Modelling & Simulation of a Grid Connected Hybrid Power Plant with Photovoltaic, Wind & Diesel Power for Cox's Bazar

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Abstract—**This paper emphasis on establishing a hybrid power plant which consists of two renewable sources photovoltaic, wind energy and non renewable diesel source for the production of energy to contribute national power demand in Bangladesh. Solar power & wind power are our main source and diesel power is used as a standby power. If we will not able to fulfil our target demand, then we will use diesel energy. We consider renewable source because it provides clean energy. On the other hand, non renewable sources such as, oil, coal, gas will finish approximately within next 20 years. So, it is very necessary for us to find out new source of energy to overcome our power crisis. In this proposed system we came up with an idea to establish an environment friendly power plant combining Photovoltaic and wind energy at various sea shores throughout the country. For design and optimization, we have chosen Cox's Bazar sea shore where wind flow is available as well as solar radiation is optimal. The system is connected to national grid for contributing our national electricity demand.**

Keywords — Hybrid System; Photovoltaic; Wind; Diese;, National Grid; Cox's Bazar;

I. INTRODUCTION

Electricity is the most superior form of energy and a key factor for the economic development of any country. Bangladesh is a developing country. Recently, energy demand is increasing rapidly because of urbanization and industrialization. Therefore, the production of electricity is not sufficient enough for its rapid development. To overcome this situation, government has taken some necessary steps. For instance, proposed various power plants which are based on oil, coal, nuclear sources and many more which are non-renewable. Moreover, due to geographical position and lack of greater safety facilities and technical experts, nuclear power plant is not suitable for Bangladesh. So, power production and its environment related issues is a major concern for the country. However, most of the existing power plants are run through fossil fuels like natural gas. The gas reserve has fallen to such an alarming level that if no new reserves are discovered. It reserve may last for another 6 to 7 years[1]. We didn't create energy, only transform energy from one form to another one. So, generation of electricity from the alternative sources has become essential for Bangladesh. The vast Bay of Bengal on the south of the country along with the V-shaped coastal belt is the main source of the south westerly wind blowing over the terrain. The geographical location of the country has become an ideal place for utilization of solar energy. Wind flow is also reasonable in coastal areas and annual average solar radiation is similar throughout the coastal areas of Bangladesh. Cox's Bazar is one of the coastal area with an average annual solar radiation of 4.77 KWh/m2/day and monthly average wind speeds at a height of 20 meters is 3.55 m/s. Combination of wind and solar along with standby diesel power is a bright prospect. In Bangladesh, around 62% [2] of the total population (counting renewable energy) have access to electricity and 321 KWh [3] is per capita generation. Compared to other developing countries this power generations very low. To meet the growing electricity demand the use of fossil fuels need to be increased which in turn has negative environmental effects. Because the power sector alone contributes to 40% of total CO_2 emission of Bangladesh [4]. In this situation, it is obligatory to develop and endorse renewable energy sources which will ensure energy security without raising environmental impacts. This paper proposes a grid connected hybrid power system by utilizing two renewable energy sources solar and wind along with standby diesel power at Cox's Bazar Seashore where we can overcome the power demand also emits less CO_2 gas compared to other conventional power system.

II. DATA ANALYSIS IN COX'S BAZAR

Cox's Bazar long beach is located at 21 degrees 26.69 minutes North latitude and 91 degrees 57.89 minutes East longitude. We collected one year wind speed and solar radiation from NASA.[5] . Table I. shows the GHI value & wind speed for Cox's Bazar.

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TABLE I. GHI VALUE & WIND SPEED FOR COX'S BAZAR

Month	Clearness Index	NASA Daily Radiation (KWh/m^2/day)	NASA Average wind speed (m/s) Height(20m)
January	0.653	4.750	2.90
February	0.641	5.330	3.13
March	0.620	5.930	3.40
April	0.579	6.090	3.68
May	0.503	5.520	3.75
June	0.372	4.110	4.87
July	0.347	3.810	4.83
August	0.380	4.030	4.32
September	0.424	4.150	3.35
October	0.527	4.530	2.70
November	0.601	4.480	2.86
December	0.659	4.560	2.82
Annual Average	0.526	4.77	3.55

III. PROPOSED HYBRID SYSTEM

We will propose a grid connected hybrid system consists of two renewable sources (solar, wind) and non renewable source diesel including load , battery , converter & inverter. Our target is producing 2MW electrical power per day and average production is 83 unit per hour. In addition, the power will be supplied to control room load and excess electricity will be supplied to national grid to contribute our national power demand. Table II. Shows System Architecture. Figure 1. Shows the hybrid power plant model.

TABLE II. SYSTEM ARCHITECTURE

PV	Generic flat plate PV	200	kW
Wind Turbine	Norvento nED	100 kW	8
Generator	100kW Genset	100	kW
Battery	CELLCUBE® FB	1	Strings
Converter	ZBB EnerSection®	150	kW
Grid	Grid extension	2	Km

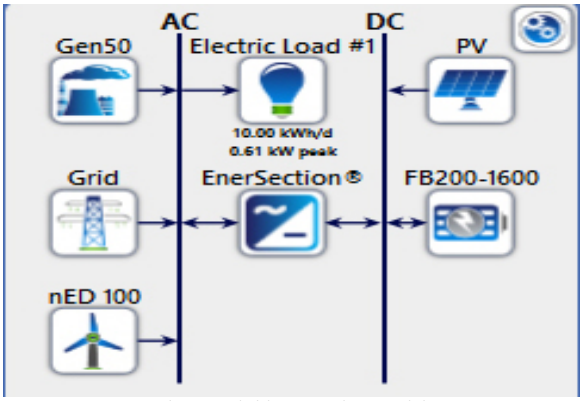

Fig. 1. Hybrid power plant model

IV. ENERGY SPECIFICATION FOR SIMULATION

A. Solar Energy

Solar panel converts light energy into the electrical energy. Sun radiation is absorbed with the panel material and electrons are emitted from the atoms that they are bounded. This released current creates solar power is converted into electrical power by solar cell [6]. When PV cells are joined physically and electrically it's called solar panel or PV module. Panels joined together form a solar array. The sunlight impinging on panels, i.e. irradiance or insulation (incoming solar radiation), is measured in units of watts per square meter (W/m2).We can use only 40% of sunlight radiation for PV module [7]. The PV system gives output as a DC Power. The PV generator can be calculated according to following equation:

$$P = A \cdot x2 + B \cdot x + C \text{ (in Watts)} \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where, x= solar radiation, P=power generation, and A, B, C are constants, which can be derived from measured data. Figure 2. Shows the solar radiation curve

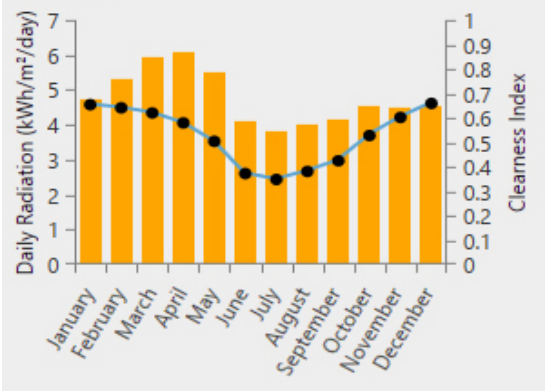

Fig. 2. Solar radiation

B. Wind Energy

Wind power involves converting wind energy into electricity by using wind turbines. It converts the kinetic energy into mechanical energy [8]. A wind turbine is composed number of propellers-like blades called a rotor. Wind comes from change of the air move around the surface of the earth[9]. The power output of a turbine is a function of the cube of the wind speed. If wind speed increases, output power also increases. We can convert only 59% wind energy into electricity according to Betz limit. The output equation for a wind generator is given

$$P = (1/2) \times \rho \times A \times v^3 \text{(in Watts)} \ldots\ldots\ldots.. (2)$$

Where, A = area perpendicular to the direction of flow (in m^2), V = wind velocity (m/s), ρ = density of air (in Kg/m^3) and P = power generation. Figure 3. Shows the wind speed curve

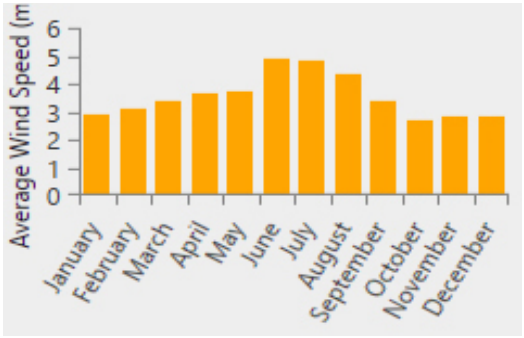

Fig. 3. Average monthly wind speed data

C. *Diesel Generator*

The Non renewable source diesel generator which operates at low load is inefficient and fuel cost low diesel generator consumes 30% of full-load fuel consumption[10]. The autonomous diesel generator has high operation cost, demands constant maintenance and the transportation of fuel to remote locations is difficult and costly, mainly rainy season in Bangladesh [11]. We used diesel generator to help fulfill our target demand. Fuel cost is 0.8$/L.

D. *Battery*

TABLE III. BATTERY CELL SPECIFICATION

Nominal Voltage	700 V
Nominal Capacity	2285.71Ah
Nominal Capacity	16000kwh
Round Trip Efficiency	65%
Float Life	20year
Maximum Capacity	3297.384Ah
Capacity Ratio	0.505c
Rate Constant	0.801k
Suggest life throughout	17520000 kWh
Max. Charge rate	1 A/Ah
Max. Charge current	230.35
Max. Discharge current	354.385

E. *Electric Load*

We used only a control room load demand, the using instrument are light, fan, computer, charger, etc.

TABLE IV. CONTROL ROOM LOAD DEMAND

Scaled annual average	10kWh/day
Scaled peak load	0.616kw
Load factor	0.68
Total annual load	3650kWh/yr

F. *Grid*

2km grid extension needed for the system to connect the National Grid.

TABLE V. GRID SPECIFICATION

Grid extension	2 km
Grid purchases capacity	100 kw
Grid sell capacity	1000 kw
Grid purchases price	0.15$/kWh
Grid sell price	0.16$/kWh

V. OPTIMIZATION RESULT

HOMER software is use to simulate the system. We used input data of solar radiation, wind speed and load on the basis of HOMER software requirement. PV sell produce 301905kWh/year. Wind turbine produce 390307kWh/year And Diesel generator produce 134920kWh/year. The main purpose of the propose system is contribute to national power demand. Grid sell is 797298kWh/year and grid purchase is 437kwh/year. Figure 4. Hybrid system production curve. Figure 5. Shows grid purchases & sell curve. Table.VI shows Electricity production. Table VII. Shows Electricity consumption

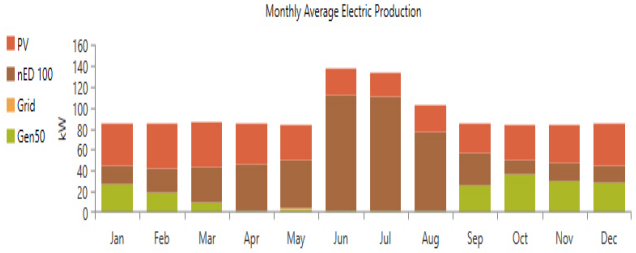

Fig. 4. Hybrid Electricity Production curve

The following result are obtained

TABLE.VI ELECTRICITY PRODUCTION

Component	Production (kWh/yr)	Friction %
PV	301,905	36.48
Wind turbine	390,307	47.16
Diesel generator	134,920	16.30
Grid Purchases	437	0.05
Total	827,569	100

TABLE VII. ELECTRICITY CONSUMPTION

Load	Consumption (kWh/yr)	Fraction %
AC	3650	0.46
DC	0	0
Grid Sells	797,298	99.54

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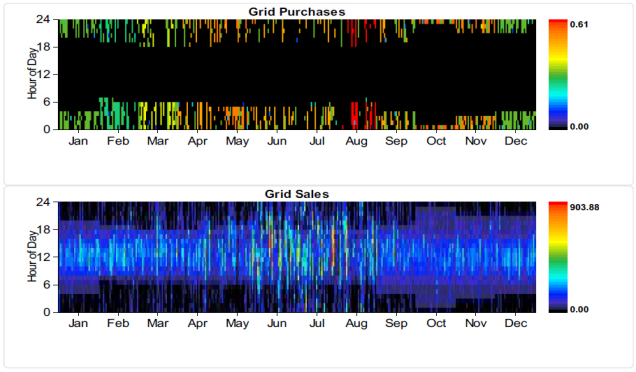

Fig. 5. Grid Purchases & Sales curve

VII. COST OF THE SYSTEM

currently 1$ = 80 BDT. Table VIII. Shows total hybrid system cost analysis

TABLE VIII. TOTAL SYSTEM COST ANALYSIS

Component	Capital	Replacement	O&M
PV	1,45,000	24,858	2,586
Wind turbine	2,40,000	67,884	51,710
100kW Genset	10,000	1,308	1,308
Converter	18,000	5,091	3,878
Grid	10,000	0	1,369
Battery	1,00,000	80,000	1,293
System	523,000	179,141	62,144

We proposed a hybrid power plant for 25 year , but battery will be replaced after 15-20 years. Figure 6. shows the overall 25 year cost curve

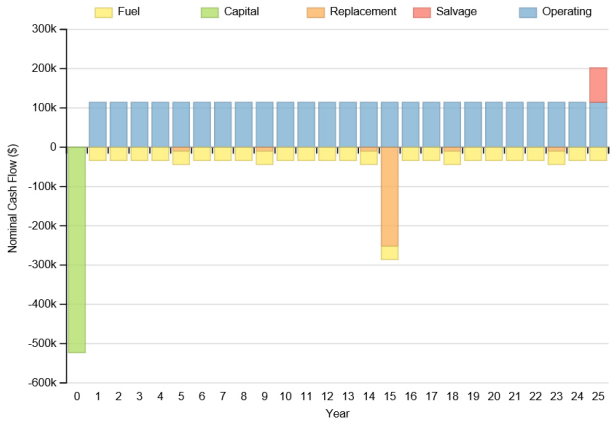

Fig. 6. The overall 25 year cost curve

VIII. CONCLUIONS

The main target of our propose system is to reduce power crisis and contribute to our national power demand, also creates different scope for producing electricity. This hybrid system is more effective than conventional quick rental coal based power plant where per unit cost is 0.23$/kWh. The per unit cost of this system is 0.13$/kWh. We used non renewable diesel power which provides some pollution. Compared to other conventional power systems it is less enough for generating electricity. But, we used diesel generator only 17%. Our collected wind speed data high are 20m, but standard wind turbine setup is 25-30 meter. If the height is increased, wind speed will be increased. Therefore, we may not need to use diesel generator for producing electricity for our target demand. Proposed hybrid system is profitable creating direct & indirect employment opportunities, but initial cost is high.

REFERENCES

[1] M. M. Hasan, M.F. Khan, "A comparative study on installation of solar PV system for grid and non grid rural areas of Bangladesh", *Developments in Renewable Energy Technology (ICDRET),2012.*

[2] http://www.powercell.gov.bd, *accessed on August 29, (2015).*

[3] www.powerdivision.gov.bd/user/brec1/30/1, *accessed on August 29,(2015).*

[4] R. M. Shrestha, G. Anandarajah, and M. H. Liyanage, "Factors affecting CO_2 emission from the power sector of selected countries in Asia and the Pacific,"*Energy Policy,* vol. 37, pp. 2375-2384, Jun 2009.

[5] NASA surface meteorology, solar & wind energy , *http://eosweb.larc.nasa.gov*

[6] (2010) Mir NahidulAmbia, Md. Kafiul Islam, Md. AsaduzzamanShoeb, Md. Nasimul Islam Maruf, A.S.M. Mohsin, "An Analysis & Design on Micro Generation of A Domestic Solar-Wind Hybrid Energy System for Rural & Remote Areas-Perspective Bangladesh.".

[7] Molla Shahadat Hossain Lipu "A Feasibility Study of Solar-Wind-Diesel Hybrid System in Rural and Remote Areas of Bangladesh" *INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH, Vol.3, No.4, 201).*

[8] Potential of micro hydro power units in Bangladesh. Available at:*http://www.lged-rein.org/*

[9] How wind turbine works. Available at:*http://www.energymatters.com.au/renewable-energy/wind-energy/*

[10] S.W. Shaahid and M.A. Elhadidy, "Optimal sizing of battery storage for stand-alone hybrid (photo-voltaic + diesel) power systems", *International Journal of Sustainable Energy*, Vol. 24, pp. 155-166, 2005.

[11] Z. Nikolic, V. Shiljkut, and D. Nikolic, "Diesel-solar electricity supply for remote monasteries", *Journal of Renewable and Sustainable Energy, Vol. 5, 041815, July 2013)*