Optimization and energy management of hybrid renewable power generation using HOMER and FLC

Nesar Uddin
Dept. of IET, CUET
Chittagong, Bangladesh.
nesar15cuet@gmail.com

Sayed Abu Nahian
Dept. of IET, CUET
Chittagong, Bangladesh.
nahians@cuet.ac.bd

Md. Saiful Islam
Dept. of ETE, CUET
Chittagong, Bangladesh.
saiful05eee@gmail.com

Jewel Sikder Joy
Dept. of IET, CUET
Chittagong, Bangladesh.
jewelsikderjoyeee@gmail.com

Abstract—**This research paper proposes an energy generation system to utilize renewable energy for off-grid area of Bangladesh which includes hill track areas and Rohinga camps. Most of the hill track areas and Rohinga camps did not access electricity. Again, present system loss of electricity is a great problem in Bangladesh. The main purpose of the paper is to design an optimal hybrid energy management system using HOMER control technique and Fuzzy Logic Controller (FLC). The system consists of PV arrays, Biogas generator, diesel generator, converter and Battery. We have used the HOMER software for effective size calculation of the system components. FLC is used to manage the obtained power from renewable energy sources efficiently. Optimum fuzzy rules are designed to control the shifting of the switches considering the load profiles and availability of renewable sources on a given period of time. For the justification of cost effectiveness and power management system simulation result from our control strategy have been compared with other prevailing systems. In addition, we obtain lower CO_2 emission from the system renewable fraction which indicates the environment friendliness. This simulation result provides a summary to utilize renewable energy with properly on recent energy crises in Bangladesh.**

Keywords—**Hybrid energy generation system; PV array; Biogas; Hybrid optimization of multiple energy resources (HOMER); Fuzzy logic controller (FLC);**

I. INTRODUCTION

The capacity of installed electricity generation in Bangladesh is about 15,755 MW in 2017 which does not exist for total population [1]. About 71.42% electrical energy comes from natural gas followed by furnace oil 15.44%, diesel 2.91%, and imported 5.37% those are limited [1]. Since, energy cannot be created or destroyed, so the source of non-renewable energy will run out very rapidly. It also increases air, water and soil pollution, greenhouse gases with the amount of carbon dioxide emission that attributes to global warming. Again energy consumption is increasing day by day. On the other hand, most of the hill track and remote areas are out of electricity. So, energy generation from renewable sources is the best choice for protecting the environment and fulfilling the total load demand of those areas. It is a solution towards the limited availability of fossil fuel and climate change.

There are many kinds of renewable sources such as solar energy, hydro energy, wind energy, tidal energy, geothermal energy and biomass energy etc. Among them Solar and biogas energy are more suitable for electricity generation in hill track areas, remote areas and Rohinga camps in Bangladesh. Present share of renewable energy in Bangladesh is only 1% which envisions having 10% by 2020 which is shown in Table I [2]. The target of our government about electricity generation from renewable sources for domestic house is 2,470MW within 2021, and 3,864MW within 2041. Again, according to the view of government, the production of biogas from domestic house is 600,000 m^3/day by 2031 which will be increased to 3 million m^3/day by 2041 [2]. In Bangladesh, cattle dung is available from 11.6 million cows, buffaloes, goats and sheep [3]. One kilogram of dung can produce .037m^3 biogas. Therefore, available dung of cattle and buffaloes can produce $2.97x10^8$ m^3 of biogas which is equal to $1.52x10^6$ tons of kerosene or $3.04x10^6$ tons of coal [3]. So, generation of electricity from biogas is an enormous source in Bangladesh. Besides, a substantial amount of biogas can be produced from human and animal excreta, garbage water hyacinth and forest residue. Therefore, the combination of solar energy and biogas energy can play a vital role to fulfill the load demand for those areas. This paper is offered for multi households with 220 kW load demand in a day. The available average solar radiation is 4-7kWh per square meter per day on that area with near 250–300 sunshiny days in a year that can eliminate a precent of the total load demand in this area [4]. Again the fuel of biogas energy is also available in this area which can mitigate a large amount of load demand of required energy.

TABLE.I RENEWABL EENERGY STATUS IN BANGLADESH [2].

Category	Achievement (MW)	Target (MW)
Solar Energy	More than 300	1800
Wind Energy	2	364
Biomass Energy	Less than 1	45
Biogas Energy	Less than 5	9
Hydro Energy	230	237
Other RE	Less than 1	15
Total	539	2,479

To minimize the system loss and increase efficiency, effective energy management system is most important. So, an Artificial Intelligence (AI) as fuzzy logic controller in MATLAB is one of the most widely used applications of fuzzy set theory that is used for management system which must minimize power loss [5]. This management system is one of the more effective systems that optimize energy efficiency. The control strategy based on fuzzy logic theory has been proposed to achieve the optimal result of the battery charging/discharging, PV operating condition, biogas generator and diesel generator off-on performance.

II. METHODLOGY

A. STUDY AREA & RESOURCES ASSESSMENT

In this research, study area has been selected for Bashkhil in Boalkhali Chittagong that is located at 22 degrees 50 minutes North latitude and 92 degrees 22 minutes East longitude [6]. It is a hill track area in where solar and biogas fuel is available and most of the people are not access of electricity. About 140-150 family can get benefit of electricity from this study by utilizing renewable energy for 220 kWh load demands for a day. Overall research method has been presented in Fig. 1.

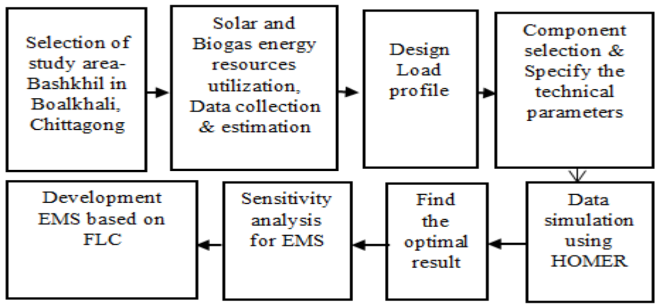


Fig.1 The overall methodological outline of the research.

For this research typical monthly solar radiation data has been collected from NASA by using Homer that is shown in Table II.

TABLE II. AVERAGE SOLAR RADIATION AND BIOMASS FUEL IN PROPOSED AREA [6].

Month	Clearness Index	Daily Solar Radiation ($kWh/m^2/day$)	Daily Biomass (ton/day)
January	0.641	4.523	1.5
February	0.616	5.005	1.2
March	0.605	5.699	1.3
April	0.552	5.781	1.2
May	0.528	5.807	1.2
June	0.390	4.344	1.2
July	0.362	3.987	1.1
August	0.403	4.272	1.3
September	0.417	4.064	1.2
October	0.575	4.874	1.3
November	0.597	4.345	1.3
December	0.649	4.350	1.4
Average	0.641	4.523	1.26

By investigation the study area, total number of the cows is 50. Dung potential for total cows is 500 kg/day. Domestic waste potential is 250 kg/day and forest residue is 400 kg/day. Total compost manufacture is 1500 kg/day. From this manure, the potentiality of biogas is 75 m^3 /day which are shown in Table III. Biogas produces by Photosynthesis process. Photosynthesis can be described by flowing chemical reaction [7]:

$$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O + 19\ MJ/m^3 \quad \text{.........(1)}$$

Where, $C_6H_{12}O_6$ represents biomass resource.

TABLE III. BIOGAS RESOURCESS UTILIZATION OF PROPOSED AREA [6]

Specifications	Details
Total Domestic Waste	250kg/day
Total cow	50
Forestry residue	400kg
Dung for one cow	10 kg/day
Overall dung	500 kg/day
Other manure	350 kg/day
Gas profit	.05 m^3/kg
Total amount of biogas	75 m^3
1 m^3	19 MJ
Total electricity produced	1425 MJ = 395 kWh
Efficiency of Generator	35%
Overall electricity produced	138 kWh/day

B. SYSTEM DESCRIPTION

The proposed hybrid system consists of PV arrays, Biogas generator, Diesel generator, converter and batteries which is shown in Fig. 2. According to load demand, PV array and Biogas generator, Diesel generator supply electricity. The extra energy from PV and Biogas generator is stored in the battery until full charge. When generation of electricity from PV and Biogas generator, Diesel generator is unavailable, then battery is used as backup system. The converter is recovered as an inverter and rectifier.

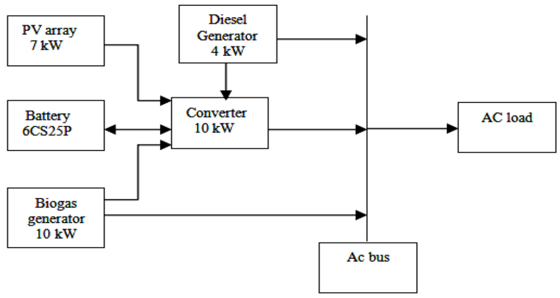


Fig.2 Block diagram of the system.

C. PV array

Photovoltaic (PV) array produce electrical energy through semiconductor materials from light energy based on a phenomenon called photovoltaic effect [8]. Generated power from PV array can be denote by below equation [9]

$$P_{pv}(t) = \eta_{pv} . A_{pv} . S(t) \text{......... ....} (2)$$

Where, η_{PV} – efficiency PV arrays, A_{PV} - total area of PV array in m^2 and S(t) - solar radiation kW/m^2. Average monthly solar radiation from January to December has been presented in Fig. 03.

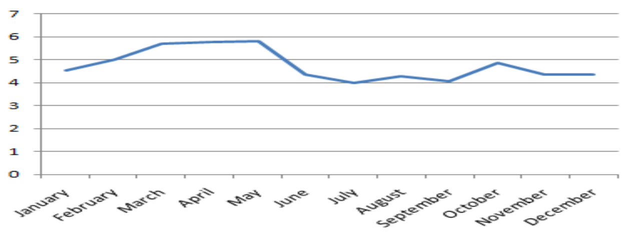


Fig. 3 Average monthly solar radiation.

For proposed system, 350 watt of 72pic Mono crystalline Silicon SKT350P-12 PV array has been considered. By optimizing, we have got 7 kW PV arrays according to HOMER software. The capital cost, replacement costs and lifetime of PV arrays have been considered \$700, \$600 and 25 years respectively which is shown in Table VII.

D. Biogas model

Biogas generally is the combination of different gases like (CH_4, CO_2, H_2S) that composed from farming waste, manure, municipal waste, forest deposits, plant material, sewage, green waste or food waste by the breakdown of organic matter in the absence of oxygen [10]. Biogas is a kind of renewable energy source because of it's created from atmospheric carbon by plants grown within current growing seasons. Generated gas is used as fuel that can be used as heating purpose or cooking purpose. This gas can also be used to generate electricity through gas engine. General specification of biogas generator which is shown in Table V. Fig.4 indicates monthly average biomass fuel in ton.

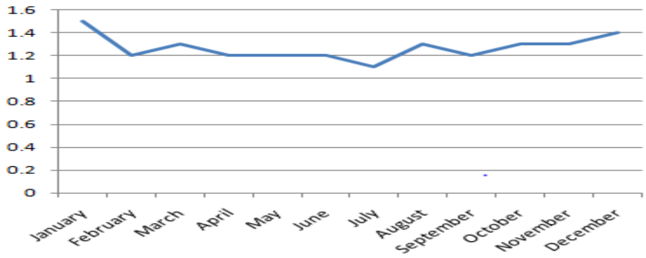


Fig. 4 Monthly average biomass fuel in ton.

TABLE V. GENERAL SPECIFICATIONS OF BIOGAS GENERATOR [11]

Specifications	Details
Model	YDNY-10
Output	AC 3 phase, 50 Hz
Rated Power	10kW/12.5Kva
Rated Current	18 A
Fuel	Biogas
Gross Weight	510 kg
Rated Speed	1500 rpm
Gas Consumption	6.5 m^3/h
No. of Cylinder	4

The capital cost, replacement cost and operation time of biogas generator is considered $1100, $1000 and 20,000 hours which is shown in Table VII.

E. Generator model

A diesel generator is a machine that connects with a diesel engine with an electric generator to produce electricity by rotating the alternator [12]. The working principle of diesel engine depends on Carnot cycle. Again, the mechanism of electric generator depends on principle of electromagnetic induction. General specification of diesel generator which is shown in Table VI.

TABLE VI. GENERAL SPECIFICATIONS OF DIESEL GENERATOR [13]

Specifications	Details
Model	POWERHOUSE, PH3826
Output power	AC, 3 phase, 50 Hz
Rated Power	4.8kW
Fuel	Diesel
Fuel volume	16 L
Rated Speed	3400 rpm
Oil Consumption	1.9 L/h

The capital and replacement cost of diesel generator is considered $150 and $130 for 1 kW which is shown in Table VII. The lifetime of diesel generator is considered 30,000 hours.

F. Battery model

Battery is used to stock extra energy from renewable sources that will be used when the system is not capable to give required power. The lifetime of battery depends on charge or discharge rate per day. By optimizing input data, we have got the number of battery having capacity 11 of 6CS25P model 6 volt 820Ah 6.94kWh. The capital and replacement cost of the battery is considered $1100 and the replacement cost $1000 for five years [14].

G. Converter model

Converter is used as both rectifier (AC to DC) and inverter (DC to AC). By simulation, the program finds an optimum result 11kW for converter. The capital cost and replacement cost of converter is considered $180 and $150 per kW for 15 years which shown in Table VII [14].

H. Load profiles

TABLE VII. THE INPUT HYBRID SYSTEM COMPONENTS.

Quantity	Size (kW)	Capital ($) for 1 kW	Replacement ($) for 1 kW	O & M ($) per year	Life Time
PV arrays	7	700	600	10	25 year
Biogas generator	10	1100	1000	1539	20000 hour
Diesels Generator	4	150	130	233	30000 hour
Battery	6.94kWh	1100	1000	8	5 year
Converter	10	180	150	5	15 year

The target of load demand is 220 units per day for selected zone. Daily load profile is presented in Fig. 05 (summer season) and Fig. 06 (winter season). Day to day load variation has been considered 16% and time to time load variation has been considered 22%.

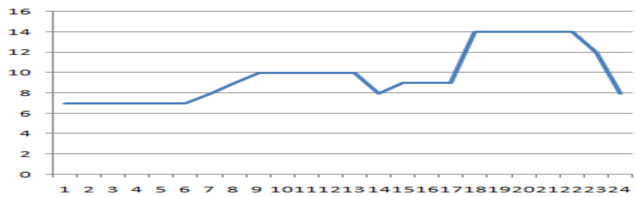


Fig. 5 proposed daily load profile for March to November in kW.

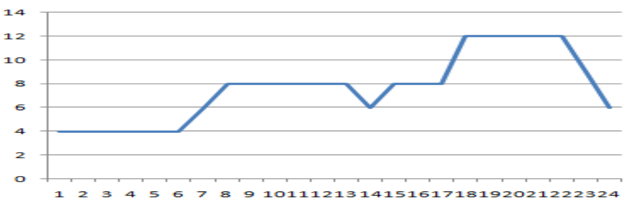


Fig. 6 proposed daily load profile for December to February in kW.

This proposed system is designed for four or five family member with 150 to 170 families. We consider typical electrical appliances such as CFL bulbs, electric Fan, TV, electronics charges in each family with standard voltage (220V AC, 50Hz). Table VIII presents the electric load characteristics of each house.

TABLE VIII. ELECTRIC APPLIANCES OF HOUSE.

Domestic Appliances	Number of Appliances	Power in watt	Summer (Avg. hr./day)	Winter (Avg. hr./day)	Approximate Total (kWh/day)	
					Summer	Winter
CFL Bulbs	3	20	9/10	10/11	1.508 kWh/day	.738 kWh/day
Ceiling Fan	2	35	10/11	0		
TV	1	18	4/5	4/5		
Mobile Charger	2	6	3/4	3/4		

III. OPTIMIZATION MODEL USING HOMER

Total Architectural view of research has advanced with the load profile, solar & biomass resources, system component as input of HOMER. Net present cost, optimum result, cash flow, and total capital cost, energy saving cost, renewable energy fraction, and excess energy fraction% as output by Homer. The configurations of proposed system's component are PV array, biogas generator, diesel generator, battery and power converter. PV array and Biogas generator are main renewable sources of electricity. Generated current from PV array is DC. Again we used AC biogas generator. So, inverter is used to change DC to AC and vice versa to adjust overall system. The simulation diagram of proposed system is shown in Fig. 7.

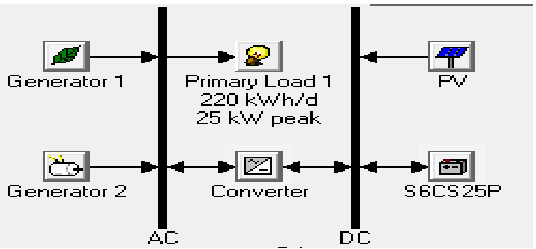


Fig. 7 Proposed hybrid energy generation system.

IV. POWER MANAGEMENT MODEL USING FLC

A fuzzy inference system (FIS) is a kind of artificial intelligence system that is created on a fuzzy set and IF-THEN rules [4]. Fuzzy logic can make ideas that not only "true" or "false" but also incomplete truth in where the truth rate may range between absolutely true and absolutely false [15]. It has four main parts i) Fuzzification which changes a actual value into a fuzzy set, ii)Knowledge base depends on IF-THEN rules, iii)Inference Engine depends on human analysis that create fuzzy inference between inputs and IF-THEN rules, iv) Defuzzification converts to real value as output from the fuzzy set which obtained from inference engine [15]. Fuzzy logic method is capable to apply in knowledgeable control system, nuclear fusion in order to increase efficiency and simplicity of the design procedure. Proposed management system has been developed based on FL technique using a Mamdani interface system.

The system consists of five inputs and four outputs shown in Fig. 8. The five inputs are PV (have four triangular membership function zero, low, medium, high shown in Figure 9), biogas generator, diesel generator, Load demand (LD) and State of Charge (SOC). Biogas generator and diesel generator have two triangular membership functions representing available and not available shown in Fig. 10 & 11. Last two input of load demand (LD) and state of charge (SOC) have three triangular membership functions of low, medium and high representing for 24 hours shown in Fig. 12 & 13. Four output membership function are PV-OFF-ON, BIOGAS-OFF-ON, GENERATOR–OFF-ON and Battery_NU_C_DC(B). PV-OFF-ON, BIOGAS-OFF-ON and GENERATOR–OFF-ON have two switches as OFF (S1) and ON (S2). Battery_NU_C_DC(B) has three switch as not use (S1) charge (S2) and discharge (S3

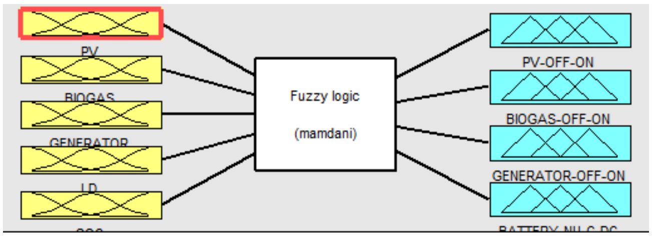


Fig. 8 Block diagram of proposed fuzzy logic controller

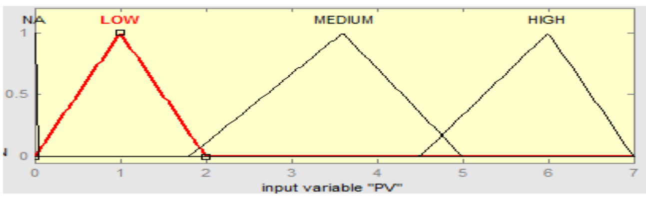


Fig. 9 Membership function of PV array

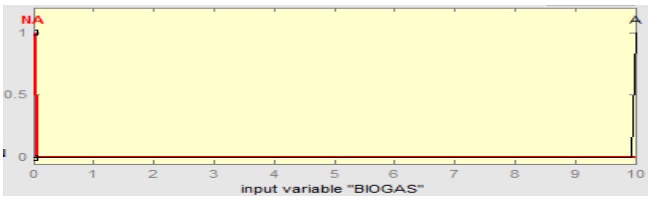


Fig.10 Membership function of Biogas Generator

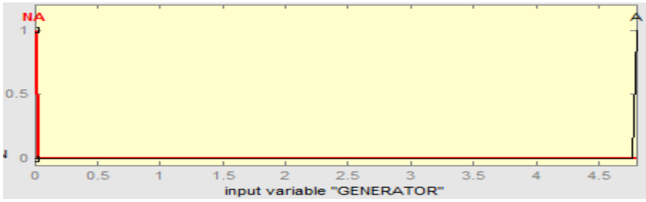


Fig.11 Membership function of Diesel Generator

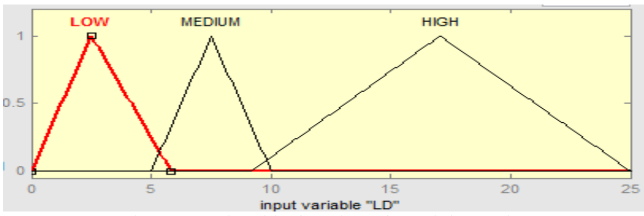


Fig.12 Membership function of Load demand

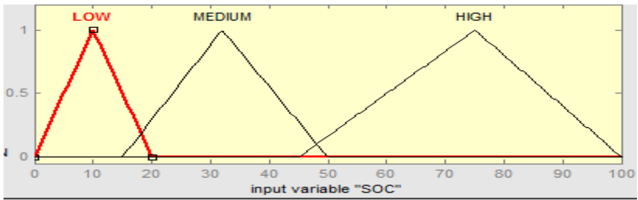


Fig.13 Membership function of SOC

FLC is related to inputs and outputs segment with a list of IF-THEN statements which is known as fuzzy rules. The IF known as input parts and THEN known as outputs part. In this research, we have established 24 rules to develop effective energy management system for different operational conditions which is shown in Table IX.

TABLE IX. CONSIDERING FUZZY RULES

		IF					THEN			
RULES NO.	TIME	PV	BIOGAS GENERATOR	DIESEL GENERATOR	LOAD DEMAND (LD)	STATE OF CHARGE (SOC)	PV-OFF-ON	BIOGAS-OFF-ON	GENERATOR-OFF-ON	BATTERY_NU_C_DC(B)
SUMMER & WINTER										
1-2	00-6	NA/NA	NA/NA	NA/NA	L/L	M/H	S1	S1	S1	S3
3-5	6-10	L/L/L	A/A/A	NA/NA/ NA	M/M/M	L/M/H	S2/S2/S2	S2/S2/S2	S1/S1/S1	S2/S2/S1
6-8	10-13	H/H/H	A/A/A	NA/NA/ NA	M/M/M	L/M/H	S2/S2/S2	S2/S2/S2	S1/S1/S1	S2/S2/S1
9-10	13-14	H/H	NA/NA	NA/NA	M/M	M/H	S2	S1	S1	S3
11-13	14-16	M/M/M	NA/NA/NA	A/A/A	M/M/M	L/M/H	S2/S2/S2	S1/S1/S1	S2/S2/S2	S1/S3/S3
14-15	16-17	L/L	NA/NA	A/A	M/M	M/H	S2	S1	S2	S3
16-17	17-21	NA/NA	NA/NA	A/A	H/H	M/H	S1	S1	S2	S3
18	21-22	NA	NA	NA	H	H	S1	S1	S1	S3
19-20	22-24	NA/NA	NA/NA	NA/NA	M/M	M/H	S1/S1	S1/S1	S1/S1	S3/S3
EXTRA RULE FOR SUMMER										
21-22	15-16	M/M	NA/NA	A/A	H/H	M/H	S2	S1	S2	S3
23-24	16-17	L/L	NA/NA	A/A	H/H	M/H	S2	S1	S2	S3

V. RESULT & ANALYSIS

On the basis of HOMER software requirement as input data of solar & biomass rescores, oil consumption and load demand, we have got some optimum & one sensitive result by simulation which is shown in Fig. 14.

	PV (kW)	Label (kW)	Label (kW)	S6CS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Biomass (t)	Label (hrs)	Label (hrs)	Batt. Lf. (yr)
	7	10	4	11	10	$ 30,300	11,500	$ 177,303	0.173	0.90	2,700	198	7,528	2,850	12.0
		10	6	7	9	$ 21,130	12,807	$ 184,841	0.180	0.86	3,554	218	8,083	2,961	12.0

Fig. 14 Sensitivity analysis by Homer

The annual electric energy production and consumption parameters from system which is shown in Table X. Average monthly generated electricity in the system which is shown in Fig. 15.

TABLE X. ELECTRIC ENERGY PRODUCTION & CONSUMPTION PARAMETERS.

Production	KWh/yr	Fraction in%	Consumption	KWh/yr
PV array	10547	12	AC load	80268
Generator 1	65199	77	Excess electricity	123
Generator 2	8692	10		
Total	84438	100	Total	80268

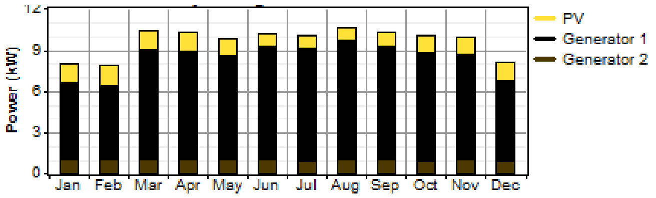


Fig.15 Monthly average electricity production in the system.

Fig. 16 indicates operation of PV array. Yearly electrical production is 10,547 kWh/yr. Maximum electrical output is 6.94 kW. Mean electrical output is 28.9 kWh/day. Capacity factor is 17.2%. Total operation hours is 4,375 hr/yr .

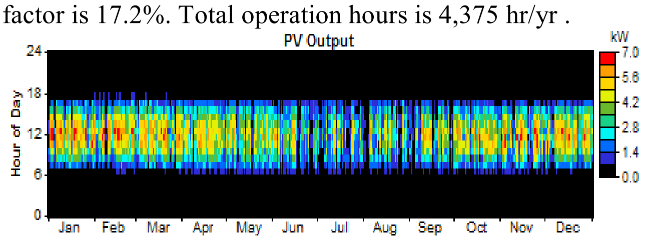


Fig.16 PV operation in the system.

Fig. 17 indicates operation of biogas generator. Yearly electrical production is 65,199 kWh/yr. Maximum and minimum output is 10 kW and 3 kW. Mean electrical output is 8.66 kW. Fuel consumption is 198 ton/yr. Specific fuel consumption is 2.124 kg/kWh and efficiency has been considered is 35% . Capacity factor is 74.4%. Total operation hours is 7,528 hr/yr .

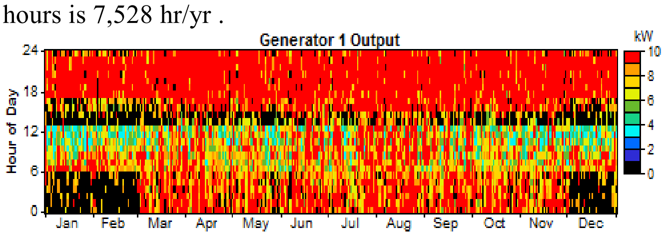


Fig.17 Biogas generator operation in the system

Fig. 18 indicates operation of diesel generator. Yearly electrical production is 8,692 kWh/yr. Maximum and minimum output is 4 kW and 1.20 kW. Mean electrical output is 3.05 kW. Fuel consumption is 2,700 L/yr. Specific fuel consumption is 0.311 L/kWh and efficiency has been considered is 32.7%. Capacity factor is 24.8% . Total operation hours is 2,850 hr/yr .

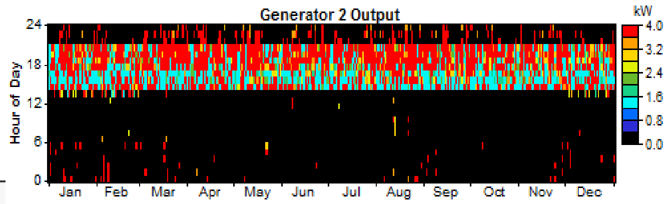


Fig.18 Diesel generator operation in the system

Fig. 19 indicates operation of battery. Energy in and out through battery is 8,795 kWh/yr and 7,044 kWh/yr . Total loss is 1,743 kWh/yr in rectifier.

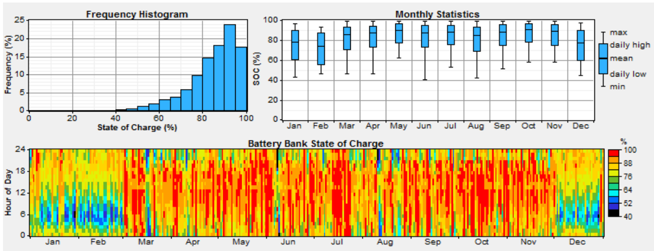


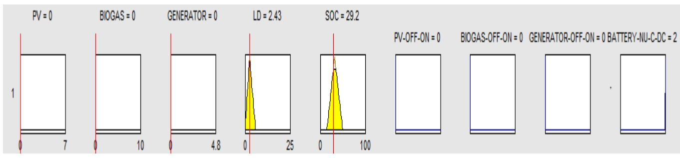
Fig.19 Battery status in the system.

VI. MANAGEMENT STRATEGY EVALUATIONS

By optimizing input data of load demand, solar-biomass resources and system component, we have got 7 kW PV array, 10 kW biogas generator and 5 kW diesel generator. So the range of input membership function of PV array, biogas generator and diesel generator are 7kW, 10kW and 5kW. Fuzzy logic controller is designed with 24 rules for winter and summer season. We have generated only effective rules based on human knowledge that must minimize power loss. Optimum power is obtained through the tuning of fuzzy rules that depends on our thinking and analysis. At a time we have used different rules for meeting any condition within 24 hours, then shifted to another rules by depending on generated power and load demand.

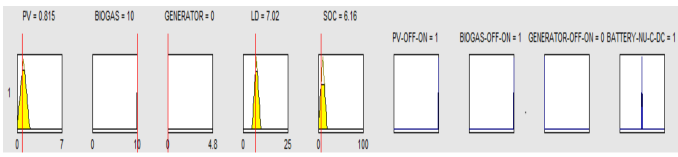
CASE STUDY-1, FOR FUZZY RULE 1(TIME,00-6)

At night, when PV is not available, Biogas is not available, the fuel of diesel generator is not available, load demand low and state of charge is medium then PV-Biogas generator-diesel generator are OFF,Load demand is fullfiled by battery.



CASE STUDY-2, FOR FUZZY RULE 3(TIME,6-10)

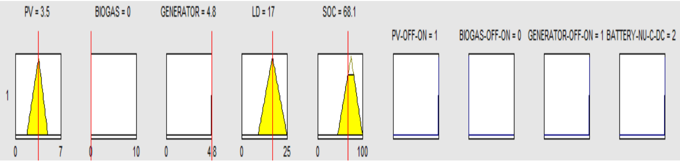
At morning, when PV is low, Biogas is available, the fuel of Diesel generator is not available, load demand medium and state of charge is low then PV is ON, Biogas generator is ON, Diesel generator is OFF, Load demand is fullfiled by PV and Biogas. At a time extra power is used for bettery charge.



CASE STUDY-3, FOR FUZZY RULE 22(TIME,15-16)

At afternoon, when PV is Medium, Biogas is not available, the fuel of diesel generator is available, load demand is high and state of charge is high then PV is ON, Biogas generator is

OFF, Diesel generator is ON, Load demand is fullfiled by PV and diesel generator. But diesel generator and PV are not capable to fulfill the total load demand . So, bettery is discharge.



VII. COST SUMMARIES

Cash flow summary and net Present cost summary in terms of component are shown in Fig. 20 & 21 respectively. The system cost is defined as equation.

$$C_{SYSTEM} = C_{PV} + C_B + C_G + C_{BA} + C_{CON} \quad \ldots\ldots(3)$$

Where, Cpv indicate PV array cost, C_B indicate biogas generator cost, C_G indicate diesel generator cost, C_{BA} indicate battery cost and C_{CON} indicate converter cost [15]. Total net present cost is $177,303, levelized cost of energy is $ 0.173/kWh and operating cost is $ 11,500/yr.

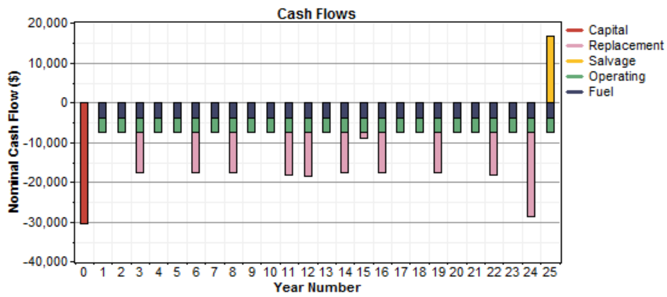


Fig. 20 Cash flow summary based on the selected components.

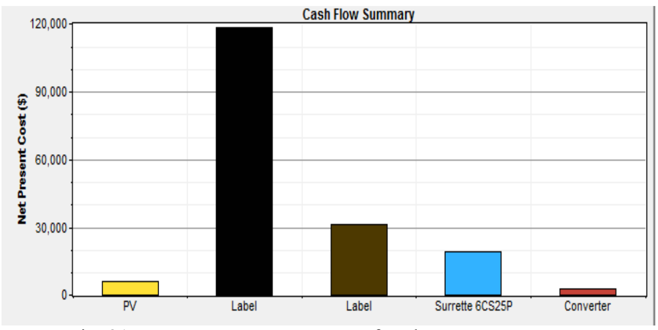


Fig. 21 Net present cost summary of each component.

VIII. CONCLUSIONS

The application of renewable energy is growing rapidly in all fields of the engineering to minimize CO_2 gas emissions in the system. This hybrid model is more effective than any other conventional systems that can easily applicable in everywhere in Bangladesh specially hill track areas, remote areas and Rohinga camps in where electricity is not available. By applying this proposed system, we can easily manage our domestic wastage and forest residue. HOMER Software is used to carry out optimal power based on load profiles and available renewable resources. Fuzzy Logic Controller (FLC) is used to manage the energy of the system properly. Component sizes calculation of PV arrays, biogas generator, diesel generator, battery and converter have been selected by using HOMER software and those are used as input of FLC for effective management system to reduce energy loss. Cost summary, cash flow summary and electrical production are the result of optimizing input data from HOMER. The solar energy, biogas energy and diesel generator contribute 12%, 77% and 10% respectively to generate power. Besides, the system is atmosphere approachable and favourable. The proposed system decreases CO_2 emissions and delivers clean energy that reduces our power crisis.

REFERENCES

[1] Bangladesh economic review 2017. Available:https://mof.portal.gov.bd/site/page/946aee4d-78bd-43b5-be2a-ed29342acba6, 2018.08.12

[2] Power Division Ministry of Power, Energy and Mineral Resources Government of the People's Republic of Bangladesh.2016

[3] A. S. N. Huda, S. Mekhilef , A. Ahsan "Biomass energy in Bangladesh: Current status and prospects" Renewable and Sustainable Energy Reviews 2014

[4] M. F. Ansari, S. Chatterji and A. Iqbal" A fuzzy logic control scheme for a solar photovoltaic system for a maximum power point tracker" International Journal of Sustainable Energy Vol. 29, No. 4, December 2010, pp.245–255.

[5] S. D. Saranya, S. Sathyamoorth and R. Gandhiraj" A fuzzy logic based energy management system for a microgrid" ARPN Journal of Engineering and Applied Sciences, Pp.2663, April 2015.

[6] Chittagong Hill track area. Available:https://en.wikipedia.org/wiki/Chittagong_Hill_Tracts , 2018. 9.29

[7] K. M. Kabir, M. A. M. Bhuiyan, Md. S. Uddin Chowdhury, R. Chowdhury, "Design and Analysis of Grid Connected Biomass System Utilizing Chittagong Municipal Food Waste "3rd International Conference on Electrical Information and Communication Technology (EICT), 7-9 December 2017, Khulna, Bangladesh.

[8] M. A. Islam, M. Maitra, A. B. Khan Majlis, S. Rahman" Spatial Changes of Land Use/Land Cover of Moheshkhali Island, Bangladesh: A Fact Finding Approach by Remote Sensing Analysis". Available:https://www.researchgate.net/publication/258837230, 2018.09.

[9] M. M. Sediqi, M. E. Lotfy, A. Yona and T. Senjyu" Optimal Economical Sizing of Grid-Connected Hybrid Renewable Energy System" Journal of Energy and Power Engineering, April 30, 2017.

[10] H. Tian, F. Mancilla-David, K. Ellis, and P. Jenkins, E. Muljadi" A Detailed Performance Model for PV Systems": Available: https://www.nrel.gov/docs/fy12osti/54601.pdf

[11] Salehin S. , Islam S., Hoque R., Rahman M., Hoque A. and Manna E. "Optimized model of a solar PV-biogas-diesel hybrid energy system for Adorsho Char Island, Bangladesh" in International Conference on Developments in Renewable Energy Technology (ICDRET), Dhaka, vol. 17, pp. 1-6, May 2014.

[12] Bala B. and Siddique S. "Optimal design of a PV-diesel hybrid system for electrification of an isolated island – Sandwip in Bangladesh using genetic algorithm", in Energy for Sustainable Development, vol. 13, pp. 137-142, November 2009.

[13] Diesel generator: Available:https://www.alibaba.com/product-detail/4-8kw-silent-dieselgeneratorportable_60501108654.html?spm=a2700.7735675.2017115.211.LUq1v6&s=p, 2018. 8. 17

[14] Biogas generator: Available:https://www.alibaba.com/product-detail/10kw-biogas-generator_60770277824.html?spm=a2700.7724857.normalList.2.65934a8efywXBp&s=p, 2018. 8.22

[15] J. M. Yang, K. W. E. Cheng, J. Wu, P. Dong, and B. Wang" The Study of the Energy Management System Based-On Fuzzy Control for Distributed Hybrid Wind-Solar Power System.