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Design of a Cost Effective and environment friendly Off-Grid Wind-Diesel Hybrid Power System in Kutubdia Island of Bangladesh

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Abstract

This paper presents the Design of a cost effective andenvironment friendlyoff-grid wind-diesel hybrid power system in a grid isolated island, kutubdia, Bangladesh.Wind power is the clean source of renewable and free from harmful emissions and life cycle costs.Thiswind-diesel hybrid system is analyzed by using homer simulation software, local wind speed and estimated electric loads are used.Cost andenvironmental effects are also analyzed.Homerhas been used to perform comparative analysis of solar and wind energy with diesel and hybrid systems. Initially total net present cost (NPC), cost of energy (COE) and the renewable fraction (RF) have been measured as performances metrics to compare the performances of different systems. For better optimization, the model has been refined with sensitivity analysis which explores performance variations due to wind speed, solar irradiation and diesel fuel prices

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

1. Introduction

The HOMER Micro power Optimization modeling software, developed by the National Renewable Energy Laboratory (NREL), was designed to compare multiple power production capabilities in order to meet a particular load.The software models power systems based on the physical behavior of a system as well as on economic ramifications. HOMER allows a user to compare many different Design options based on the inherent technical and economic estimates. The details of each comparison are derived from the performance characteristics of the equipment and the unique availability of the required resources for a particular location, such assolar radiation profile, wind patterns, and price of fuel. Bangladesh is a developing country having large Population. The coastal area in the southern part of Bangladesh has a huge potential of wind power generation. On the other hand islands like Sandwip, Kutubdia, Maheshkhali, and St. Martin are not suitable for grid-connected system. WIND-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]. Introduction of wind generators in wind-diesel hybrid power systems, system stability is becoming an important factor to the power companies.

Due to the changing characteristics of wind speed the most crucial issue is to assess the capacity adequacy of the hybrid system in addressing the electricity demand of the consumers. Wind-Diesel Hybrid power systems with long term energy storage can optimally use RE resource [4].A suitable mathematical model can be developed for wind-diesel hybrid power system [5] to study frequency disturbance on an island electric system. Improved sizing method of storage units is reported in [6] and [7].This paper presents a cost effective design of off-grid wind-diesel hybrid power system in the island Kutubdiaof Bangladesh.

2. Wind Data In Kutubdia

Kutubdia is one of the coastal area of bangladesh.It has an areaaround 36 square miles (93 km^2), 18 miles (29 km) in length and 2 miles (3.2 km) in breadth. The strong south/south-western monsoon wind come from the Indian Ocean traveling a long distance over the Bay of Bengal, through the coastal area of Bangladesh [8]. This wind blows over Bangladesh from March to September with a monthly average speed of 3 m/s to 9 m/s at different heights. According to the studies of Bangladesh Meteorological Department (BMD), wind speed is high in Bangladesh during the Monsoon (7 months, March–September). In rest of the months

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(October–February) wind speed remains either calm or too low.

2.1 Wind Velocity Calculation

Wind velocity changes with height. The rate of increase of velocity with height depends upon the roughness of the terrain. The variation of average wind speed can be determined from the following power law expression terrain. The variation of average wind speed can be determined from the following power law expression [8],

$$\frac{V_Z}{V_{ref}} = \left(\frac{h}{h_{ref}}\right)^{\alpha} \text{------------}(1)$$

Where,

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

V_{ref}= average wind 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.

Table 2.**1.**Wind speed in kutubdia at 45 m height [9]

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

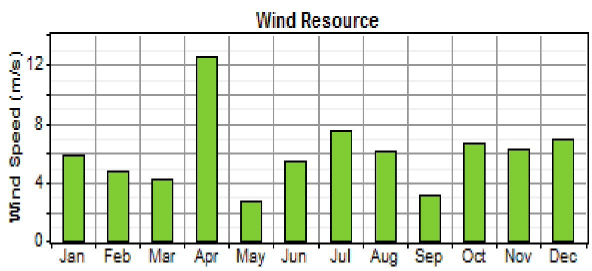

Figure 2.1: Wind resource in Kutubdia Island.

Figure 2.1 shows the wind resource in Kutubdia Island. During April the wind speed is highest, during May and September wind speed is lower. Average wind speed is 5.995 m/s, which is sufficient to generate electricity commercially.

2.2 Power Generation by Wind Turbine

Power generated by a wind turbine at particular height can be calculated by using following equation

Power in the Wind = $\frac{1}{2}\rho A V^3 C_p$[10]- - ------- --(2)

Where,

ρ = wind power density (w/m^2)

A = area swept by the rotor (m)

V = velocity of wind (m/s)

C_p = rotor efficiency

3. Wind-Diesel Hybrid Model

To design the hybrid power system in Kutubdia Diesel generator is combined with wind power generation [3].Following figure shows block diagram of wind-diesel hybrid system.

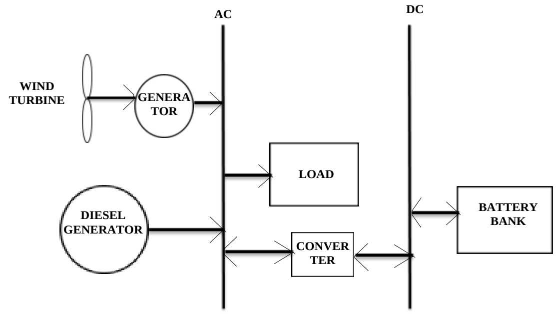

Figure3.1:Simple block diagram of wind-diesel hybrid system

Figure 3.1 shows that wind turbine is connected to a generator and a diesel generator is used. Both generators are connected to the system bus. For storage of electricity battery bank is used. Converter is used for convertion from AC to DC and DC to AC. Load is connected to the AC bus.

3.1Analysis of Electrical Demand in Kutubdia:

Table 3.1.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

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

3.2 Proposed hybrid system for Kutubdia

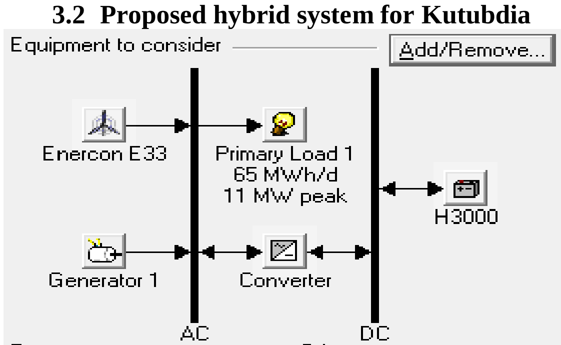

Figure 3.2: Diagram forHOMER simulation

Figure 3.2 shows the proposed hybrid system for HOMER simulation. Enercon E33 wind turbine produces AC output, so it is connected to the AC bus in parallel with the diesel generator. Battery bank is connected to the DC bus. Converter is placed between the two buses. Load is connected to the system through AC bus.

3.2.1Wind Turbine

Average wind velocity at 45m height is 5.995 m/s in Kutubdia. But at winter, wind speed goes below the average wind velocity. Cut-in speed of high capacity wind turbine is more than about 4 m/s. 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.

3.2.2Diesel Generator

In the proposed system diesel generator is used. 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.

3.3 Cost of other equipment's

Table 3.2.Cost of equipment's

Equipment	Cost($)
Battery	1500/string
converter	1350/MW

4. Simulation Result And Analysis

In the simulation, wind turbine output, monthly average electricity production, cash flow summery and environmental effects are analyzed.

4.1Economic Analysis:

Here HOMER software is used for economic analysis.Cost of diesel considered here is 0.7$/L.The simulation results depict that the production cost of electricity per KWh is 0.184$.

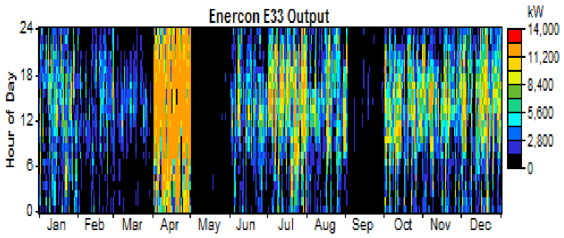

Figure 4.1: Enercon E33 output

Figure 4.1 shows the Enercon E33 turbine output during different months of the year. In the abovefigure,during April,the wind speed is higher and Enercon E33 generates more electricity. During May, due to lower wind speed Enercon E33 generates less electricity.

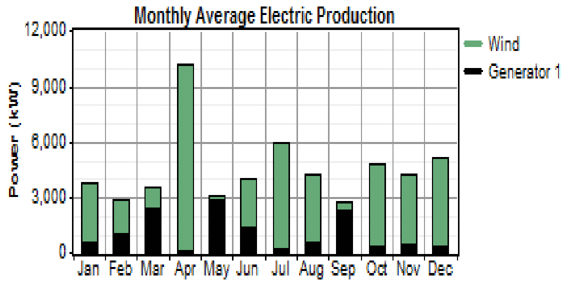

Figure 4.2: Monthly average Electricity production

Figure 4.2 shows electricity production by wind turbinesand diesel generators. Green color indicates electricity production by wind and black color indicates electricity production by diesel. When wind speed is higher, we have to be less dependent on diesel generators. As a result cost of electricity production reduces during that time. During May the wind speed is lowest. To meet the demand of consumers, here we have to depend on diesel energy.

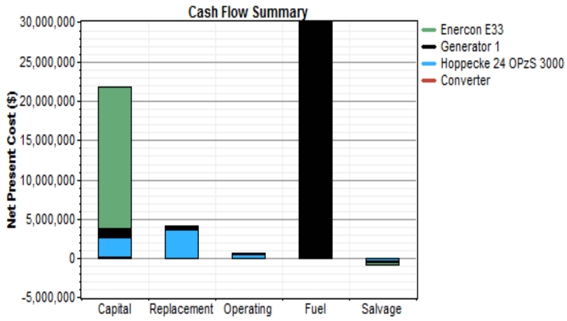

Figure4.3: Cash flow Summery

Figure 4.3 shows net present cost of different equipment's.

4.2 Environmental Effect

Wind-diesel hybrid system with reduces gas emission by a significant amount due to reduced fuel consumption. The reduction in gas emission is determined using HOMER software.

Table 4.1.Environmental pollutants

Pollutant	Emissions (kg/yr)
Carbon dioxide	8,827,363
Carbon monoxide	21,789
Unburned hydocarbons	2,414
Particulate matter	1,643
Sulfur dioxide	17,727
Nitrogen oxides	194,426

5. Conclusion

In Bangladesh only 39% of the populations have access to electricity. Remote areas, like islands cannot be connected to the grid as they are discrete from main land. Due to high cost of diesel, only diesel-based power generation is not economically feasible. For this island, wind-diesel hybrid can be a perfect solution for electrification of the households.

The proposed production cost of electricity per KWhis 0.209$.So, per unit cost of electricity generation in kutubdia Island is lesser than the proposal of [11].Here environmental pollution is lesser in comparison with the proposal of [8] and [11], due to more use of wind energy than diesel energy. The results of HOMER simulation and modeling shows that if, cash flow summary, electrical production or emissions and cost of wind turbine, battery and converter us considered as a whole, Wind-diesel hybrid system is far better than a system with only diesel generator due to high cost of diesel.

6. Future Work

Future researchers may design cost effective wind turbine and implement it in the wind-diesel hybrid power system.

7. Acknowledgement

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