Design and simulation of an Off-Grid Wind-Solar-Diesel Hybrid Power System in Kutubdia, Bangladesh

Sham Datto*, Md. Harun Or Roshid, Asma-Ul-Husna, Mafin Muntasir Rahman

Abstract-- This paper presents the Design and simulation of an off-grid wind-solar-diesel hybrid power system in kutubdia, Bangladesh. Wind and solar energies are the alternative energy sources that can be used to supplement the conventional energy sources particularly in Bangladesh. Homer simulation software is used to analyze the wind-solar-diesel hybrid system, local wind speed and solar radiation in kutubdia and estimated electric load in kutubdia is used. Per unit cost of energy and environmental effects like Carbon emission, sulfur dioxide, nitrogen oxides are also analyzed.

KEY WORDS: Renewable energy, Off-grid, Wind-Solar-Diesel hybrid system, Wind Turbine, converter

1. INTRODUCTION

Bangladesh is a developing country. Most of the parts of development are depend on industrialization. This is a age of science.so that industries are highly adopted with technologies. Peoples are also used technology in their domestic life. Most of the technologies are operated with electrical energy. But there is a huge shortage of electrical energy in Bangladesh. Because the sources are used for producing electricity like coal, diesel, water, gas are limited. On the other hand combustion of that fuel pollutes the environment which is a dangerous threat for all. We have unlimited and clean source energy. Those are wind and solar energy. By proper utilizing of wind and solar sources we can easily minimize the crisis of electrical energy. The cost of generation of electricity using renewable source is relatively low. The coastal area in the southern part of Bangladesh has a huge potential of wind power generation. Sandwip, Kutubdia, Maheshkhali, St. Martin are not suitable for grid-connected system. Wind-Solar-Diesel hybrid power system considerably reduces the fuel consumption cost, and carbon emission in the environment as opposed to their conventional diesel only counterpart [1],[2] and [3].This paper presents a complete design and simulation of off-grid wind-solar-diesel hybrid power system in the island Kutubdia of Bangladesh.

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2. ABOUT KUTUBDIA

Kutubdia is a coastal area of Bangladesh. Kutubdia has an area of 36 square miles, 18 miles in length and 2 miles in breadth. It is famous for the only lighthouse in Bangladesh which was built by the British during the British rule. Kutubdia is rich in producing salt and dried fish, locally known as 'Shutki'.

Native Name: Kutubdia
Locator Position: right
Latd: 21.8167
Longd: 91.8583
Division Name: Chittagong Division
District: Cox's Bazar District
Population As Of: 1991
Population Total: 95055
Population Density: 440
Area Total: 215.8

3. SOLAR DATA ANALYSIS

As some of the coastal inland parts may be viable for wind energy generation and some of the northern parts are best for solar energy.

According to the method suggested by Rangarajan et al.[4], the relation between the relative sunshine duration and state of the sky is

$$\frac{n}{N'} = \frac{an_1 + bn_2 + cn_3}{n_{123}} \quad ---(1)$$

Where n1 is the number of clear days, n2 is the number of mixed days, n3 is the number of overcast days in a month, n123 = n1 + n2 + n3 is the total number of days in the month under consideration, and a, b, c are climatological parameters. N ′is the period when the Campbell-Stokes sunshine recorder remains sensitive over the representative day for the month and [5]

$$N' = \frac{\arccos((\cos 85 - \sin\phi\sin\delta)/\cos\phi\cos\delta)}{7.5} \quad ---(2)$$

ϕ is the latitude of the station and δ is the declination . Generally to estimate the monthly averaged daily global radiation on a horizontal surface a simple and well-known model is Angstrom equation modified by [6]

$$\frac{\bar{H}}{H_o} = a + b\frac{\bar{n}}{\bar{N'}} \quad ----------(3)$$

H′/H′0 is the ratio of monthly averaged daily global to monthly averaged daily extraterrestrial radiation on a horizontal surface [6]. This ratio is known as clearness index KT, gives the percentage deflection by the sky of the incoming global radiation, and therefore indicates both the level of availability of solar radiation and changes in atmospheric conditions in a given locality while relative sunshine duration, n′/N′ is a measure of the cloud cover. Here, a and b are regression coefficients. The solar radiation data in kutubdia are given bellow.

Table 3.1 baseline data in kutubdia

Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.627	4.601
February	0.605	5.054
March	0.581	5.559
April	0.551	5.785
May	0.511	5.586
June	0.367	4.045
July	0.324	3.549
August	0.351	3.731
September	0.418	4.116
October	0.559	4.852
November	0.587	4.432
December	0.641	4.486
Average:	0.496	4.647

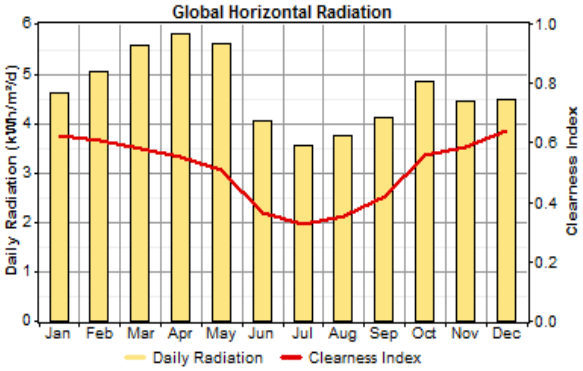

Figure 3.1: Solar resource in Kutubdia Island

4 WIND DATA ANALYSIS

The current global success story of the renewables sector is wind power, particularly where it is grid connected. Worldwide wind power installation is 8000 MW [11]. As wind velocity is rarely sufficient all the year round, wind - solar-diesel hybrid plants appear to be the most appropriate for the generation of electricity for off grid situations. Wind is generally seen as nonpolluting but the sheer size and number of turbines required can create environmental impacts. The variation of average wind speed can be determined from the following power law expression,[11]

$$\frac{V_Z}{V_{ref}} = \left(\frac{h}{h_{ref}}\right)^{\alpha} \quad ----------(4)$$

Where,

V_z = average wind velocity at height h meter (m/s)

V_{ref}= average velocity at reference height (m/s)

h = the height where the velocity of wind is to be calculated (m)

h_{ref}= reference height (m)

α = dimensional constant that varies from 0.1 to0.4 depending on the nature of the terrain

Wind speed is measured by anemometer.

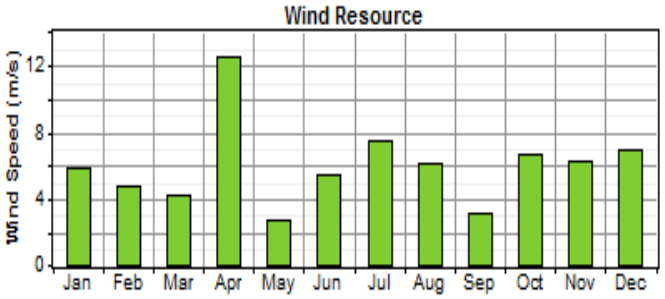

Figure 4.1: Wind resource in Kutubdia Island.

Table: 4.1 Wind speed in kutubdia at 45 m height [7]

Month	Wind speed(m/s)
January	5.830
February	4.790
March	4.150
April	12.500
May	2.700
June	5.420
July	7.500
August	6.120
September	3.140
October	6.710
November	6.200
December	6.870

5 ELECTRICAL DEMAND ANALYSIS

Kutubdia has 14,463 households in entire islands.Energy demand per day is 65 MWhr and the peak demand is 11 MW in Kutubdia.[7]

Table 5.1. Estimated demand of electricity per house

Appliance	Number(s)	Unit capacity
Light	2	50 W
Fan	2	80W
TV	1	100W
Other	1	40W

Total = 400W

6 EQUIPMENT CONSIDERED

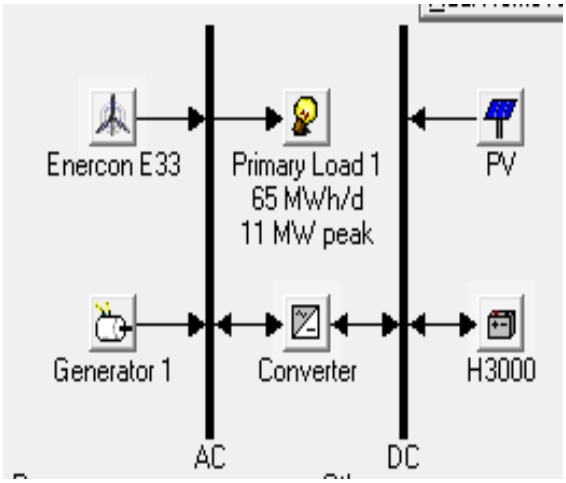

Figure 6.1 Diagram for HOMER simulation

The search space list of system component sizes, which HOMER considered for this analysis, is outlined in Table 4.1 All equipment details are given here.

Table 6.1 System Components Considered

Component	Size	Capital Cost ($)	Replacement Cost	O&M Cost ($)
PV Panels	1kw	6500	6500	0
Wind turbine	330kw AC	500000	250000	500
Trojan T-105 Batteries	225 Ah / 6 volt	1500	1500	20
Converter	1000kw	10000	10000	100
Generator	1000kw	200000	150000	0.05

6.1 Photovoltaic Panels

Photovoltaic panels were specified with capital and replacement costs of $6500/kW. This cost includes Shipping, tariffs, installation, and dealer mark-ups.

A rerating factor of 90% was applied to the electric production from each panel. This factor reduces the PV production by 10% to approximate the varying effects of temperature and dust on the panels. The panels were modeled as fixed and tilted south at an angle equal to the latitude of the site.

6.2 Wind Turbine

Average wind velocity at 45m height is 5.995 m/s in Kutubdia. Enercon E33 wind turbine is a perfect selection for low wind speed. The irregularity of wind velocity can be fixed by gear system. It has a rated capacity of 330 kW and cut-in speed of 2.5m/s .The installation cost for Enercon E33 is $500000. Considering the above factors, Enercon E33 turbine is chosen for the hybrid system.

6.3 Diesel Generator.

Diesel generators operate in parallel with the wind turbine to increase the maintenance flexibility, efficiency and distribute the electric load more optimally. Cost of per MW of diesel generator is considered to be around $ 200000.

7 SIMULATION AND RESULT

Here wind turbine output, monthly average electricity production, cash flow summery and environmental effects are discussed.

7.1 Economic Analysis:

HOMER software is used for economic analysis. Cost of diesel considered here is 0.7$/L. The simulation results depict that the production cost of electricity per KWh is 0.175$.

7.2 Homer Simulation Output

HOMER's optimization process is focused on finding the best possible system configuration from the successfully simulated configurations. The optimization process hinges on finding the lowest net present cost (NPC), which is best described in the following excerpt from the programmers. In HOMER, the best possible, or optimal, system configuration is the one that satisfies the user-specified constraints at the lowest total net present cost.

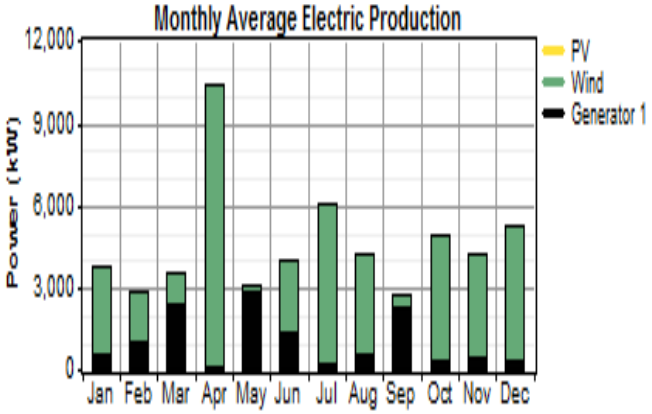

Figure 7.1 Monthly average Electricity production

Above figure 5.2.1 represent the monthly average electricity produces by wind-solar-diesel generator. Green color indicates electricity production by wind and black color indicates electricity production by diesel and yellow color indicates electricity production by the solar panel.

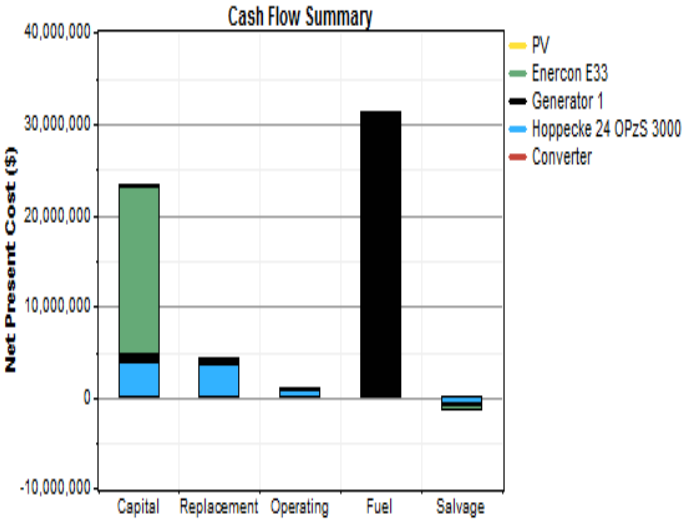

Figure 7.2: Cash flow Summery

Figure 4.3 shows net present cost of different equipment's. To meet the demand of consumers, here we have to depend on wind and diesel energy.

Less amount of solar energy is used here.

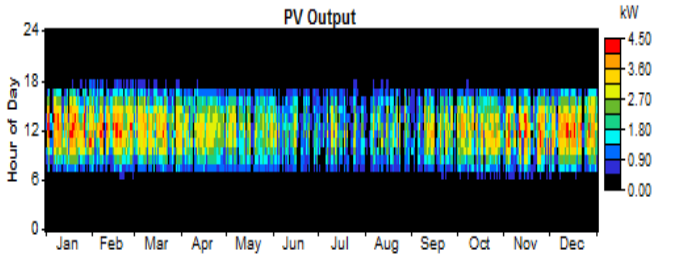

Figure 7.3: PV solar output

The PV solar cell output is shown in figure 5.2.3

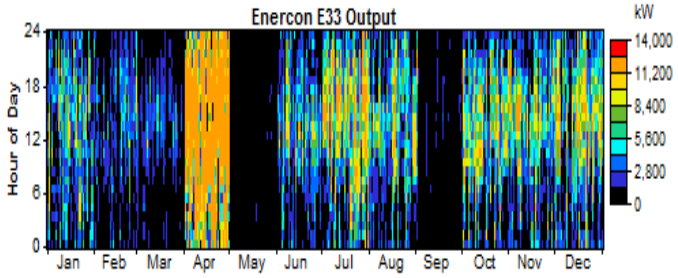

Figure 7.4: Enercon E33 output

Figure 4.1 shows the Enercon E33 turbine output over different months of the year. In April, the wind speed is high so that Enercon E33 generates more electricity. But in May, due to lower wind speed Enercon E33 generates less electricity.

8 ENVIRONMENTAL EFFECT

Due to use of renewable energy the emissions of harmful gasses are also reduced. The reduction of gas emission is determined using HOMER software.

Table 8.1. Environmental pollutants

Pollutant	Emissions (kg/yr)
Carbon dioxide	8,328,399
Carbon monoxide	20,557
Unburned hydocarbons	2,277
Particulate matter	1,550
Sulfur dioxide	16,725
Nitrogen oxides	183,436

9 CONCLUSION

Governments have now placed the environment at the heart of policy making and are committed to combining environmental sustainability with economic and social progress by using renewable energy. Concerns about the environmental impact of energy production from fossil fuels, which are finite resources, has resulted in an increased interest in renewable energy worldwide. In Bangladesh, there is some movement towards renewable energy. Kutubdia is one of the coastal area of Bangladesh.it

is an island so that it's not connected with grid. Off-Grid Wind-Solar-Diesel Hybrid Power System can be a perfect solution for electrification of the households. The proposed production cost of electricity per KWh is 0.175$.So, per unit cost of electricity generation in kutubdia Island is lesser than the proposal of [8].Here environmental pollution is lesser in comparison with the proposal of [9] and [8], due to more use of wind and solar energy than diesel energy.

10 FUTURE WORK

Future researchers may implement Off-Grid Wind-Solar-Diesel Hybrid Power System in Bangladesh.

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