The electrical power supplied to the electric drive motor(s) is used to generate an electromotive force, which turns the shaft of the electric motor(s). This shaft is coupled to the wheels of the vehicle and causes movement either forward or reverse, depending on the direction the shaft is turning through a gearbox.

The dc motor actuator is driving the vehicle, a power controller for matching the various voltage and power levels of the battery according to the motor speed, a control circuitry control the driving speed and human interface. The display shows the battery performance through the instrumentation system. In this way, the electric energy is converted to mechanical energy that drives the vehicle. The proposed vehicles physical specification is given in the Table 3.

Table 3. Physical Specification for Auto Vehicle

Components	Value
Outline dimension(L*W*H)	2650*1000*1650 mm
DC series excitation Motor	60V--1000W
Top speed	40~50km/h
Front wheel	4.00-12
Back wheel	4.00-12
Break distance	25km/h less than 4m
Storage battery	12V, 120AH(5 set)
Solar panel	260W, 44.6V
Solar panel size	1955*982mm
Daily distance covered	160km ~ 180km
Vehicle weight	300~400 Kg
Loading Capacity	450~500 Kg

4. Energy Storage System

In order to improve the vehicle efficiency, a hybrid energy storage scheme has been proposed. The battery module is charging by the home charge, solar charge and regenerative charge in a convenient way. The hybrid energy storage system block diagram is shown in figure 2.

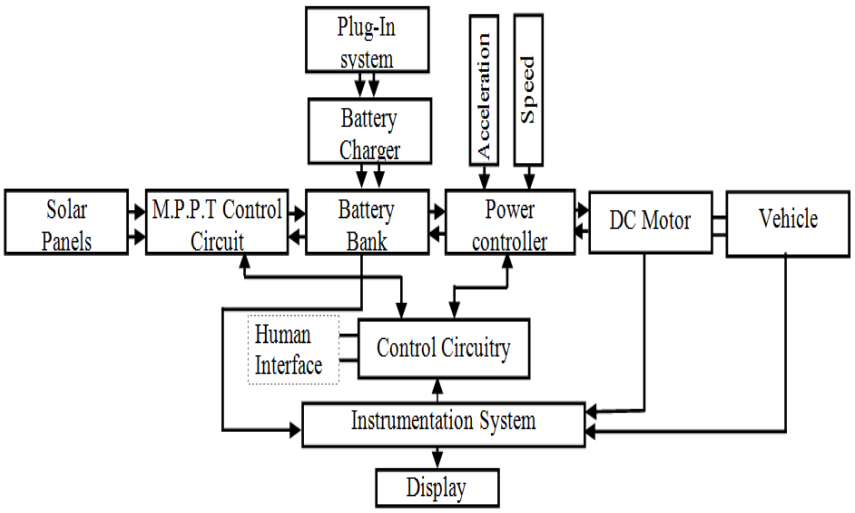


Fig. 2. Hybrid Energy Storage System

4.1 Home Charge

When the auto vehicle is parked at home at night, the vehicle on-broad-charger can be connected to a single phase AC plug for slow night time charging. The battery is recharged at the correct charge rates and the current is automatically switched off when the charge is completed. In Figure 2 shows block diagram of a typical controlled on-board-charger. Depending on the battery capacity and depth of discharge, the charging time takes about 6-8 hrs and charging current is usually limited to 12A to 15A. This on-board-charger should be light & inexpensive. As the electricity demand is relatively low at night, this home charging scheme can facilitate the low level control of power utilization.

4.2 Solar Energy

In order to further enhance the vehicle drive time, batteries can also be charged by the solar panel embedded in the vehicle roof. The rickshaw has about 2.65 m^2 of space available on the roof alone to put solar panels. The output characteristic of PV cells could be expressed by volt-ampere (I-V) characteristic. The I-V characteristic is changed with the solar radiation intensity(S) and temperature (T). MPPT systems can be designed in such a way to achieve great output even under changing atmospheric conditions, shading, or irradiance conditions, such as those that would inevitably occur on the roof of a vehicle and in addition, to prolong the life-span of battery, a three-stage charging method is controlled the battery charge [8, 9]. A fully charged battery needs only trickle charge. The equivalent circuit of a PV cell is shown in Figure 3. [10, 11]

$$I = A_T J_O \{\exp[\frac{q(U - IR_s)}{akT}] - 1\} + \frac{U - IR_s}{R_{sh}} - A_E J_L \quad (1)$$

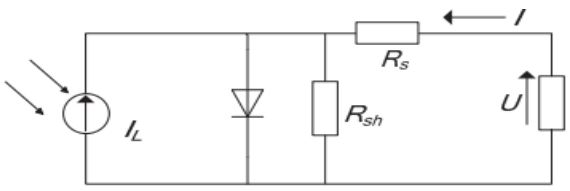
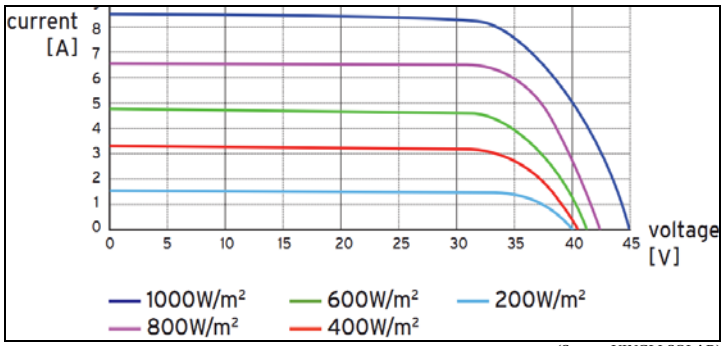


Fig. 3. PV cell model Electrical equations of the model is [12]

Where, A_T= total light area, A_E= effective light area, J_0= saturation current intensity of diode, J_L= light current intensity, q= electronic charge, K= Boltzmann's constant, T= temperature.
The Solar panel used in the proposed system is 260Wp. In Bangladesh, the monthly average solar radiation is around 4.5 to 5 kWh /m^2/day and the MPPT system track the maximum power from the panel. Considering only being able to capture about 5–10% of that energy due to inefficiencies of the panel, converters, dust, shadow and less-than-ideal tracking conditions, the actual energy recoverable per day is more than 1.8–1.9 kWh when using the entire surface. The I-V characteristic of a PV panel was given under factory laboratory conditions, just as shown in figure 4 and panel specification is shown in Table 4.



(Source: YINGLI SOLAR)

Fig. 4. I-V Curves of a Solar Panel

Table 4. 260W Solar Panel Specification

Parameter	Value
Power Output	260W
Module Efficiency	13.3%
Voltage at P_{max},V_{mpp}	35V
Current at P_{max},I_{mpp}	7.43A
Open circuit voltage, V_{oc}	44.6V
Short circuit current, I_{sc}	8.04A

(Source: YINGLI SOLAR)

4.3 Regenerative Charge

For recapturing the wasted energy to the battery pack regenerative braking system is used in driving schedules which involves in the vehicle frequently starts and stops. This method can increase the vehicle driving range by 8-25%. [13], [14]. Energy can be saved about 20% in a low speed urban based schedule with stops at about one km intervals and a cruise speed of 10 m/s and, vehicle range can be expected to increase proportionately [15]. However, high speed suburban cycles with relatively long steady state cruise modes of about 15 km and a cruise speed of 30 m/s save only about 6% energy for a modest extension of range. Fig. 2 shows the regenerative braking system block diagram.

5. Simulation Result and Discussion

The battery module is fully charged by the on-board battery charger and the module capacity is 540Ah. The battery is also charged by the PV panel and increase in power due to MPPT system. Theoretically Max. Energy available from solar panel = 260W*7.55h= 1963Wh and Energy extracted by MPPT system=1805.96Wh. In this system, assume only 2% energy is recaptured by the regenerative braking system and it is approx. 150Wh. The proposed system the vehicle is running more than one and half an hour and it increased the driving range from 35Km to 40Km compare to the existing vehicle. The Solar system also acts as a pulse charging, and it reduces the battery charge-discharge current and prolongs the battery life span [16]. The auto vehicle is designed and

simulated by the ADVISOR software. ADVISOR is written in the MATLAB/Simulink and developed by the National Renewable Energy Laboratory. It is used to analyze performance, fuel economy, and emissions of conventional, electric, hybrid electric, and fuel-cell vehicles [17]. The first two ADVISOR input screens provide the interface to change the vehicle parameters and test the vehicle. By clicking "View Block Diagram," it may look at and change the Simulink blocks of the overall vehicle model. In this way, the solar panel model was chosen by subtracting a constant value from the required power of the power bus and also adding a corresponding weight to the vehicle, which can be done at the first input screen. The constant value is based on research for the power ratings of the feasible panel. This method will not show dynamics but will give the general results for the extended range of the vehicle and the effects on vehicle efficiency. To develop the standard driving cycle, some approaches were considered and some are similar to the Indian urban driving cycle [18]. From the ADVISOR software the vehicle Torque vs. speed curve, driving cycle speed vs. time curve, battery energy discharging efficiency curve is shown in Figure 5, 6 and 7.

Fig. 5. Motor Torque vs. Speed

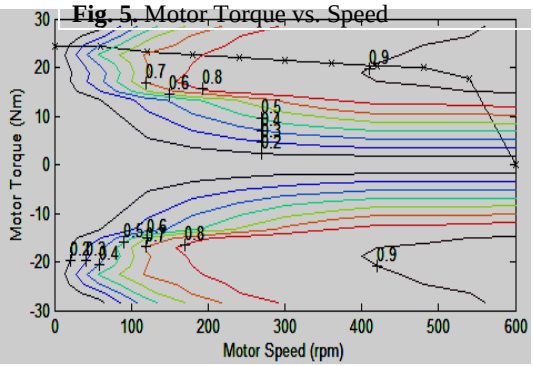
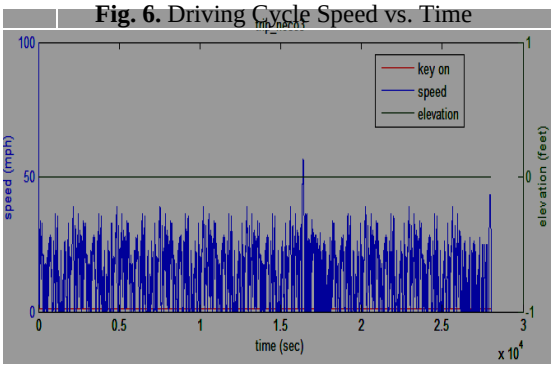


Fig. 6. Driving Cycle Speed vs. Time



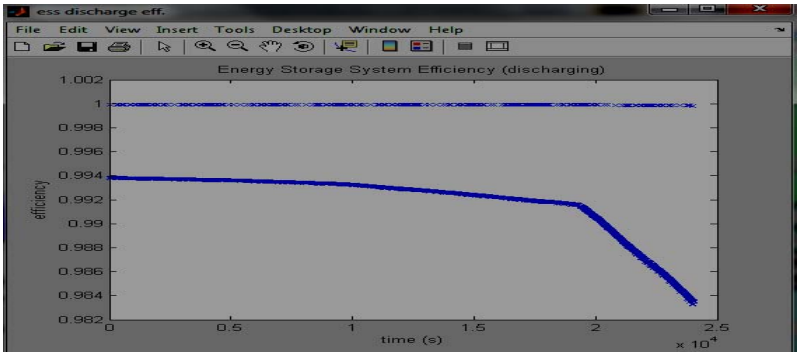


Fig. 7. Battery Energy Storage System Efficiency

The simulator results showed that the vehicle covered 179.26 Km at an average speed 14.3 mph and maximum speed 56.7 mph. The hybrid energy storage system increases the vehicle performance and efficiency. The vehicle does not need to charge at day time and it minimizes the charging cost.

6. Conclusion

The auto vehicles play a fundamental role in the world. Moreover, this vehicle is very popular day by day for the developing country due to the low transportation cost. Research showed that there are adequate renewable energies to support the infrastructure development of the auto vehicle. Thus, simulations have been performed on the electric vehicle supporting infrastructure and built a prototype system. The results showed that the vehicle can be achieved around 179 Km during a single charge with zero environmental pollution. The system facilitate with such feature that reduces the energy dependency, eliminate the additional pressure of the grid in day time, the drivers will not be worried about the battery charge, driving smoothly and avoid the prolong road accident in night. The driving range is increased more than the conventional vehicle. In Future research, the vehicle will be practically developed and analysis the result. To further increase the drive range more efficient motor controller, solar system and mechanical losses will be explored.

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Paper ID: ET-28

Low Voltage Ride Through (LVRT) Capability Improvement of Wind Power Generator by Using STATCOM

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Abstract

Nowadays asynchronous wind turbines are widely used in renewable energy to produce electricity. However, the asynchronous wind turbine which used in home and abroad doesn't have enough LVRT capability. If any faults occur in the wind turbine and voltage fall down, then the induction generator become in unstable position and it requires to be shut down the power system. But a shut sown of large wind farm can have a serious effect on power system operation.
So this paper proposes a method to improve the LVRT capability of fixed speed induction generator (FSIG) based on wind farm using static synchronous compensator (STATCOM). And this paper establishes the simulation model of asynchronous wind generator based wind farm and STATCOM in Matlab/Simulink environment. The research results show that the STATCOM device can improve asynchronous wind farm LVRT capability and keep working and reducing the adverse effects of power grid.

Keywords: LVRT capability improvement, superconducting magnetic energy storage (SMES), voltage source converter (VSC), wind energy conversion systems (WECS), pulse width modulation (PWM).

I. Introduction

Recently, the generation of electricity using wind power has received much interest and considerable attention all over the world. One of the simplest methods of operating a wind generation system is to use an induction generator connected directly to the power grid, because an induction generator is the most cost-effective and robust machine for wind energy conversion. However, fixed speed wind generator system with the induction generator requires reactive power support [1] for voltage regulation and improvement of low voltage ride-through (LVRT) capabilities. As wind speed continuously changes, the voltage at the point of common coupling (PCC) also fluctuates. One of the effective methods to improve this situation is by using STATCOM. There are various type of STATCOM, SMES is one of them. SMES has the ability to provide both active and reactive power simultaneously and quickly.
When a fault occurs, the voltage at the WECS terminal drops. Thus the generated active power falls, while the mechanical power does not change and so the induction generator accelerates. After faults clearance, the reactive power consumption increases resulting in reduced voltages near the generator unit. Thus the induction generator voltage does not recover immediately after the fault. As a consequence, the generator continues to accelerate, resulting in rotor speed instability [2]. Then the WECS requires to be disconnected from the power system. But shutdown of a wind farm during and after a network disturbance is not acceptable and not desirable by transmission system owners (TSO). So, the recent trend is to decrease the shut down operation, because a shut down of large wind farm can have a serious effect on the power system operation. As for example, in Germany the wind generator shut down phenomenon has been reduced by adopting the LVRT requirement from German grid operator named E.ON Netz [3]. But due to the recent increase of large wind farms, in many countries [4] the new grid codes have been developed to ensure secure power system operation. Therefore, it is important to investigate a suitable method to enhance the LVRT capability of fixed speed wind generators.
Many authors have discussed the application of FACTs controllers like SVC to improve the LVRT capability of induction generators. However, these devices cannot provide active power control [5-7]. Also results are not compared with the grid code. Therefore in this study effectiveness of the proposed system have been compared with the grid code.

The SMES is a well-known system [1] where energy is stored within a magnet that is capable of quickly releasing megawatt amounts of power. The ability of injecting/absorbing real or reactive power independently enhances the controllability and provides operation flexibility to a power system. Therefore, the SMES system can augments the transient stability as well as LVRT capability of wind farm. The proposed SMES can provide not only the reactive power support to enhance the LVRT capability and voltage regulation but also active power support to enhance the transient stability of wind farms. Therefore SMES is used in this study.

II.1 Model System for Simulation Analyses [1]

The model system as shown in Fig. 1 has been used for the simulation of wind generator stabilization in this work. The model system consists of one synchronous generator (100 MVA), SG, and one wind turbine generator (50 MVA induction generator, IG), which are delivering power to an infinite bus through a transmission line with two circuits. Though a wind power station is composed of many generators practically, it is considered to be composed of a single generator with the total power capacity in this paper. There is a local transmission line with one circuit between the main transmission line and a transformer at the wind power station. A single squirrel-cage induction machine model, which is represented by a steady state equivalent circuit shown in Fig. 2 where s denotes a rotational slip, is used for the wind generator. To establish the rotating magnetic field of the stator, reactive power is needed to be supplied from the network to the stator winding of the induction generator. So to compensate the reactive power demand at steady state, a capacitor bank is inserted at the terminal of IG [8]. The value of the capacitor C is so chosen that the power factor of the wind power station becomes unity when it is operating in the rated condition (V=1.0, P=0.5)**.** The SMES unit is located at the induction generator terminal bus. Generator parameters are shown in Table I. The system base power is 100 MVA.

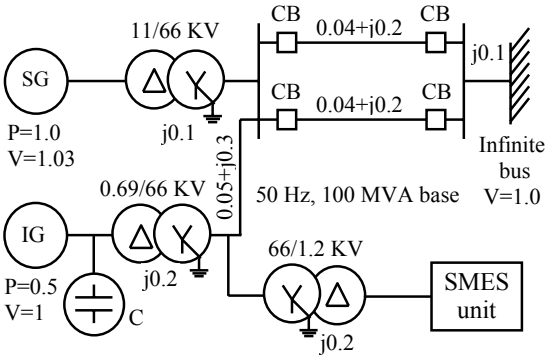

Fig.1. Power system model [1]

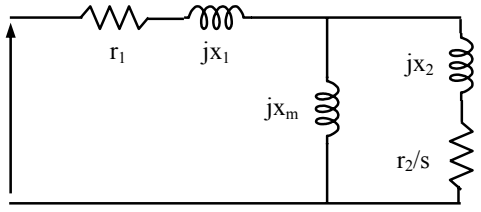

Fig.2 Steady state equivalent circuit of single squirrel-case induction generator [1]

Table I
Generator parameters

SG		IG	
MVA	100	MVA	50
Ra(pu)	0.003	r1(pu)	0.01
Xa(pu)	0.13	x1(pu)	0.18
Xd(pu)	1.2	Xmu(pu)	10
Xq(pu)	0.7	r2 (pu)	0.015
Xd′(pu)	0.3	x2(pu)	0.12
Xq′(pu)	0.22	H(sec)	1.5
Xd″(pu)	0.22		
Xq″(pu)	0.25		
Td0′(sec)	5.0		
Td0″(sec)	0.04		
Tq0″(sec)	0.05		
H(sec)	2.5		

II.2. Two-mass Drive Train Model

In case of conventional WECS model, accurate results are obtained by increasing the number of masses, springs and damper which are used to represent the physical characteristics of the actual system. It has been proved that the two-mass model for WECS representation is fairly accurate [1]. Thus this approach is adopted here and is shown in Fig. 3. As shown in the Fig. 3, the wind turbine and the generator rotor are modeled as two masses and the wind mill shafts as spring element. The dynamic equations of the two-mass representation are given by [1],

$$\frac{d\omega_t}{dt} = \frac{T_t - K_s\delta}{2H_t} \quad (1)$$

$$\frac{d\omega_e}{dt} = \frac{K_s\delta - T_e}{2H_e} \quad (2)$$

$$\frac{d\delta}{dt} = 2\pi f\left(\omega_t - \omega_e\right) \quad (3)$$

where T is the torque, δ is the angular displacement between the two ends of the shaft, ω is the angular speed, H is the inertia constant and K_s is shaft stiffness.
The indexes t and e stand for wind turbine and generator parameters, respectively.

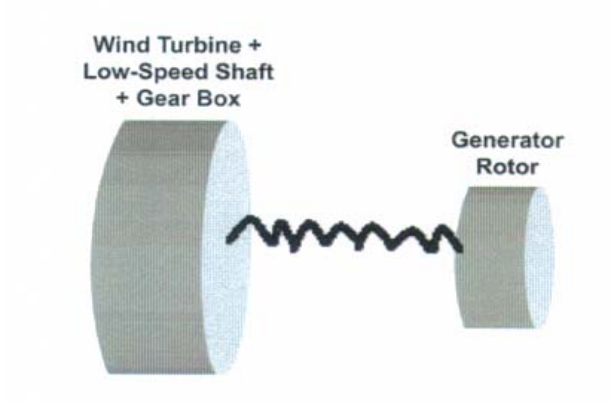

Fig. 3. The simplified two-mass model [1]

III. Modeling of Wind Turbine

The model of wind turbine rotor is complicated. According to the blade element theory [1], modeling of blade and shaft needs complicated and lengthy computations. More over, it also needs detailed and accurate information about rotor geometry. For that reason, considering only the electrical behavior of the system, a simplified method of modeling of the wind turbine blade and shaft is normally used. The mathematical relation for the mechanical power extraction from the wind can be expressed as follows:

$$P_W = 0.5\rho\pi R^2 V_W^3 Cp(\beta,\lambda) \quad (4)$$

Where, P_w, is the extracted power from the wind, ρ is the air density [kg/m^3], R is the blade radius [m] and C_p is the power coefficient which is a function of both tip speed ratio, λ, and blade pitch angle, β[deg]. The C_p equation can be written as:

$$\lambda = \frac{V_W}{\omega_B} \quad (5)$$

$$C_p = \frac{1}{2}\left(\lambda - 0.022\beta^2 - 5.6\right)e^{-0.17\lambda} \quad (6)$$

Where, ω_B is the rotational speed of turbine hub [rad/s]. Here wind speed, V_w, is in mile/hr. The C_p-λ curves are shown in Fig.4 for different values of β.

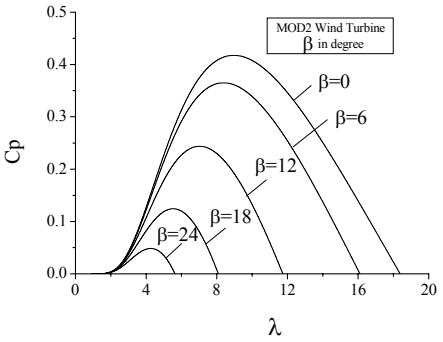

Fig. 4. C_P- λ curves for different pitch angles

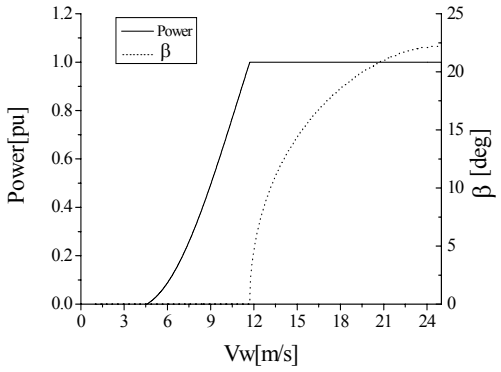

Fig.5 Output power versus wind speed and pitch angle versus wind speed characteristics

Power versus wind speed characteristic is also shown in Fig.5. When the wind velocity exceeds the rated speed, then the pitch angle of the blade needs to be controlled to maintain the output at the rated level. Fig. 5 also shows the control of pitch angle with the variation of wind velocity to control the output power nearly constant at rated capacity. Now the turbine torque, Tw, can be calculated from eq. (4).

$$T_W = 0.5\rho\pi R^2 V_W^2 Cp(\beta,\lambda)/\lambda \qquad (7)$$

IV. Control System of SMES

A. Brief Overview of SMES System

The SMES system used in this paper consists of a Wye-Delta transformer, a 6-pulse PWM voltage source converter using IGBT, a DC link capacitor, a two-quadrant DC-DC chopper using IGBT, and a superconducting coil or inductor of 0.5 H. The VSC and the DC-DC chopper are linked by a DC link capacitor of 50 mF.

B. PWM Voltage Source Converter

The PWM voltage source converter provides a power electronic interface between AC power system and superconducting coil. DC link voltage V_{dc} and grid point voltage V_G are maintained as constant by the VSC. We consider here the simplified VSC single-phase equivalent circuit shown in Fig. 6, where V_{ac} and V_{conv} are the rms values of the ac system line voltage and VSC output ac voltage respectively, and R and X are the converter transformer resistance and leakage reactance respectively. With positive directions specified for real power, P, and reactive power, Q, as well as the current, I, as shown in the figure, we have the following equations, where V_d and V_q indicate real and imaginary components of the VSC output ac voltage respectively, $\bar{I}$ is a phasor of the current flowing from ac system side to the converter side, and I_d and I_q are the real and imaginary components of $\bar{I}$ respectively.

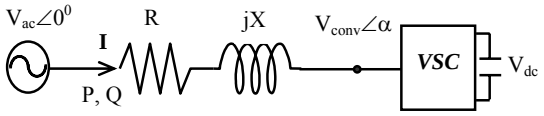

Fig. 6 VSC single phage equivalent circuit

$$\bar{I} = \frac{V_{ac} - (V_d + jV_q)}{R + jX} \qquad (8)$$

$$I_d = \frac{1}{R^2 + X^2}\left[R(V_{ac} - V_d) - XV_q\right] \qquad (9)$$

$$I_q = \frac{-1}{R^2 + X^2}\left[X(V_{ac} - V_d) + RV_q\right] \qquad (10)$$

$$P=\mathrm{Re}\left(V_{ac}\bar{I}^{*}\right)=V_{ac}I_d \qquad (11)$$

$$Q=\mathrm{Im}\left(V_{ac}\bar{I}^{*}\right)=V_{ac}I_q \qquad (12)$$

From eqs. (13) and (14), it can be shown that

$$P\propto I_d \quad \text{and} \quad Q\propto I_q$$

Again, if R is very small, then from eqs. (11) and (12) it can be shown that

$$I_d \propto V_q \quad \text{and} \quad I_q\propto V_d$$

Therefore, it can be said that

$$P \propto V_q \quad \text{and} \quad Q \propto V_d$$

i.e, active and reactive power of SMES are proportional to the d- and q-axis currents and thus also to the q- and d-axis voltages.

Based on this concept, the control system of the VSC is constructed. The control system of the VSC is shown in Fig. 7. The PWM signal is generated for IGBT switching by comparing reference signal, which is converted to 3-phase sinusoidal wave with the triangular carrier signal. The frequency of the triangular carrier signal is chosen 450 Hz. The DC voltage across the capacitor is 2000 Volt, which is kept constant throughout by the 6-pulse PWM converter.

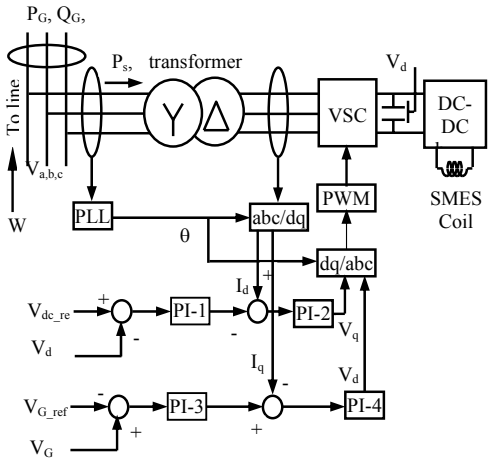

Fig. 7. The control system of the

V. Simulation Results

To verify the effectiveness of the proposed system the wind speed is considered as constant. The wind farm compatible grid code is more or less similar. The wind farm terminal voltage, for example, has to return to 90% of the nominal voltage within 3s after the starting of voltage drop [4]. Shutdown of a wind farm during and after a network disturbance is not acceptable. In order to enhance the LVRT capability, the system with high response speed for both active and reactive power compensation is needed. This paper shows a control methodology to overcome the voltage dip of wind farm during a network disturbance in power system.

The symmetrical 3LG fault in the transmission line connected to SG as shown in Fig.1 is considered as network disturbance. For analyzing the transient stability, it is considered that a 3LG fault occurs at 0.1 s and circuit breakers (CB) on the faulted line are opened at 0.2 s and finally, at 1.0s the CBs are reclosed. The time step and simulation time have been chosen as 0.00001 and 10.0 s, respectively.

Terminal voltage responses of the wind farm for 3LG fault without and with SMES considered are shown in Fig. 8. In the case without SMES, when network disturbance occurs in the system, the wind farm terminal voltage drops quickly but it cannot return back to 90% of the nominal voltage within 3 s after the beginning of the voltage drop. Thus it does not satisfy the grid code shown in fig [10] . But when the proposed SMES is used, since the necessary reactive power is supplied from the SMES properly according to the error signals, the wind farm terminal voltage returns back to its pre-fault value in less than 1 s. IG rotor speed also return back to original value as soon as possible when SMES is used. Shown in Fig: 9.

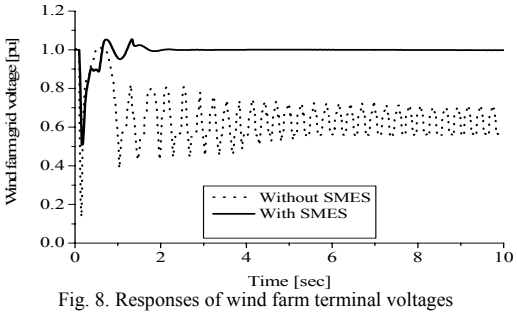

Fig. 8. Responses of wind farm terminal voltages

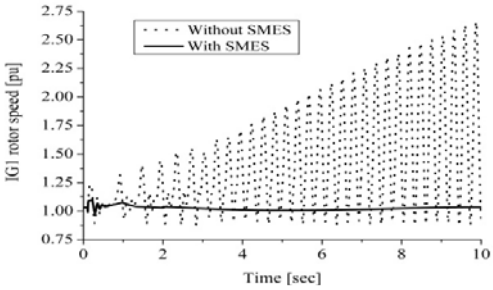

Fig. 9. Responses of IG1 rotor speed

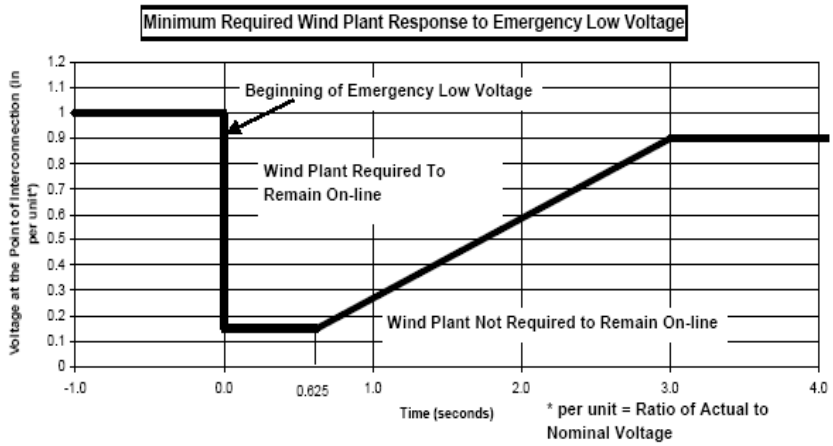

Fig. 10. Low voltage ride through standard set by FERC, U.S. [3]

6. Conclusions

In this paper, STATCOM is proposed to enhance the transient stability of wind farm integrated power system. The proposed STATCOM is able to stabilize the wind farm during a fault in the grid. The STATCOM is very effective to damp out the rotor speed oscillations. Moreover, LVRT capability of the wind farm can be enhanced by using the proposed STATCOM. Therefore, it is concluded that the integration of the proposed STATCOM to wind farm can be an effective means to improve the stability and LVRT capability of the wind farm.

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Design, construction and performance test of a portable solar cooker

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Abstract

This paper presents the thermal performance of a light weight portable solar cooker (PSC) based on a parabolic shaped umbrella with aluminum foil. An umbrella of 125 cm diameter was used as a frame of the portable cooker because it is more convenient to transport and its surface area is almost parabolic. The aluminum foil was attached to the inner side of the umbrella with white glue which acts as reflector plate. The focal length of the parabolic surface was 26.16 cm. The maximum temperature of the experimental water recorded was 97.8˚C at around 1:30PM. The experimental time period was from 10:00 to 14:00 solar time. The energy output of the PSC varied between 33.18 W and 182 W. The energy and exergy efficiencies were in the range 2.088% to 17.48% and 0.023% to 1.80%, respectively.

Keywords: Solar cooker, portable cooker, parachuina collector, aluminum foil

1. Introduction

The increasing population on the earth causes increasing demand of energy. To alleviate part of our energy crisis and environmental degradation, it has become imperative to make use of appropriate technologies for the possible recovery of resources from non-conventional sources, like solar energy technology. It is widely dispersed and could contribute zero net emission to the atmosphere. Cooking with solar energy has long been presented as an attractive solution to the world's problem of decreasing fuel wood sources and other environmental problems. The use of solar cookers results in appreciable fuel and time savings as well as increased energy security for rural households using commercial fuels [1].

Bangladesh is situated between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east which is an ideal location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 kWh per square meter [2]. Maximum amount of radiation is available on the month of March-April and minimum on December-January. So the climate conditions of Bangladesh are favorable for solar energy applications. Solar cooking is a good option for widespread use in Bangladesh.

Al-Soud et al. [3] designed, constructed and tested a portable solar cooker. The test performed for three days from 8:30 h to 16:30 h and showed that the water temperature inside the cooker's tube reached 90˚C in typical summer days, when the maximum registered ambient temperature was 36˚C. Badran et al. [4] designed, built and tested a parabolic portable solar water heater. The authors found that, the device was able to heat 30 kg of water from 20 °C to 50 °C in 2½ h in the collector mode. The highest efficiency obtained for this mode was 77% and the slope of the efficiency curve was 10.63 W/m^2 °C.

Ozturk [5] constructed and designed a low cost PSC and experimentally evaluated its energy and exergy efficiencies. The energy output of the PSC varied between 20.9 and 78.1 W, whereas its exergy output was in the range of 2.9–6.6 W. It was found that the energy and exergy efficiencies of the PSC were in the range of 2.8–15.7 and 0.4–1.25 respectively. Sonune and Philip [6] designed a Fresnel type domestic concentrating cooker, which has an aperture area of 1.5 m^2 and a focal length of 0.75 m and was found to provide an adequate temperature needed for cooking, frying and preparation of chapattis and capable of cooking food for a family of 4–5 persons. Concerning the application, designing, performance testing of PSC, studied has been carried out by many researchers [7-10].

Despite their ability to provide adequate temperatures needed for cooking, frying and preparation of chapattis, all the aforementioned types of concentrating solar cookers suffer due to some drawback. The main drawbacks of these previous works are heavy weight of the cooker, complexity in construction and comparatively high cost.

In this research a light weight umbrella have been used to construct the portable solar cooker. So, the presented work is able to resolve the above mentioned limitations.

2. Methodology

The experiments were carried out locally at Rajshahi, Bangladesh. The latitude and longitude of Rajshahi are 24˚ 22□ 0″ N and 88˚ 36□ 0″, respectively. The experiments were conducted on 2012.

Experimental Section

The photograph of the experimental set-up has been shown in Fig. 1. The main components of the developed PSC were (1) An Umbrella (2) Aluminum foil (reflection index: 85%) (3) Cooking pot and (4) Stand.

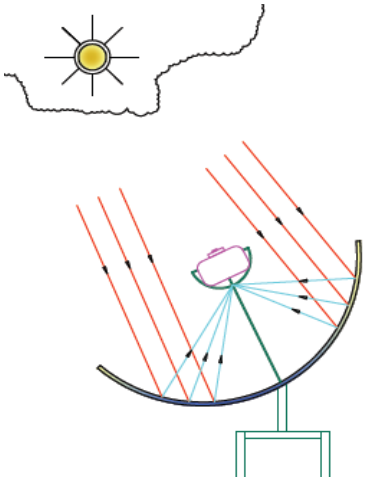

Fig. 1. Schematic of portable solar cooker

The portable solar cooker was designed to be both adjustable and dismountable, with a screen and heat concentrator made from reflective aluminum foil. The solar cooker is divided into two units- the supports and reflector. The support is a stand made of iron (angle bar) and G.I. pipe in which the whole arrangements are mounted by screw mechanism. An umbrella of 125 cm diameter was used as a frame of the presented portable solar cooker because it was more convenient to transport and its surface area is almost parabolic.

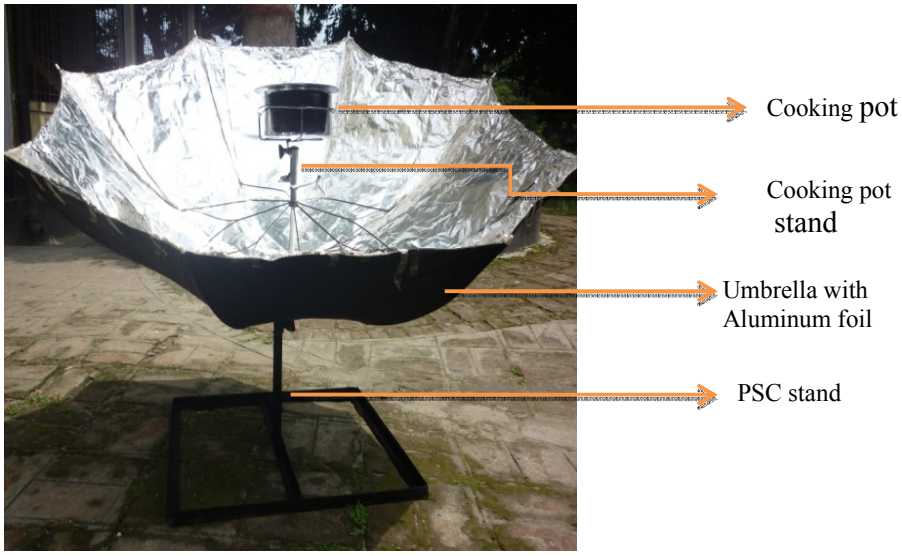

Fig. 2. Photograph of the portable solar cooker.

The aluminum foil was attached to the inner side of the umbrella with white glue which acts as reflector plate.

The reflector surface was faced towards the sun, such that the most shining zone was located on the handle with permanent leveler that was obviously on the focal point of the reflection surface. The focal length of the parabolic surface was 26.16 cm. The umbrella can be tightly attached by the screw to give a stable footing on uneven ground and allowing any necessary inclination for the reflector. The pressure cooker stand can also be inclined to any direction by screw mechanism for keeping it in most shining zone. The sunlight was reflected off of the inner surface of the umbrella and onto the underside of the kettle.

3. Result and discussion

A large of experiments has been carried out on a parabolic concentrator type solar cooker under various operating and climatic conditions. The experimental set up has been established at Rajshahi University of Engineering & Technology, Rajshahi, Bangladesh (latitude=24°24′ N, longitude=88°30′ E). Experiments on the proposed PSC were carried out on May 15, 2012; May 15, 2012; June 12, 2012. The experimental works was fully carried out in the heat engine laboratory at Rajshahi University of Engineering & Technology located in Rajshahi, Bangladesh. Each experiment started from 11.15 h to 13.15h.

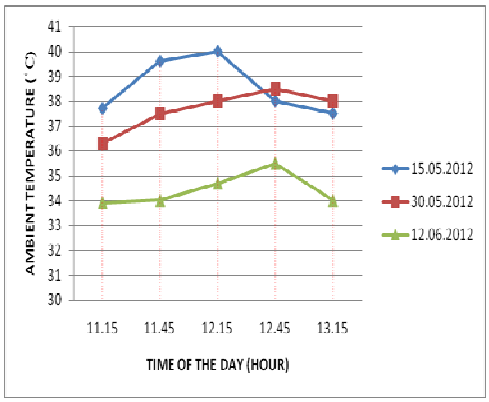

Fig. 3. Hourly variation of the ambient temperature

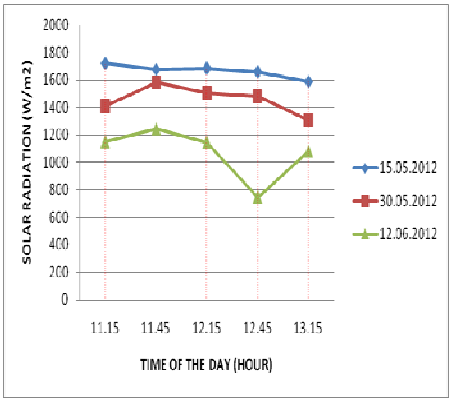

Fig 4. Hourly variation of the solar radiation

The electronic measurement instruments and devices were tested and calibrated before being used. Fig 2. exhibits the proposed parabolic solar cooker. Fig. 3 shows the ambient temperature measured at the site during the test hours for the three days in which the experimental part was conducted. Higher temperatures were observed during daytime with peaks occurring between 12.15 h and 12.45 h. Hourly variation of the solar radiation, during the test period is exhibited in Fig. 4. Higher values of solar radiation were noticed between between 11.15 h and 12.45 with a peak occurring at about 11.15 h. Fig. 5. show the measured values of hourly variation of water temperature inside the pressure cooker. An increase in water's temperature was noticed during early hours of the day until it reaches its maximum values around noon hours when solar radiation values are the highest.

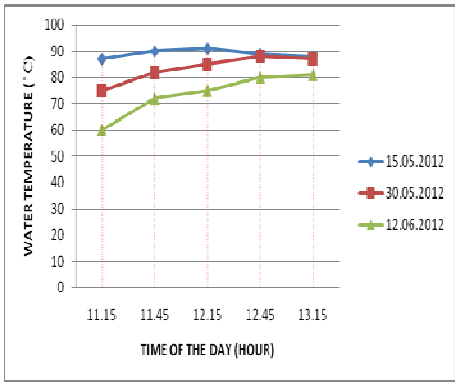

Fig 5. Hourly variation of water temperature

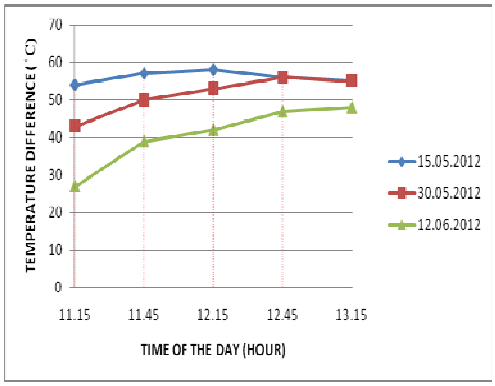

Fig 6. Hourly variation of the temperature difference

The water temperature inside the pressure cooker reached 90 □ C in typical summer days, where the maximum registered ambient temperature was 38 □ C. It was noticed that the water temperature inside the pressure cooker increases when the ambient temperature is higher or when the solar intensity is abundant. Fig. 6 Shows the change of the temperature difference between the water in the pressure cooker and the ambient air over time. The temperature difference was only 42 □ C at 11.15 in the morning and it reached 57 □ C at 12.45 in the noon for a specific day.

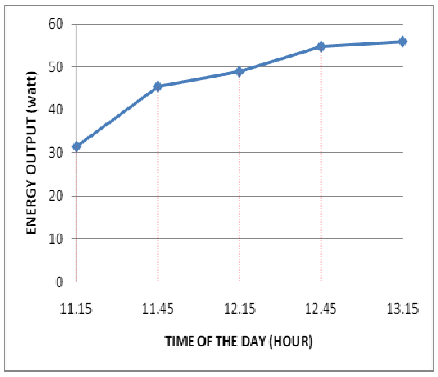

Fig.7. Hourly variation of energy output

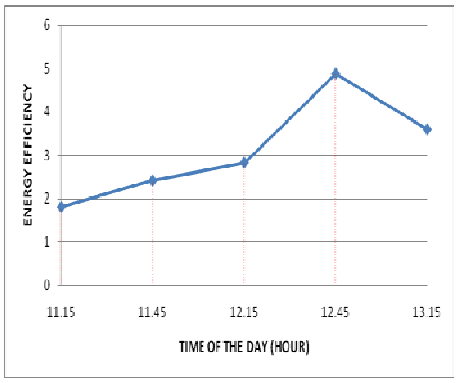

Fig. 8. Hourly variation of energy efficiency

Fig. 7 shows the variation of the energy output as a function of time. The energy outputs were calculated according to the respective numerators of the efficiencies expressions. The energy output varied from 31.5 to 56 W. As indicated in Fig. 7, the energy output increased at a fast rate in the first 1 h, and then at slow rate during 12:15–13:15. During the experimental period the average daily energy output of the SPC was around 47 W. The exergy output was significantly different from its energy output.

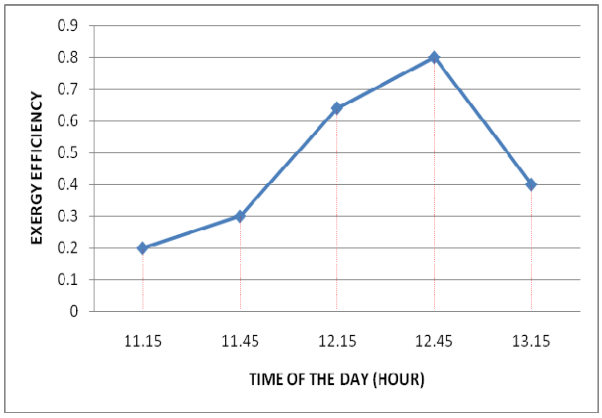

Fig. 9. Hourly variation of exergy output

The exergy output ranged from 2.9 to 4.8 W at the daily average of 3.50 W. The maximum energy output (56W) occurred at 13:15, while the maximum exergy output (4.8 W) occurred at 12:45.The variation of the instantaneous energy and exergy efficiencies as a function of time for the SPC is presented in Fig. 8 and 9 respectively. The energy efficiency of the SPC varied from 1.81% to 4.88%. The daily average energy efficiency of the SPC was 3.10%. The exergy efficiency of the SPC varied from 0.20% to 0.80% and the average daily exergy efficiency was found to be 0.50%. Energy and exergy efficiencies are affected mainly by three factors; the level of water temperature Tw, solar radiation energy I and ambient temperature Ta. The

combination of these three factors generates a characteristic maximum of exergy efficiency, whereas the energy efficiency monotonously diminishes during the measurement time period.

4. Conclusion

The use of readymade umbrella frame have simplified the design of the solar cooker for the user, reducing the assembly (2 min) and disassembly (1 min) times to a minimum. Even with all these improvements, the cooker can be sold at a reasonable price. The low weight (5 kg) and volume (approximately the same as a conventional umbrella when folded) of this solar cooker make it easy to take anywhere using conventional means of transport. Trials carried out with the prototype have determined that the solar cooker reaches an average power of 50 W on a sunny day, assuming that adjustment toward the sun occurs every 20 or 30 min. This supplies sufficient energy to cook a simple meal for two in an average time of 2 h. This parabolic solar cooker therefore provides a portable, inexpensive, and environmentally friendly food heating system, which will contribute to improving the quality of life of needy people in the third world and reduce consumption of conventional energy.

Acknowledgements

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Solar Cooling System: Progress, Prospect and Future Directions

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Abstract

The paper provides a review on the use of solar energy as a renewable energy source. Special attention has been given to the solar cooling methods which are in use at present. The paper discusses the need, existing technologies, studies and a tentative way to improvise the existing cooling methods using solar energy on the basis of researches carried out. While electricity- powered conventional cooling systems are providing us with a better output it is imperative to look for a new, economic and greener way to produce cooling effects since electrical energy is dependent on non-renewable energy sources. Again thermo-electric method of cooling has an adverse effect on climate which can't be ignored. This paper highlights the role of solar energy as an alternative to electrical energy to provide cooling effects with literary explanations and numerical evidences..

Keywords: Solar Energy, Cooling Technology, Liquid Desiccant, Solar cooling performance, Solar cooling.

1. Introduction

Different refrigeration and cooling systems are inseparable parts of our modern life. From preservation of food to scientific researches we use various cooling methods to meet our demand. While refrigeration or air-conditioning is very much available in the industrialized countries, people from all over the world don't have access to these necessities. The reasons behind that are the existing comparatively costly methods of producing cooling effect using electricity and unavailability of a stable alternative energy source. Moreover the production of electricity ultimately depends on the burning of fossil fuels which is detrimental to the environment too. Utilization of solar energy can be a solution to all these problems. There exist different cooling cycles like absorption cooling, adsorption cooling, desiccant cooling etc. At present many researches are being carried out by scientists all over the world in order to find a way to make an efficient and inexpensive solar cooling system. Although the idea of solar cooling may seem a very attractive one its practicality is still in question as it needs costly components for solar energy storing and merging with cooling components. Also the present solar driven cooling systems are not giving enough output to outrun the electrically driven or gas-fired cooling systems. Since the existing cooling cycles are providing very good output completely replacing them with new ones will not be very intelligent way to approach, rather merging the common and more advanced cooling techniques (like desiccant cooling or Metal hydride cooling or ejector driven cooling) with solar energy source is the only way of improving efficiency of cooling methods. Throughout the paper gradually traditional cooling cycles, cooling methods, analysis of existing plants, environmental and economic impact etc. have been discussed to observe the recent trend on solar cooling technology.

2. Cooling systems using solar energy

As the civilization is developing the demand of cooling is also increasing at a proportional rate. A huge amount of electrical energy is used on cooling. This electrical energy in most cases comes from the fossil fuel. But if we can use renewable energy like solar energy as an alternative it will be both cost effective and environmental friendly.

There are different ways of cooling using the solar energy. These are discussed below along with various designs. There are different cycles for cooling using solar energy. The basic ways are shown in the diagram [1] given below.

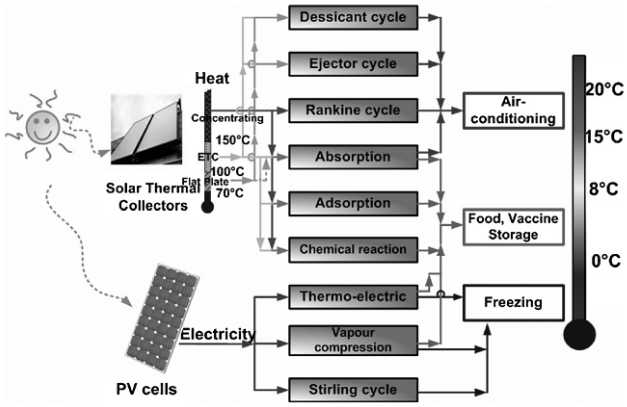

Fig.1. Solar cooling paths

2.1. Adsorption chiller

Adsorption chillers generally use silica gel and water pair as a working fluid. This chiller operates on 60-80 degree Celsius hot water. We have to use two adsorbers, one condenser and one evaporator for the continuous cooling power. By using a mass recovery system and heat recovery system between the two beds the COP can be improved. This is done by introducing vacuum valve. But in the practical system we place our adsorber, condenser and evaporator in a vacuum chamber. As for this system temperature needed is about 60-80 degree Celsius, it is efficient to use flat plate solar collector rather than vacuum tube solar collector. Later in Germany it was further developed [2, 3, 4] and now it is possible to get cooling capacity about 5.5 KW and hot water temperature (18-15 degree Celsius) and chilled water temperature about 67-75 degree Celsius. Saha et al. [5, 6] first developed four bed two stage silica gel water adsorption chiller and at 2006.

2.2. Ammonia –water absorption chiller

This type of chiller is quite popular. Here we use ammonia and water solution as the working fluid where water is the absorber and ammonia is the refrigerant. This chiller consists of generator, condenser, evaporator and absorber. As the solar collector heat the solution (here ammonia is a solute) the concentrated or rich solution becomes weak solution and ammonia becomes vapor. This ammonia vapor is condensed and then goes through the throttle valve and is evaporated in the evaporator creating the cooling effect. There is a GAX (generator-absorber exchanger) which improves the COP of the cycle but for this we need higher temperature [4]. For supplying heat we can use flat plate, evacuated tubes or concentrating collector. This solar collector working temperature is normally 80-120 degree C and COP developed is .3-.7.In Germany 10 KW single effect ammonia –water absorption chiller is developed by the solar next company. In this chiller the driving temperature is about 68-75 degree C and cooling water temperature is about 24-29 degree C and the chilled water temperature is about 16-19 degree C. Robur company in Italy has produced a Cooling capacity of 17 KW.[7] In a research in Austria using a 40 m^2 flat plate collector chilled temperature was 16-19 degree C and it produced a cooling capacity of 9 KW.[8].

2.3. LiBr-water absorption chiller

In this type of chiller weak solution of LiBr-water solution enters the generator. The generator is heated by the solar collector. So after entering into the generator the weak solution becomes concentrated and rich solution. This strong solution returns back to the absorber through an inner heat recovery system. This desorbed water become liquid in the condenser then it passes through an evaporator. By the absorber the strong solution absorbs water vapor continuously and causes evaporation. This evaporation gives the desired cooling effect. This process required higher temperature about 88 degree C. By this system we can now make 100 KW cooling capacity [9] By using double stage hot water temperature can be reduced to 70-75 degree C and a COP of about 0.4 can be developed. In the University of Hong Kong Li and Sumathy developed a system[10] in which a flat plate collector array with a surface area of 38m^2 is used to drive a LiBr–water absorption chiller that gives 4.47 KW cooling capacity and COP .07.

2.4. Solid desiccant cooling system

In this system ambient air flows through the desiccant wheel where the desiccants material consumes the moisture. A heat exchanger is used for the adsorption of heat and for the preheating of the regeneration air. This is a continuous process where the desiccant material is heated one time and cooled again. Nowadays desiccants materials are LiCl, Silica gel, molecular-sieve. Molecular sieve is used since it has a good dehumidification capacity but it requires high temperature. So for using solar energy it is not convenient. Researchers are now focusing on how to lower the regeneration temperature. Vacuum tube collector is proposed for this system as it needs high temperature for the regeneration. The important thing to notice about the solid desiccant cooling is that this is a CFC free system and requires no pump.

2.5. Liquid desiccant cooling system

Liquid desiccant (LiCl) has strong affinity for water. At first air is dehumidified by the desiccant solution. Then the processed air is again cooled by evaporator. There is a regenerator to regenerate the concentration of the liquid desiccant. This regeneration can be done in a very low temperature at 50-80 degree C. As the temperature required is low so we can use flat plate solar collector for this purpose. Jain and Bansal [11] showed that this system can work on 40 degree C temperature. Mei and die [12] describe about three kinds of regenerators powered by solar energy exist, i.e. open regenerator/collector, closed regenerator/collector, and regenerator plus collector. Gommed and Grossman [13] settled a system whose average dehumidification capacity reaches 16 kW powered by 20m^2 solar collector areas.

2.7. Ejector based cooling system

Ejector based cooling system is basically the jet refrigeration. We can reduce throttle loss by using an ejector. The ejector is introduced in order to utilize energy from the high-pressure side of the weak solution in the generator. The high-pressure weak solution in the generator expands through the nozzle in the ejector and creates a vacuum at the other end of the ejector. As a vacuum occurs, the vapour from the evaporator is drawn into the ejector. So Zen and O zalp [14] proposed a solar-driven ejector-absorption system operated with aqua-ammonia.

3. Data and analysis

The different system gives different ranges of temperature, COP cooling capacity. In this section we compare between different systems of cooling. Quality of cooling systems depends on the following facts:

- Temperature range that can be attained by solar collector.
- Desired cooling capacity
- Expected temperature.

Some graphs are plotted on monthly average COP and solar thermal gain to compare between the methods in figure 2. [15]This analysis shows us the year around performance of different solar systems along with COP and solar thermal gain for different type of cooling system and collector type.

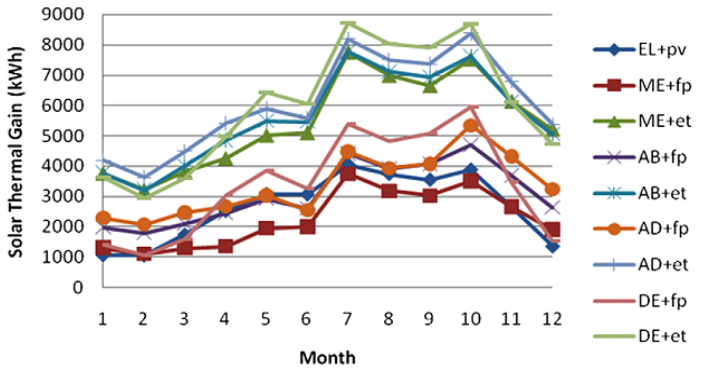

Fig.2. Annual profiles of solar thermal gain of different solar cooling systems. (Abbreviations: AB: absorption refrigeration; AD: adsorption refrigeration; DE: desiccant cooling; EL: electric compression refrigeration; ME: mechanical compression refrigeration; et: evacuated tubes; fp: flat plate collectors; pv: photovoltaic panels)[15]

From this analysis it is clear that the solar thermal gain is very high in the desiccant cooling system and low in the vapor compression cycle. From the analysis of the figure 3 it can be concluded that desiccant cooling gives higher COP, but the COP is varying with time where adsorption cooling gives a constant COP around the year.

It can be said that every system has some advantages and some disadvantages. So it is wise to use different system on the basis of condition available. However vapor compression cooling gives very low output where others give better output.

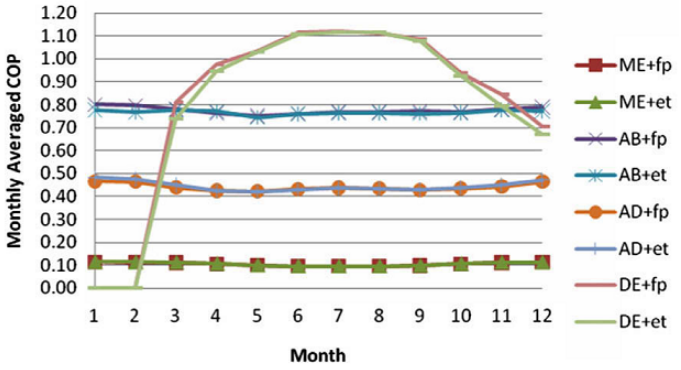

Fig.3. Annual profiles of co-efficient of performance of different solar cooling systems. (Abbreviations: AB: absorption refrigeration; AD: adsorption refrigeration; DE: desiccant cooling; ME, mechanical compression refrigeration; et, evacuated tubes; fp: flat plate collectors; pv: photovoltaic panels)[15].

Table 1. Comparison and main feature of different available cooling technology

Sorption Refrigeration technologies		**Refrigeration output**	**Capacity range**	**Cooling method**	**COP**	**Suitable application**
LiBr-H_2O Absorption	Single effect	5-10 degree C chilled water	5-7000kw	Cooling water	0.5-0.7	Industry, commercial and institutional building
	Double effect	5-10 degree C chilled water	20-11630kw	Cooling water	1.0-1.2	Industry, commercial and institutional building
	Triple effect	5-10 degree C chilled water	530-1400kw	Cooling water	1.4-1.7	Industry, commercial and institutional building
Water-ammonia absorption	single effect	5-10 degree c chilled water	10-90kw	Cooling water or air cooled	0.5-0.6	Large capacity industrial use and residential use, building cooling
	Double effect	5-10 degree c chilled water	<110kw	Cooling water or air cooled	0.8-1.2	Large capacity industrial use and residential use, building cooling
Adsorption	Silica gel-water	7-15 degree c chilled water	5-1000kw	Cooling water	0.3-0.7	Experimental and ice making
	Activated carbon	Ice or -10to-15 degree c glycol water	<12kw	Cooling water	0.1-0.4	Experimental and ice making
Solid desiccant cooling	-	18-26 degree c dehumidified cold air	5-50kw 500-50000 m^3h^{-1}	Cooling water	0.3-1.0+	Industrial process and storage.
Liquid desiccant cooling	-	18-26 degree c dehumidified cold air	50-500kw 3000-140000 m^3h^{-1}	Cooling water or air cooled	0.5-1.2	Large capacity industrial deep drying building comfort and indoor air quality control ,removing airborne particles

Comparisons on different solar cooling technology along with their application field are presented in the table 1. From the comparison it is clear that though absorption cooling has higher value of COP still dessicant cooling show good results also. And for some perspective dessicant cooling show excellent result such as for liquid dessicant cooling it can also work for a few hour in night hour

4. Economic feasibility

Economic feasibility is the major issue for any kind of engineering system design. At present days the absorption system is mostly used, but it is not economically feasible always. For the adsorption chiller large solar collector area is required. As a result the COP of the cycle decreases. So the researchers are trying to improve the silica gel water adsorption chiller and their control system to make them more profitable.

The desiccant cooling system is very much cost effective. It is better than any other sorption system on the point of economic feasibility. Its installation cost and maintenance cost both are significantly less than other systems. A 5 KW solar system is capable of heating, cooling and providing hot water supply could be with a cost of 5 K£ , which means the rated kW cooling cost is 1 K£/ kW.[16]A typical installation of dessicant cooling plant in Althengstett of Germany is shown in the figure 4.From which the distribution of installation cost can be found.

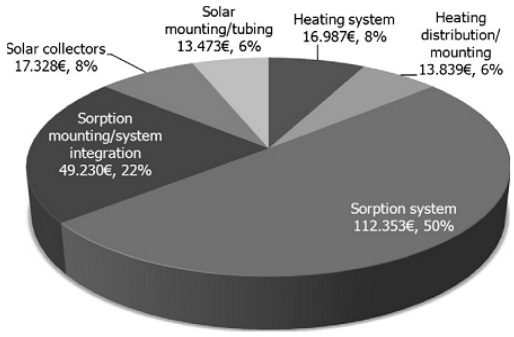

Fig .4. Distribution of investment costs for the German desiccant cooling plant in Althengstett

5. Environmental issue

Refrigerants are the major element in a cooling system. Some refrigerants yielding high performance are not environment-friendly. Some have a high ODP (an impact on the stratospheric ozone layer compared to R11) or a high GWP (a factor indicating the relative effect on global warming compared to CO_2). Many working fluids such as R11, R113, or R114 are nowadays forbidden. New refrigerants are now developed and under study, for example, R123, R134a, R152a and ammonia. Using the solar energy we are able to reduce the use of electrical energy. As most of the electrical energy come from burning the fossil fuel by using solar technology we can reduce the carbon emission. This can make a little contribution to the improvement of the world temperature-rise crisis as well as greenhouse effect.

6. Results and Discussion

Every engineering system has its pros and cons. To discuss on solar energy aided cooling systems we can mention the following key points on the viability issue:

- This technology completely relies on the solar power and hence can't be used at nights unless there is a backup power system. But backup power system means unwanted cost. However a recent liquid desiccant technology can store thermal energy which can give 4 hours of backup.

- In absorption and adsorption system we need pump which is a rotating machine. If any how it stops working it will disturb the whole process. For this we can pay attention to the ejector based cooling system.

- For using the liquid desiccant cooling system we need the regenerator temperature of only 40-50 degree C. But it is not achievable as it has corrosive effect. So we need to develop some kind of desiccant by which we can create cooling effect using very low energy

- If there is any kind of bad weather, it is not possible to operate the cooling system from poor solar radiation. So we should always be careful about the backup system. It can be either electrical heating or gas heating.

- The cooling capacity largely depends on the solar collector. As the collector is not yet that improved so we can't convert the maximum solar energy into heat energy. So a careful attention should be given on improving the solar collector and the thermal storage system.

7. Conclusion

The paper gives a general overview of the modern cooling systems and most recent developments on the field of cooling. From discussion it can be seen that many of the technologies which are used nowadays have a great potential for improvement and some have practical shortcomings. In an era when severe energy crisis is sauntering towards the modern civilization it is impossible to be completely oblivious to the new prospects in alternative energy source. Proper attention and extensive research can make solar cooling technology an attractive option for us.

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Characterization and Improvement of Char Product Obtained from Pyrolysis Conversion of Solid Tire Wastes into Liquid Fuels

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Abstract

Characterization and improvement of by-product char obtained from tire waste pyrolysis plants have been taken into consideration in this study. The char samples were collected from a commercial plant and also from a pilot plant. The samples were characterized through sieving , proximate and ultimate analysis, calorific values and TG/DTG analysis to investigate their suitability for upgrading / improved utilization. Upgrading experiments on char samples have been conducted by using briquetting technology. Tire char were mixed with rice husk at 25wt%, 35wt%, and 45wt% of total mixture and briquettes were produced by using screw press high compaction technique. The briquettes produced using 25wt% of tire char showed good compaction quality with substantial increase in heat value and bulk density. Char plate were also produced from tire derived char powder by low compaction technology using sugarcane molasses, cow dung and boiled rice water as binding materials. Boiled rice water creates very good bonding of the char powders among three types of binding materials. Thus, the tire derived pyrolytic char have good potential to be used as fuel.

***Keywords**:* Solid tire wastes, Pyrolysis, Char product, Characterization, Improvement

1. Introduction

It is estimated that about 90,000 metric tons tires become scrap and are disposed of every year in Bangladesh [1]. The disposal of non-biodegradable solid tire wastes from human activity is a growing environmental problem for the modern society, especially in developing countries. Unfortunately, most of these scrap tires are simply dumped under open sky and in landfills in developing countries. Open dumping may result in accidental fires with highly toxic emissions or may act as ideal breeding grounds for disease carrying mosquitoes and other vermin with the aid of rain water. Landfills full of tires are not acceptable to the environment because tires do not easily degrade naturally. In recent years, many attempts have been made to find new ways to recycle tires: reconstruction of waste tires, shredding or grinding and crumbling to recycle rubber powders, incineration to supply thermal energy in utility boilers to produce electricity, in cement kilns and brick fields.

However, grinding is quite expensive because it is performed at cryogenic temperatures and requires energy-intensive mechanical equipment, while incineration may produce hazardous polycyclic aromatic hydrocarbons (PAHs) and soot during the combustion process.

Pyrolysis as an attractive method to recycle scrap tires has recently been the subject of renewed interest. Pyrolysis of tires can produce oils, chars, and gases, in addition to the steel cords, all of which have the potential to be recycled. Tire pyrolysis liquids (a mixture of paraffin's, olefins and aromatic compounds) have been found to have a high gross calorific value (GCV) of around 41-44 MJ/kg, which would encourage their use as replacements for conventional liquid fuels [2-10]. In addition to their use as fuels, the liquids have been shown to be a potential source of light aromatics such as benzene, toluene and xylene (BTX), which command a higher market value than the raw oils [2-4, 8, 11-13]. Similarly, the liquids have been shown to contain monoterpenes such as limonene [1-methyl-4-(1-methylethenyl)-cyclohexene], a high value light hydrocarbon. Pyrolytic char may be used as a solid fuel or as a precursor for the manufacture of activated carbon [2, 8, 10, 14]. Roy et al. [9] found that another potentially important end-use of the pyrolytic carbon black (CBp) may be as an additive for road bitumen. Furthermore, active carbons were prepared from used tires and their characteristics were investigated by Roy et al. [9], Zabaniotou and Stavropoulos [15], and Zabaniotou et al. [16]. Some of the previous research groups [2, 4, 8, 11, 17] studied the composition of evolved pyrolysis gas fraction and reported

that it contains high concentrations of methane, ethane, butadiene and other hydrocarbon gases with a GCV of approximately 37 MJ/m^3, a value sufficient to provide the energy required by the pyrolysis process.
Very different experimental procedures have been using to obtain liquid products from tire wastes by pyrolysis technology including [18-22]. all over the world for the last two decades. Within the past ten years, research and development works have also been carried out for the fixed-bed fire-tube heating pyrolysis reactor system at Rajshahi University of Engineering & Technology (RUET). Pyrolysis of various organic solid wastes in the fixed-bed fire-tube heating pyrolysis reactor including pilot plant have been successfully completed and the results are published elsewhere[18-23].
The products yield distributions in the RRE Ltd. tyre wastes pyrolysis plant were found oil: 45 wt%, char: 35 wt%, and gases: 10 wt%, in addition to the steel cords: 10 wt% of solid tire waste. Among the four products oil and gases are using as fuels while steel cords can be recycled in steel industries. A large amount of carbon black is producing in each run of tire waste pyrolysis and there is no economic and sustainable use of this by-product. The pyrolysis plant at RRE Ltd. is dumping the by-product char in the plant site and facing a serious problem for its management. However, it is a crucial issue to find out a sustainable use of this char product. Thus, in this study several attempts have been taken into consideration for the development of new techniques of using the char product.

2. Charaterization of Char Sample

2.1. Bulk density

Bulk density of the char product greatly depends on the particle size. The collected char samples were screened and classified according to sieve mesh sizes of BS 410-86 specification. When the particle size range increases then the bulk density decreases for both commercial and pilot plant pyrolysis char are presented graphically in Fig 1.

2.2. Weight percentage

It is one way of expressing the composition of a mixture in a dimensionless size (mole fraction is another). Weight/mass fraction can refer to the fraction of the weight/mass of one size range to the total mass of a mixture. The weight percentage distribution for the collected char samples are presented in Fig. 2. The results show that the highest weight percentages of char particle sizes were 300-600 µm (47.30wt%) and 2.36 mm < (70.60wt%) for commercial and pilot plant, respectively.

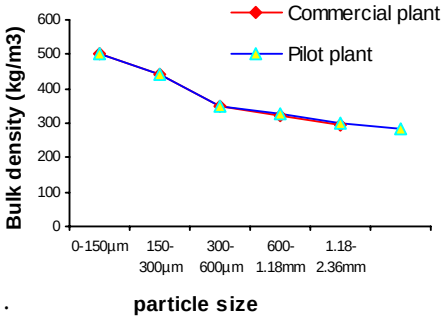

Fig. 1: Bulk density distribution of char product from commercial and pilot plant for different size range

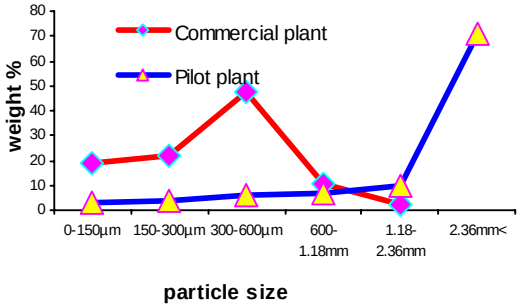

Fig. 2 : Weight percentage distribution of char product from commercial and pilot plant for different size range

2.3. Proximate, ultimate analysis and gross calorific value

Proximate, ultimate analysis and gross calorific value of the char samples compared to solid tire and coal are shown in Table 1,2,3 respectively. The table shows that volatile content of char products is very low compared to solid tire and coal while the fixed carbon content is high. Ash present in pyrolytic char is higher than that of solid tire and it is lower than that of coal. Elemental composition by ultimate analysis, in terms of carbon, hydrogen, nitrogen, oxygen and sulfer (CHNOS) content of the selected pyrolytic tire char is essential for their

uses as fuel or any other feedstock. The GCV of the pyrolytic char fraction is 28 MJ/kg, which is comparable with that of the good quality coal.

Table 1. Proximate analysis of solid tire, pyrolytic tire char compared to coal

Sl. No.	Component (wt.%)	Solid tire	Pilot plant char	Commercial plant char	Bangladeshi coal (Barapukuria)
1.	Moisture	0.64	0.60	0.5~1	10.00
2.	Volatile matter	64.46	5.60	7.4	29. 20
3.	Fixed carbon	30.02	84.29	86.00	48.40
4.	Ash	4.88	9.51	6~6.5	12.40

Table 2. Elemental analysis of char compared to coal

Sl. No.	Sample (wt.%)	Solid tire	Pilot plant char	Commercial plant char	Bangladeshi coal (Barapukuria)
1.	C	85.37	81.23	77.30~83.34	64.41
2.	H	7.65	0.92	0.70~1.10	3.96
3.	N	0.47	0.35	0.25~0.40	1.32
4.	S	1.6	2.54	2.35~3.35	0.52
5.	O+Ash	4.91	14.96	11.81~19.40	29.79

Table 3. Gross calorific value of char samples

Test	Solid tire	Pilot plant char	Commercial plant char	Bangladeshi coal (Barapukuria)
GCVs (MJ/kg)	28-40	28.00	28.2	25.68

2.4. TGA and DTG analysis of char sample:

Thermo gravimetric analysis (TGA) and differential thermal gravimetric analysis of char samples are shown in Fig. 3. TG curve indicate the fractional weight loss of volatile in the char sample with temperature and time. DTG indicate the rate of weight loss for the samples.

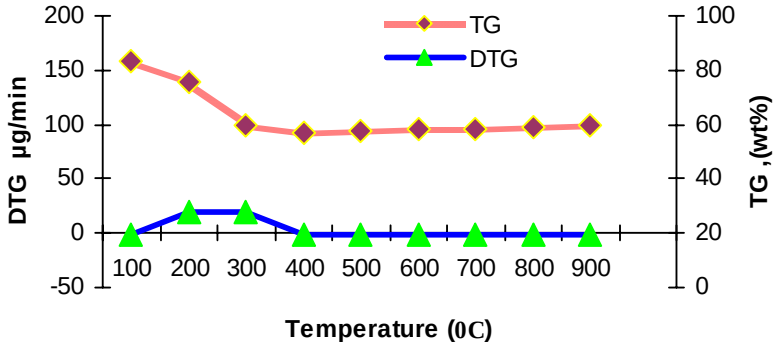

Figure 3 TG and DTG plots for tire char at heating rate of 60^0C/min

3. Improvement of Tire Char Powder

The improvement of tire-derived pyrolytic char have been conducted by using biomass briquetting technology.

Densification / briquetting technology

Usually briquetting technology is used for biomass fuel. Biomass briquetting is the densification of loose biomass material to produce compact solid composites of different sizes with the application of pressure. Briquetting of residues take place with the application of pressure, heat and binding agent on the loose materials to produce the briquettes. The densification techniques provides the following benefit :

- This is one of the alternative methods to save the consumption and dependency on fuel wood.
- Densities fuels are easy to handle, transport and store.
- They are uniform in size and quality.
- The process helps to solve the residual disposal problem.
- The process assists the reduction of fuel wood and deforestation.
- Indoor air pollution is minimized.

Briquetting technology

There are two types of briquetting technologies

- High compaction technology
- Low compaction technology

High compaction technologies

High compaction technology or binder less technology consists of the piston press and the screw press. If fine materials which deform under high pressure, are pressed, no binders are required. The strength of such compacts is caused by vender Wales' forces, valence forces, or interlocking. Natural components of the material may be activated by the prevailing high pressure forces to become binders.

Screw press technology

In the screw press technology, the biomass is extruded continuously by a screw through a taper die which is heated externally to reduce the friction. The screw press technology uses a screw to force the feedstock under high pressure into a heated die thereby forming large cylinders 25 to 100mm in diameter. Normally the die temperature is maintained between 250^0C to 300^0C depending on the raw materials. The raw materials get heated up to 220^0C in this process. The concept is to heat the biomass at a temperature which is sufficient enough to soften the lignin, which is one of the major component of all types of vegetation, as well as pushing through the die to get it compacted. In this process lignin itself works as the binding material so that there is no need to add any additional binding material. This technology is currently operating in Bangladesh and gained much popularity. The merits and demerits of this technology are:

- The output is continuous and the briquette is uniform in size.
- The outer surface of the briquette is partially carbonized facilitating easy ignition and combustion. This also protects the briquettes from ambient moisture.
- A concentric hole in the briquette helps in combustion because of sufficient circulation of air.
- The machine runs very smoothly without any shock load.
- The machine is light compared to the piston press because of the absence of reciprocating parts and flywheel.
- The machine parts and the oil used in the machine are free from dust or raw material contamination.
- The power requirement of the machine is high compared to that of piston press.
- Briquette quality and production procedure of screw press is definitely superior to the piston press technology.

3.1. Production of tire char-rice husk mixed briquette

Literature studies [24] shows that good compaction in biomass briquetting is obtained from a mixing of feed size 6-8 mm with 10-20% powdery component (< 4 mesh). Higher compaction is also obtained with moisture content of the feed materials less than 10% [25]. Besides, in order to upgrade heat value and combustibility of the biomass briquette, charcoal or coal in fine form can be added up to 20% [23]. Characterization study shows that more than 95% of commercial plant char is within sizes < 4 mesh. Moisture content of tire char is also less than 10% with a heat value of 28 MJ/kg, sufficiently higher than that of coal (25 MJ/kg). Thus, we have a better option for utilization of tire char as a suitable additives in biomass briquetting. Collected tire char samples were mixed manually with rice-husk at three different proportions.

The mixed dry feed materials were taken into the feeding hopper for briquette production. Then the furnace was started to heat the die. The screw was rotated inside the die by an electric motor. The briquetting machine uses a large screw to grind, compress and extrude the biomass into briquettes. The natural lignin content in the husk is liberated under high pressure and temperature. When temperature of die raised up to 300^0 C, the material can feed continuously into briquetting machine. In the briquetting process lignin serves as the binder and bonded the particles of char-rice husk together. Finally the briquettes were collected into collector. The whole operational procedure for the complete briquettes production is presented by a flow chart in. The diameter of the briquettes is closely related to the output port of the machine. In this process pallets of briquette produce around 1 to 4 cm diameter and length 70 to 100 cm.

The physical properties of tire char mixed have been studied for the investigation of their improvement. The tire char were mixed with rice husk at 25wt%, 35wt% and 45wt% of total mixture. The mixture with lowest weight percentage of tire char showed better compaction behavior with good machine performance. briquettes were became brittle with the increase amount of tire char in the mixture. Besides, power consumption by the motor also increased with the increase of char in the mixture. Tire char-rice husk mixed briquettes production results are summarized in Table 4.

Table 4. Briquettes production results

Sl. No.	Mixed wt% of tire char	Compaction quality	Power consumption
1.	25%	Good (Not brittle)	Low
2.	35%	Poor (brittle)	Medium
3.	45%	Very poor (Almost does not form briquettes)	high

Physical properties of 25wt% tire char mixed briquettes are presented in Table 5. The Table shows that heat value of the char mixed briquettes is higher than that of rice husk briquettes. The presence of char in the briquettes reduces its compressive load bearing capacity. This is due to the poor binding ability of char particle. Table 7 also shows that volume of the tire char increased about four times after making briquettes.

Table 5. Physical property of tire char mixed briquettes

Sl. No.	Property	Rice husk briquettes	Mixed briquettes (25wt% char - 75wt% rice husk)	Commercial plant char	Pilot plant char
1.	Heat value (MJ/kg)	19.36	20.38	28.20	28.00
2.	Compressive stress (N/m^2)	5040000	4420000	-	-
3.	Density (kg/m^3)	1145	1227	360	350

3.2. Production of Char Plate

Char plate were produced by using low compaction technology. A manually operated piston cylinder arrangement have been developed for production of char plate using cow-dung, boiled rice water or sugarcane molasses as binding material. Sufficient amount of cow dung or sugarcane molasses was mixed with tire char and spreaded over the floor. A 60mm x 60mm square shaped piston-cylinder arrangement was placed continuously on the spreaded char. The piston was pressed manually, char compacted and char plate were obtained with sufficient amount of strength. The char plate were sun dried and prepared for their characterization to be used as solid fuel. Boiled rice water produce very good compaction among the three types of binding materials. Sugarcane molasses increases the heat value of the tire char plate. The characteristics of char plate of different binding material are shown in Table 6.

Table 6. Characteristics of tire char plates

Sl. No.	Tire of binder materials	Mixing ratio(wt%)	Compaction quality	Heat value(MJ/kg)
1	Sugarcane molasses	10	Good	27.17
2	Cow dung	10	Good	26.18
3	Boiled rice water	10	Very good	25.38

Very good = higher strength than rice-husk briquettes; good = almost equal strength of rice-husk briquettes

4. Conclusions

In the presented study on the tire derived char the follow conclusions may be drawn:

- The highest weight percentages of char particle sizes were 300-600µm (47.30wt%) and 2.36mm < (70.60wt%) for commercial and pilot plant, respectively.
- Volatile content of char products is very low compared to solid tire and coal while the fixed carbon content is high. Ash present in pyrolytic char is higher than that of solid tire and it is lower than that of coal.
- Elemental analysis of the pyrolytic char showed the results (by weight): C = 77.30-83.34%; H = 0.70-1.10%; N = 0.25-0.40%; S = 2.35-3.35% and O + ash = 13.36-18.15%
- Thermal decomposition behavior shows that <10wt% moisture and volatile are present in the char samples.
- Heating value of the char mixed briquettes is higher than that of rice husk briquettes. The presence of char in the briquettes reduces its compressive load bearing capacity. Volume of the tire char decreased about four times after making briquettes.

- Boiled rice water produce very good compaction among the three types of binding materials to produce char plate. Sugarcane molasses increase the heat value of the tire char plate.

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Study on Energy Situation in Bangladesh.

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Abstract

The present energy situation of Bangladesh about the reserves of the energy resources, present consumption trends and what to do from now onward for the future has been studied here. Available energy resources under classification and their possibilities have been studied with most updated data to understand the present energy situation of the country. Their contribution into the national power and energy grid has been stated with recent data and thus their demands have been understood. An important thing associated with energy and fuel consumption is the impact on the environment which is very important for Bangladesh. That's why, alternative energy resources have been studied extensively to find out and their feasibility has been also checked.

Keywords: Energy resources, Conventional energy resources, Non-conventional energy resources.

1. Introduction

As a promising and developing country, Bangladesh needs to use its resources and wealth's in a proper manner. For industrial and technological development and to elevate the overall living standard of the general mass of people, proper utilization of energy is necessary. For this reason, Bangladesh needs to account its energy resources.

2. Sources of Energy

The Energy prospect is generally assessed on the basis of available commercial resources of energy i.e., fossil fuel like gas, coal, oil etc. Natural Gas and Biomasses is significantly used as the main energy resources in Bangladesh.

3. Conventional Energy Resources

Conventional energy resources in Bangladesh are given below:

3.1 Bio mass

Biomass is biological material derived from living, or recently living organisms. Materials derived from plant and animal waste are especially prepared to convert into fuel which gives more heat with a small amount in comparison with typical fuels like wood or coal. There are five basic categories of material:

- Virgin wood, from forestry, arboricultural activities or from wood processing
- Energy crops, high yield crops grown specifically for energy applications
- Agricultural residues: residues from agriculture harvesting or processing.
- Food waste, from food and drink manufacture, preparation and processing, and post-consumer waste
- Industrial waste and co-products from manufacturing and industrial processes.

3.2 Natural Gas

Petro bangla, and more recently international oil and gas companies (IOCs) have established the existence of a significant energy source. In Bangladesh, natural gas is most important indigenous source of energy that accounts for 75% of the commercial energy of the country. So far in Bangladesh 23 gas fields have been discovered with the rate of success ratio is 3.1:1 of which two of the gas fields are located in offshore area. Gas is produced from 17 gas fields (79 gas wells).Oil was tested in two of the gas fields (Sylhet and Kailashtila). To reduce the dependency on natural gas, alternative energy resource must be explored.

3.3 Coal

Coal has a very small contribution to the power grid of Bangladesh. Its major fields of usage are electricity where it contributes negligible with respect to gas. Otherwise it's used as running the industrial furnaces and brick fields.

1. There is a thick layer (100m–200m) of soft, waterlogged sand lying over the coal reserves in Bangladesh.

2. The region is densely populated, as is Bangladesh in general.8 Coal exploitation would result in the need to evacuate, resettle and rehabilitate large numbers of people.
3. The soil over the coal-reserve areas in Bangladesh is extremely fertile, usually sustaining two or three crops a year.
4. The coal reserves in Bangladesh are situated in ultra-thick seams. This makes underground mining rather difficult. [1]

3.4 Crude Oil

A mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. Bangladesh has remarkable crude oil reserve in Syhlet zone. Depending upon the characteristics of the crude stream, it may also include 1. Small amounts of hydrocarbons that exist in gaseous phase in natural underground reservoirs but are liquid at Atmospheric pressure after being recovered from oil well (casing head) gas in lease separators and are subsequently comingled with the crude stream without being separately measured. Lease condensate recovered as a liquid from natural gas wells in lease or field separation facilities and later mixed into the crude stream is also included; 2. Small amounts of non-hydrocarbons produced with the oil, such as sulfur and various metals; 3. Drip gases, and liquid hydrocarbons produced from tar sands, oil sands, Gilsonite, and oil shale. Liquids produced at natural gas processing plants are excluded.

3.5 Peat

Peat an unconsolidated deposit of semi-carbonized plant remains in a water saturated environment, such as a bog or fen and of persistently high moisture content. It is an early stage or rank in the development of coal; carbon content is about 60% and oxygen content is about 30%. Structures of the vegetal matter can be seen, when dried peat burns freely. [2]
Peat Soil organic soils containing more than 20% organic matter in various degrees and states of decomposition. Deposits that are decayed slightly or not at all are termed peat, while those that are markedly decomposed are called muck.

4. Non-Conventional Energy Resources

Alternative energy is normally produced by harnessing the natural world around us and the elements. Usually it does not create pollution in the atmosphere or at least it only produces small amounts. Renewable energy is energy that comes from natural resources such as sunlight, wind, rain, tides, waves and geothermal heat. About 16% of global final energy consumption comes from renewable resources, with 10% of all energy from traditional biomass, mainly used for heating, and 3.4% from hydroelectricity.

4.1 Solar Energy

Solar power systems use the sun's rays- solar radiation-as a high-temperature energy source to produce electricity in a thermodynamic cycle. The need for Concentrating Solar arises because solar radiation reaches the Earth's surface with intensity (kW/m^2) that is adequate for heating systems but not for an efficient thermodynamic cycle for electricity. This means the density has to be increased, and the incoming solar radiation concentrated by using mirrors of lenses. Types of solar power system are given below:

- Solar Powered Irrigation System
- Roof-top Solar Power
- Solar LED Street Lighting

4.2 Wind energy

Wind energy has captured interest for a long time, of several options of renewable energy. Engineers and scientists has a wide array of experience in developing wind turbines, wind towers and wind farms to convert wind energy into electricity for a clean, quiet, non-polluting power. We have experience in the design, engineering, construction. Wind farms, a group of wind turbines used to generate electricity, are cost beneficial:

- Negligible fuel costs.
- Low maintenance costs.
- Lower capital cost.
- Can be employed in both urban and rural settings.
- We provide location analysis.

4.3 Tidal Energy

Bangladesh is fortunate to have access to the sea and tidal energy can be obtained from the changing sea levels. Generation occurs when the water is flowing both in and out, with the change in rotation occurring during low and high tide. It is a direct result of tide shifting from low to high. The tides rise and fall due to the gravitational tug-of-war between the Earth, the Moon and the Sun and if energy can be obtained it is inexhaustible. Experts say tidal energy can be obtained from three types:

• Tidal Barrage
• Tidal Fence
• Tidal Turbine

Bangladesh has a long coastal belt of 740 kilometers. Some of the coastal areas are protected by embankment and sluice gates from flooding. Bangladesh has some large tidal sites and many channels of low tidal sites where barrages and sluice gates already exist. Analysis of given sites according to a report indicates that Sandwip has a very good prospect of tidal energy. The 5-metre tides experienced at Sandwip are ideally suitable. Researchers say that Bangladesh may harness energy from tidal waves by application of two technologies:

• Low head tidal movements (2-5 m head)
• Medium head tidal movements (5 m or over) [3]

4.4 Hydroelectric power

Water has been used for thousands of years for energy source, with ancient civilization using water to drive mills thru the use of water wheels. Hydropower is the most moderately economical source of renewable electricity in Bangladesh. Prospective of hydro power in Bangladesh is a lot. Feature of these power:

- The production of power through use of the gravitational force of falling or flowing water.
- Most widely used form of renewable energy.
- Produces no direct waste, and has a considerably lower output level of the greenhouse gas, carbon dioxide, than fossil fuel powered energy plants.

4.5 Geo thermal Energy

Geothermal energy is a renewable energy source because the heat is continuously produced inside the Earth. Geothermal power is cost effective, reliable, sustainable, and environmentally friendly, but has historically been limited to areas near tectonic plate boundaries. Geothermal energy is generated in the Earth's core. The core itself has two layers: a solid iron core and an outer core made of very hot melted rock, called magma. The mantle surrounds the core and is about 1,800 miles thick. It is made up of magma and rock. The crust is the outermost layer of the Earth, the land that forms the continents and ocean floors. It can be 3 to 5 miles thick under the oceans and 15 to 35 miles thick on the continents.

5. Assessment of Energy Resources in Bangladesh

Forecasting of energy plays a major role in optimal decision formula for government and industrial sector in Bangladesh. Renewable energy encompasses a broad range of energy resources.

5.1 Natural Gas

There are 23 discovered gas fields in Bangladesh of various sizes. The total reserve of 20 gas fields is about 26.84 Tcf (trillion cubic feet). Gas in most of the fields is dry, in a few fields it is wet, with considerable amounts of condensate, e.g. at Beanibazar (16 bbl/mmcfg), Jalalabad (15 bbl/mmcfg), and Kailashtila (13 bbl/mmcfg). Currently, natural gas accounts for more than 70% of the total commercial energy consumption and the major part of the future energy demand would be met from it. [4]

Petrobangla has approximately 20 natural gas fields nationwide, half of which are active. The main fields include.

- Bibiyana (discovered by Unocal in Block)
- Titas (Second largest natural gas field in the countries)
- Habiganj
- Kailastilla
- Rashipur
- Jalalabad
- Sangs off shore natural gas field.

Other possible natural gas field includes Shaldanadi, Ferchuganj, Feni, Kumta and Shahbajpur.

- Unocol announced in March 2003 that it would begin development of the Moulavi Bazar field in Block 14.
- Shahbazpur, discovered by petrobangla subsidiary Bapex in 1995, is estimated to contain 330-400 of recoverable natural gas.

Jalalabad Field

This is the biggest gas field in Bangladesh.

(1)Unocal started natural gas production from the Jalalabd Field on Block 13 in February 1999.
(2)At a production rate of 80-100 million cubic feet of natural gas per day.
(3)Jalalabad supplies approximately 12 percent of the countries gas demand.
(4)The field contains an estimated 1.6 Trillion cubic feet of gas- in place. [5]

Bibiyana Field

(1) Unocal discovered the Bibiyana gas field on block 12 in 1998.
(2) The report concluded that Bibiyana is a world class accumulation of natural gas.
(3) The Bibiyana field is estimated to hold as much as 5.5 trillion cubic feet (TCF) of recoverable reserves of natural gas and 30.7 million barrels of condensate.
(4) The 3-D seismic survey is the first time this technology has been used in Bangladesh and provides a more accurate reserve then 2-D seismic surveys. [6]

Moulavi Bazar Field

(1) Unocal has signed a natural gas purchased and sales agreement with Petrobangla to develop the Moulavi Bazar Field.
(2) Unocal expects to produce 70 to 100 million cubic feet of gas per day from the field beginning in the first quarter 2005.
(3) Unocal discovered the Moulavi Bazar field on block 14.
(4) The Moulavi Bazar 3 wall set a record for drilling time and low cost. [7]

5.2 Coal

Coal forms from compaction and indurations of variously altered plant remains similar to those of peat deposits.. Coal has a very small contribution to the power grid of Bangladesh. Its major fields of usage are electricity where it contributes negligible with respect to gas. Otherwise it's used as running the industrial furnaces and brick fields. The total coal reserves in 5 coal fields of Bangladesh are estimated to be 3500million tons (this energy is equivalent to 70Tcft of gas). [8] First let's have a glance at the five coal fields of Bangladesh.

Table of Coal reserves in 5 Coal Fields in Bangladesh [9]

Coal Field of Bangladesh	Depth(meters)	Estimated coal reserves in million tons(MT)	Proved amount of reserves(MT)
1.Barapukuria, Dinajpur	118-509	390	303
2.Khalaspeer, Rangpur	257-483	685	143
3.Phulbari, Dinajpur	150-240	572	288
4.Dighirpar, Dinajpur	328-407	600	150
5.Jamalganj, Jaipurhat	640-1158	1053	Yet to be known

5.3 Crude Oil

Bangladesh has discovered oil in two old gas fields in the country's northeastern region with an extractable reserve worth $5.5 billion, the two finds at Kailashtila and Sylhet contain proven reserves of 137 million barrels of low sulfur crude oil, of which 55 million barrels can be lifted commercially. Low sulfur, or "sweet", crude oil is highly sought after and is more easily processed into gasoline than high sulfur crude. In the current market price, the value of this extractable reserve of 55 million barrels is 450 billion taka ($5.5 billion). It's a very good news, coming at a time when are our oil import bill is growing fast. [10]

5.4 Peat

In Bangladesh, peat soils occupy about 0.13 million ha and occur in the low-lying areas of the Gopalganj-Khulna region and also more locally in some of the eastern Surma-Kushiyara floodplain and the adjoining northern and eastern Piedmont plains. These are sedimentary peats. In general, organic materials occupy more than half of the upper 80 cm of the profile and sometimes in different layers within the same soil. Dark brown muck is the most common constituent of the soil. It has been mapped in a number of basin areas along the boundary between the Ganges river floodplains and the Ganges tidal floodplain. It occupies the Agro ecological Zone-14, i.e. Gopalganj-Khulna Beels. The area remains wet in the dry season, and is mainly deeply flooded in the rainy season. The Agro ecological Zone-14 occupies a number of separate basin areas in Madaripur, Gopalganj, Narail, Jessore, Bagerhat and Khulna districts. [11]

5.5 Biomass

Bio power, or biomass power, is the use of biomass to generate electricity. There are six major types of bio power system: direct-fired, co-firing, gasification, pyrolysis and small, modular. Most of the bio power plants in the world use direct-fired systems. Two new ways include the use of micro turbines and fuel cells. Micro turbines have outputs of 25 to 500 kilowatts. Several bio power technologies can be used in small, modular systems. A small, modular system generates electricity at a capacity of 5 megawatts or less. [12] Burning fossil fuel releases carbon dioxide but biomass fuel, on the other hand, releases carbon dioxide that is captured during photosynthesis and it tends to equal itself out. As biomass fuel is readily available, the reliance on external sources of fossil fuel can be reduced.

5.6 Solar Energy

In Bangladesh, more than one million households or about five million people are using solar energy generated by solar panels that are being installed on the rooftops, which have an incredible capacity to supply power. Since 60 per cent homes in Bangladesh are not connected to the electricity grid, they see solar power as a clean and viable option for lighting up their homes. The country's energy demand is actually growing annually at 14 per cent, and not as per government's estimation of 7.0 per cent.

500MW Solar Power Program

As part of the new generation expansion initiative in line with growing demand, Government has planned to enhance national power generation capacity to be 16000 MW by 2015.

Installation of Solar Irrigation Pumps

In the FY 2009-10, the agriculture sector of Bangladesh contributed 20.16% to the GDP (Bangladesh Economic Review-2010). Out of 11 million hectares of land under rice production, modern boro rice alone covers about 4.70 million hectares and nearly 98% of this area requires irrigation.

Solar Park

100-150MW of solar power is primarily assessed for solar park in different locations. Bangladesh Power Development Board (BPDB) will be the implementing agency.

Roof-top Solar Power Solution

A typical 10 KWp roof-top solar solution will require a roof space of about 1,000 square feet which can light around 200 no's of energy saving lamps. If installed in 5,000 buildings in the metropolitan areas of the country, a total of 16.5 million liter diesel/year or 100,000 units of electricity/year could be saved.

Solar electrification at Railway Stations

Under the proposed project, 25 MW Solar Power systems would be installed at the remote railway stations and 5 MW Solar Power systems would be installed at the roof-top of unutilized large railway stations. [13]

5.7 Tidal Energy

Tidal power, also called tidal energy, is a form of hydropower that converts the energy of tides into useful forms of power - mainly electricity. Analysis of the given sites indicates that Sandwip has a very good prospect for tidal energy. The 5 meter tides experienced at Sandwip results in poor accessibility, with the island constantly surrounded by mud flats, except during high tides. During the night the excess power produced can be directed into battery charging. These batteries can be provided for households living off the grid. The installation of 75 KW turbines, generating 80% of full capacity for 23 hours per day, equates to the production of approximately 1,380 KW-hr per day. It is proposed that the manufacture and installation costs for one site will be in the order of 35 lakh Taka.

5.8 Wind energy:

Bangladesh is situated between 20O34'-26038 North Latitude and 88001'-92041' East Longitude. The country has a 724 km long coast line 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. [14] Some of the specific projects that could be undertaken were pointed out by the WEST study as follows:

- A pilot wind turbine plant may be set up and be linked with the existing 250 KW diesel power station at Kutubdia, to study the overall performance of a hybrid wind-diesel system in an isolated local grid.
- A demonstration wind power generating plant at Kuakata may be set up and connected to the existing grid to study the performance and efficiency of such a system.

5.9 Hydroelectric power:

The earth-filled dam Kaptai is an earth-fill dam. It is 45.7m (36m MSL or Mean Sea Level) high and 670.6m long. The maximum width is 7.6m and width at the foot is 45.7m. The 16-gated spillways, each 12.2m by 11.3m, can together pass a flow of 625,000 cusec. The average annual flow in the reservoir is approximately 15,646 MCM (Million Cubic Meter). The flood absorption capacity is 8.25 million Ac-ft and the flooded area at 33m MSL is 777 sq km. [15] Hydraulic Turbines transfer the energy from a flowing fluid especially water to a rotating shaft. Turbine itself means a thing which rotates or spins. Hydraulic Turbines have a row of blades fitted to the rotating shaft or a rotating plate. Flowing liquid, mostly water, when pass through the Hydraulic Turbine it strikes the blades of the turbine and makes the shaft to rotate. While flowing through the Hydraulic Turbine the velocity and pressure of the liquid reduce, these result in the development of torque and rotation of the turbine shaft. Kaptai dam is the one and only dam of Bangladesh that is used to generate hydro-electric power. The only hydropower plant in the country is located at kaptai, about 50 km from the port city of Chittagong. This plant was constructed in 1962 as part of the 'Karnafuli Multipurpose Project', and is one of the biggest water resources development projects of Bangladesh. The water storage capacity of the Kaptai dam is 11000 km^2.

Starting of Kaptai Hydroelectric Power Plant in 1957, the initial phase of the construction was completed in 1962. By this time the dam, spillway, penstock and two 40 MW Kaplan turbine-generators were built within the power station. In August 1982 a 50MW generator was commissioned. In October 1988 the 4th and 5th generating units, both 50 MW Kaplan-type turbines, were installed which raised the **total generation capacity to 230MW**.[16] The total cost of Unit 1, Unit 2 and a part of Unit 3 was Rs. 503 million and the total cost of extension was Tk. 1,900 million. The project was financed by the East Pakistan Government (at the time), United States and the Overseas Economic Cooperation Fund.

5.10 Geothermal Energy

Naturally occurring large areas of hydrothermal resources are called geothermal reservoirs. Most geothermal reservoirs are deep underground with no visible clues showing above ground. But geothermal energy sometimes finds its way to the surface in the form of: Volcanoes and fumaroles (holes where volcanic gases are released), Hot springs, Geysers

Units: Billions of barrels of oil equivalent

Crustal Heat————————79,000,000

Thermal Aquifers————————130

Oil Reserves————————5,300

Annual Global Energy Consumption—-70

Plants for 200 MW are in the pipeline in the district of Thakurgain, one of the poorest in the country, near the northern border with India. Already it has secured favorable opinions from the Geological Survey of Bangladesh, the Ministry of Water Resources and the Ministry of Environment. Anglo MGH Energy conducted preliminary feasibility studies on an area of over 3,500 hectares, in order to identify the best site for the construction of the plant. The Geological Survey of Bangladesh and the Ministry of Water Resources and Environment have given favorable advice regarding the project. [17]

6. Discussion

- Present situation indicates that we're traditionally heavily dependent on the conventional resources. This habit will worsen the present pollution problem and global warming issue in future.
- Fuel price hike is a severe problem at present. We have seen that the foreign companies are leading the gas production in Bangladesh. If government can strengthen the country owned companies technologically, it'll be easier to control the fuel price inside the country.
- Conventional energy resources are bound to be finished off one day. So, we need to gradually adapt renewable and eco-friendly resources. It will reduce the load from the conventional resources like gas and coal; on the other hand it will result in less pollution. It also alleviates the energy crisis which will result in smooth industrialization.

7. Conclusion:

The world has started experiencing energy crisis and pollution due to excessive usage of conventional energy. Competitive development of the countries will depend on the availability of energy. The future energy of the world will be non-conventional renewable energy. So, it's high time to adapt all possible sources of renewable energy.

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Power Factor Improvement of Compact Fluorescent Lamp

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Abstract

The main reason for using CFLs is the savings that can be achieved in terms of energy and running costs, which benefit the householder. Due to their higher efficiency, a 25 watt (W) CFL can provide the equivalent light output to a 100 W incandescent bulb. Up until now there has been much negativity expressed by consumers towards the CFL technology. A major problem has been a lack of knowledge about the characteristics of CFLs,. In this thesis We have tested five different brand of CFL and determine corresponding power and power factor.It is seen that power factor is low ranging about 0.5-0.7. To improve the power Factor capacitor is connected but power Factor is not increased.Then an inductive load is connected in this time power factor increases

.

Keywords: Compact fluorescent lamp,Power factor Correction, inductive Load.

1. INTRODUCTION

Compact fluorescent lamps (CFL) are lighting devices that have been available on the market for over 20 years; however, their use on a large scale has been limited by their unsatisfactory performances when compared to the classical incandescent lamps. Among the main disadvantages the consumers complained about their higher production cost and the questionable light quality. Apart from these, there is other drawbacks that should be mentioned, such as the low value power factor (0.5-0.6), the pollution of the network with harmonics of both low and high frequency, the short lifetime when it comes to repeated plugging-unplugging, unsecure performance or even non-functioning in warm or cold environment. Due to the unmatched rise in the energy demand, certain decisions regarding the streamline of consumers were taken at a worldwide level. In this respect, the marketing of the 100W incandescent lamps, consumption-wise ineffective, was prohibited at the beginning of 2010. Consequently, it is until 2016 that all the incandescent lamps should be removed from the market, with the exception of a few particular cases. These decisions bring about the CFL as one of the main alternatives in the replacement of the classical illumination lamps. Although in the past few years we noticed many improvements in the quality of the generated light, a longer lifetime and even a reduction in the production cost, the impact of this decision should be objectively analyzed. Accordingly, worldwide hundreds of millions of lamps will be replaced and the energy consumption is estimated to be up to 5 times lower. The power factor of these lamps, on the other hand, is 0.5 as opposed to the unitary power factor of the incandescent lamps, which might lead to an imbalance in the distribution network[1].

Disadvantage of Low Power Factor

One disadvantage is that the true power factor is considerably less than the output KVA.This means that for a generation station to supply a given power it may have to work above its normal KVAcapacity with the consequent excess temperature rise of the genetrator,supply cable ,sub circxuit switchgear.

Another bad feature of low power factoris that large amount of wattles KVA produced.This causes losses in the large machine as well as running cost in the whole plant.

A third disadvantage of low power factor is that a large voltage drop in alternator is caused [2].

2. DETERMINATION OF POWER AND POWER FACTOR

It is my first experiment. The objective of this experiment is to deter- mine power and power factor of five samples.

2.1 Required apparatus:

1) Ammeter
2) Voltmeter
3) Wattmeter
4) Variac

2.2 Circuit diagram:

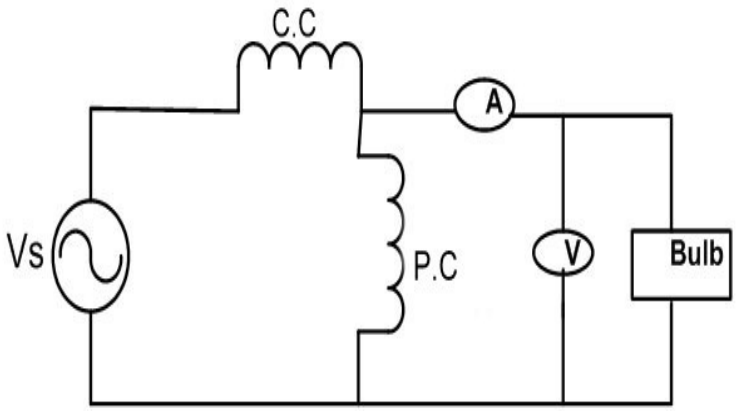

Figure. 1: Power & p.f measurement of bulb

2.3 Procedure

1) We have connected circuit according to the figure.
2) Sample bulbs are connected to the circuit one by one.
3) Then We have taken the readings

2.4 Data Table:

Table -1: Power Factor With different supply voltage

Brand name	Voltage	Current	power	Power factor
Sample-1	235	0.129	19.5	0.64
	240	.12	21	0.729
	245	.127	21.1	0.678
	253	0.15	23	0.6
Sample-2	235	0.174	19	0.46
	240	.139	19	0.5989
	245	0.14	19	0.58
	253	0.205	20	0.38
Sample-3	235	0.164	21	0.544
	240	0.174	21.5	0.511
	245	0.155	21.4	0.56
	253	0.166	21.5	0.511
Sample-4	235	0.14	20.5	0.62
	240	0.175	22	0.523
	245	.167	22.2	0.5425
	253	0.155	21.5	0.54
Sample-5	235	0.185	18.5	.4255
	240	.166	19	.475
	245	0.162	20	0.5039
	253	.158	20.5	0.5128

From the value of data table we have plotted a curve of power vs. voltage.

The figure is given below:

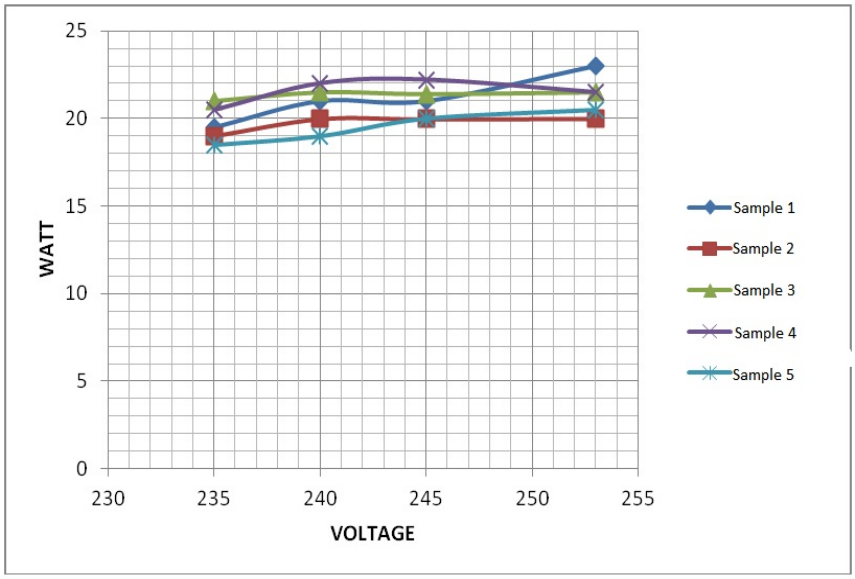

Figure.2: Power factor vs. voltage curve

From the value of data table I have plotted a curve of power factor vs voltage. The figure is given below:

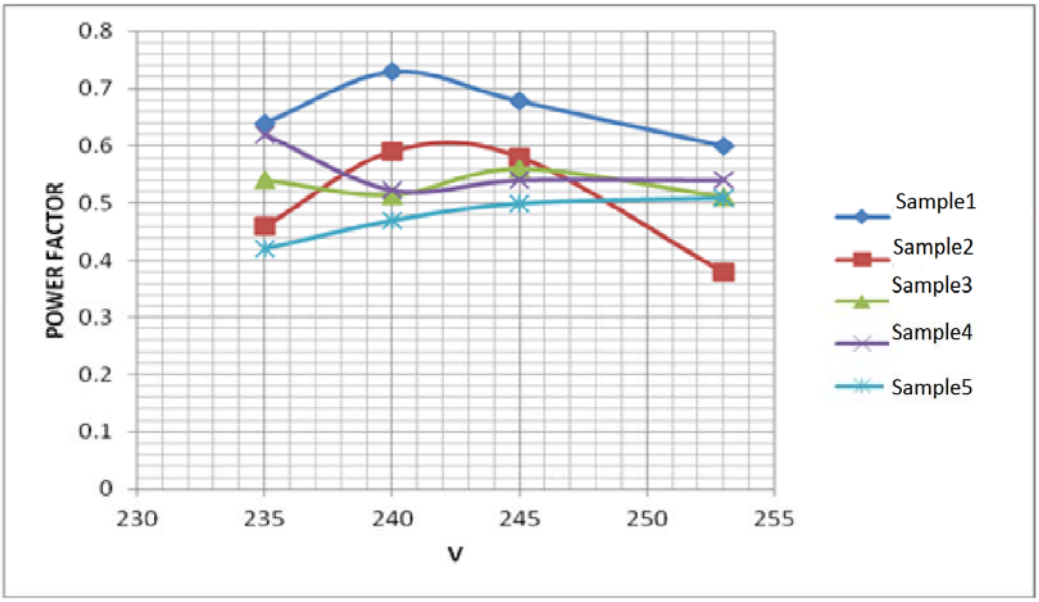

Figure.3: Power factor vs voltage curve

Discussion: The above data table shows the required power and power factor for various supply voltage. It is my first experiment. Here We have used five different supply voltages such as 230v, 235v, 240v, 245v, 253v. Then We have determined corresponding power and power factor. After knowing the values of power and power factor We have drawn two curves, first one is power vs. voltage and second one is power factor vs. voltage. The figures above shows these two curve. From the power factor curve it is evident that power factor of all the CFL is around 0.5-0.7. So it is needed to increase the power factor.

3 POWER FACTOR IMPROVEMENT WITH THE HELP OF CAPACITOR

It is our second experiment. The objective of this experiment is to improve the power factor of CFL bulb.

3.1 Required apparatus:

1) Ammeter
2) Voltmeter
3) Wattmeter
4) Variac

3.2 Circuit diagram:

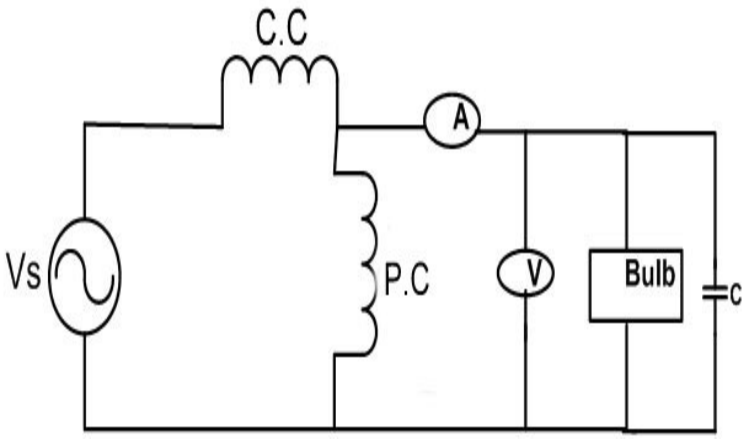

Figure.4: Power & p.f measurement of bulb with capacitor.

3.3 Procedure:

1) We have connected circuit according to the figure.
2) Sample bulbs is connected to the circuit one by one.
3) A capacitor is connected in parallel.
4) Then We have taken the readings.

Figure.5: Measurement of power factor with capacitor.

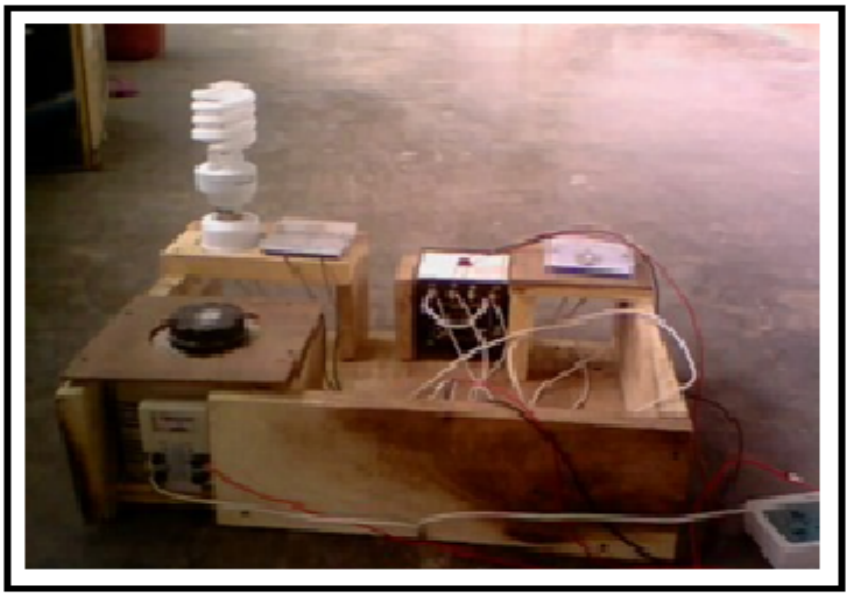

Figure6: Measurement of power factor with capacitor.

Data table with capacitor:

Table -2: Power Factor With Capacitor

Brand name	Supply voltage	POWER FACTOR
SAMPLE 1	220	.68
SAMPLE 2	220	.74
SAMPLE 3	220	.71
SAMPLE 4	220	.81
SAMPLE 5	220	.795

Data table without capacitor:

Table -3: Power Factor Without Capacitor

Brand name	Supply voltage	POWER FACTOR

SAMPLE 1	220	.75
SAMPLE 2	220	.82
SAMPLE 3	220	.82
SAMPLE 4	220	.90
SAMPLE 5	220	.81

Discussion: The data table above shows power factor with and without capacitor. From the data table it is clear that as a result of placing capacitor power factor decreases for all the CFL. For example power factor of the sample-1 bulb was .75 without capacitor and it becomes .68 with capacitor. Then the result of this experiment is not satisfactory at all.

3.5 POWER FACTOR IMPROVEMENT WITH THE HELP OF AN INDUCTIVE LOAD: It is my second experiment. The objective of this experiment is to determine improve the power factor of five samples.

3.6 Required apparatus:

1) Ammeter
2) Voltmeter
3) Wattmeter
4) Variac

3.7 Circuit diagram:

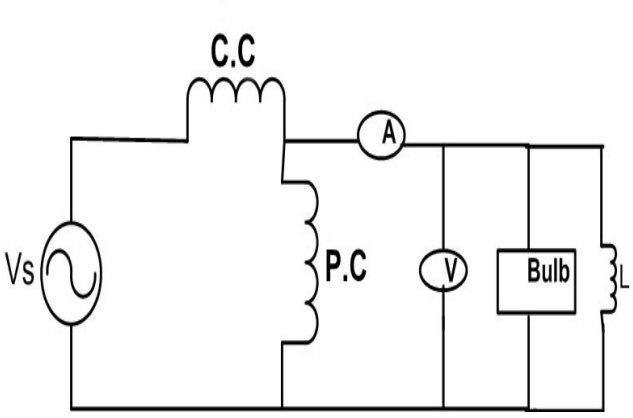

Figure.7: Power & p.f measurement of bulb with inductor

3.8 Procedure:

1) We have connected the circuit according to the figure.
2) Sample bulbs are connected to the circuit one by one.
3) An inductor is connected in parallel with the bulb.

4) Then We have taken the readings.

Figure 8: Measurement of power factor with inductive load.

Figure9: Measurement of power factor with inductive load.

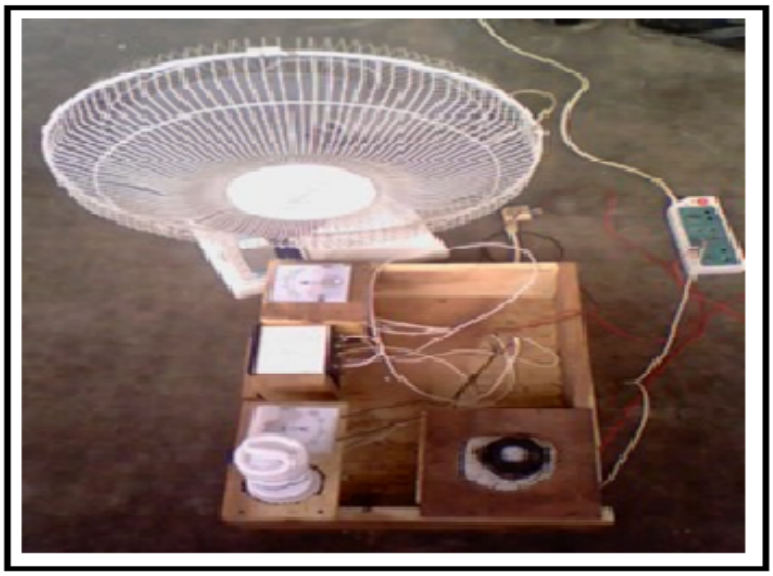

Figure 10: Measurement of power factor with inductive load

Data table with inductive load:

Table -4: Power Factor with inductive load

Brand name	Supply voltage	Power factor
Sample 1	220	.937
Sample 2	220	.96
Sample 3	220	.96
Sample 4	220	.99
Sample 5	220	.99

Discussion: The data table above shows power factor with Fan. From the data table it is clear that as a result of connecting inductive load power factor increases for all the CFL. For example power factor of the Sample-1 bulb was .75 without Fan and it becomes .937 with Fan. So the result of this experiment is very satisfactory.

CHAPTER EIGHT

4 Power factor of a typical residence having

1) Only CFL
2) CFL+others(FAN,MOTOR)

4.1 Now I will use 5 Sample bulbs having following specification:

Here I will calculate the p.f of sample-1 bulb .Data below is obtained from my first experiment**.**
1) V=220v
2) P=23w (given)

3) P=20w (measured)
Total active power P = (5*20)=100W Apparent power S =(20/.7575) =26.4VA Reactive power Q=(26.4*0.6527)=17.23VAR Total reactive power=(17.23*5)=86.16 Tan φ=0.86 Power factor COS φ=0.758
Now consider the case where I will use 5 CFL, 5 Fan, 1 motor.

Here We will calculate the p.f of five sample-1 bulb, five fan and one motor. Necessary Data is given below.

4.2 Specification of CFL:

1) V=220v
2) P=23w (given)
3) P=20w (measured)
4) Power factor=.7575
Total active power=(5*20)=100w Apparent power=(20/.7575) =26.4VA Reactive power=(26.4*0.6527)=17.23VAR Total reactive power=(17.23*5)=86.16.

4.3 Specification of Fan

Active power=60w

Power factor COS φ=0.8
Sin φ =0.6
Apparent power S=75VA Reactive power=45VAR
Total active power= (5*60) =300W, Total reactive power= (5*45) =225VAR

4.4 Specification of motor

Active power=746W
Power factor COS φ=0.9
Sin φ =0.43
Apparent power S=828.88 VA Reactive power=361.27VAR
Now we will calculate for entire residence:
Power factor COS φ=0.9173
Total active power=100+300+746=1146W Total reactive
Power=225+361-88=498VAR Tan φ=(498/1146)=0.43

4.5 Discussion:

Power factor when
1) Only CFL=0.758
2) CFL+ others (FAN, MOTOR) =0.9173
so we see that when the residence is operated with only CFL then power factor is only .758but when the residence is operated CFL and other inductive load then power factor is 0.9173.So we can say that also the power factor is low when we will use only CFL but power factor will be high when use CFL and other inductive load. Now days there are hardly any area where CFL is used alone, as a result use of CFL provide no problem as stated earlier.

4.6 Power factor of a typical residence having

1) CFL + others (FAN, MOTOR)
2) Tungsten filament bulb + others (FAN, MOTOR)
Here I will calculate the p.f of five sample-1 bulb, five fans and one motor and Five Tungsten filament bulb, five fans and one motor. Necessary Data is given below.
1)5 CFL
2)5 Fan
3)1 Motor
And
1) 5 Tungsten filament bulb
2) 5 Fan
3) 1 Motor

We have already calculated the power factor for the first combination and we have seen that power factor is 0.9173(lagging).
Now consider the second combination.

4.7 Specification of Tungsten filament bulb:

Active power=60w
Power factor COS φ =0.9
Sin φ=0.43
Apparent power S=66.66VA Reactive power=28.66VAR
Total active power= (5*60) =300W
Total reactive power= (5*28.66) =143.33VAR

4.8 specification of Fan

Active power=60w
Power factor COS φ=0.8
Sin φ=0.6
Apparent power S=75VA Reactive power=45VAR
Total active power= (5*60) =300W
Total reactive power = (5*45) =225VAR

4.9 Specification of MOTOR

Active power=746W
Power factor COS φ=0.9
Sin φ=0.43
Apparent power S=828.88 VA Reactive
Power=361VAR.
Total active power=300+300+746=1346W
Total reactive power =225+361+143.33=729.33VAR
Tan φ= (729.33/1146)=0.63
Power factor COS φ=0.84

Discussion: It is evident from the above calculation that when we will use CFL fan and motor then power factor is 0.91 lagging. But when we will use tungsten filament bulb, fan and motor then power factor is 0.84lagging.So we can say that also the power factor is low when we will use only CFL but power factor will be high when use CFL and other inductive load. Now a days there are hardly any area where CFL is used alone, as a result use of CFL provide no problem as stated earlier.

CONCLUSION AND DISCUSSION

From result of experiment it is seen that power factor is low when CFL is used alone. To improve the power factor capacitor is connected but experimental result shows that power factor decreases. Then an inductive load(Fan) is connected across the CFL .At this time power factor increases which is above .9.After that a typical residence is considered having only CFL , CFL and other inductive load. It is seen that power factor is 0.75when only CFL is used and .91 when CFL and other inductive load is used. Then a typical residence is considered having.

1) CFL+ others (FAN, MOTOR)
2) Tungsten filament bulb+ others (FAN, MOTOR)

It is seen that power factor is 0.91when CFL + others (FAN, MOTOR) is used and .84 when Tungsten filament bulb+ others (FAN, MOTOR) is used.

So it can be said that use of compact fluorescent lamp is more advantageous then tungsten filament bulb. Because there are hardly any residence or any locality where CFL is used alone. There must be some inductive load.

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