Design of a Hybrid Power Generation System for a Remote Area in Bangladesh Combining Solar & Wind Power

Shantu Ghose, Debangshu Barua, Ashab Uddin, Animesh Roy Chowdhury, Stabak Das

Abstract- This project aims at designing an off grid solar-wind hybrid system for a remote locality. First of all, availability of solar and wind resources for a particular location in Chittagong has been checked. According to the solar irradiance and wind speed data Parki Sea Beach has been chosen as project site which is situated in Gahira, Anwara thana under southern part of Chittagong, Bangladesh. Different combinations have been selected by using HOMER in order to find minimized solution considering both cost and electricity production.

Index terms- Hybrid Power System, HOMER, Weibull function.

I. INTRODUCTION

In the history of Bangladesh, power crisis has reached the worst-ever level especially during the hot summer days. Present electricity coverage in Bangladesh is only 43%. A booming economic growth, rapid urbanization and increased industrialization and development have increased the country's demand for electricity. Presently, 62% of the total population has access to electricity and per capita generation is 321 kWH, which is very low compared to other developing countries [1]. Presently, the generation capacity is nearly 10,264MW (December, 2013) [2] which implies that much endeavor is required to achieve the goal. Considering the country's future energy security, the government has rightly given due importance on renewable energy, energy efficiency as well as energy conservation. Renewable energy sources can be an effective solution of energy crisis in our country. In this paper, we designed an off grid solar-wind system for a remote locality (Parki Sea Beach, Chittagong) [3]. Absence of grid supplied electricity and availability of wind and solar resource encouraged us to select that place. In our proposed design, about 500 houses can be supplied with electricity.

II. SOLAR AND WIND RESOURCE

A. Solar Availability

Global Horizontal Irradiance (GHI) is the total amount of shortwave radiation received from above by a surface horizontal to the ground. This value is of particular interest to photovoltaic installations and includes both Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DIF). Based on the measured data on average GHI and daily sunlight hours Parki beach seems to be a perfect place for installing solar power plant.

Table I

	Average GHI kWh/m^2	**Average daily sunlight (Hour)**
Required	3	6
In Parki beach	4.23	6.6

B. Wind Energy

The wind resource varies with of the day and the season of the year and even some extent from year to year. Wind energy has inherent variances and hence it has been expressed by distribution functions. In this paper, we use Weibull probability distribution function to estimate wind feasibility for Parki beach.

Weibull probability distribution function is given by [4]

$$f(v;k,c) = (\frac{k}{c}) \times (\frac{v}{c})^{k-1} \times e-(\frac{v}{c})^k \tag{1}$$

Where k>0, shape parameter

c>0, scale parameter

v, wind speed

Here cumulative distribution function is used to describe the probability that the real valued random variable V with a given probability distribution will be found at a value less than or equal to v.

The cumulative distribution function is given by [4]

$$f(V \leq v) = 1 - e^{-(\frac{v}{c})^k} \tag{2}$$

Where Justus approximation are used [5]

$$k = \frac{\sigma}{v}^{-1.086} \tag{3}$$

$$c = \frac{\bar{v}}{\Gamma\left(1+\frac{1}{k}\right)} \tag{4}$$

The gamma function,

$$\Gamma(n) = \int_0^\infty x^{n-1} e^{-n} dn \tag{5}$$

Mean wind speed,

$$\bar{v} = (\sum_{i=1}^{n} \frac{fivi^n}{\sum_{i=1}^{n} fi})^{1/n} \tag{6}$$

Standard deviation,

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$$\sigma = \frac{\sqrt{\sum_{i=1}^{N} fi*(vi-\bar{v})^2}}{\sum_{i=1}^{N} fi} \quad (7)$$

TABLE II

Location	Annual mean value of k	Annual mean value of c
Parki beach	1.64	5.11

With the help of equation (1) and (2) we calculated annual probability distribution function as shown in fig. 1.

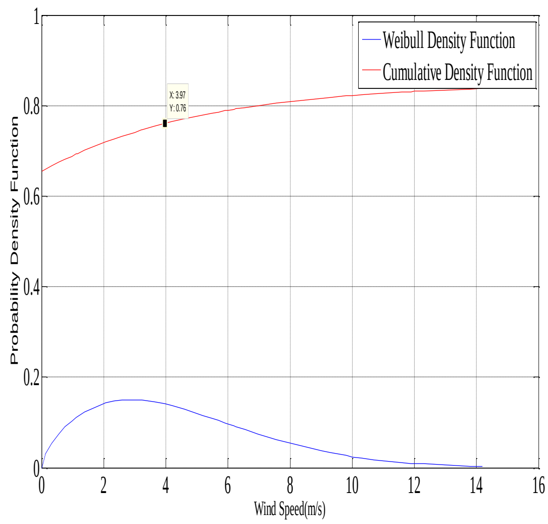

Fig. 1 Weibull Density Function vs Wind Velocity for Parki Beach

Assuming that cut in speed is 4m/s, from figure 1 we get Probability of getting output power is (v >4m/s)=1-0.76=0.24. That means 24% time we will get output power.

III. OVERALL SYSTEM

The diagram of overall system is interpreted in Fig. 2. Here we considered 9 wind turbines. The output of turbine is rectified to 120V dc and supplied to the DC bus. The output of PV panel and battery are also 120V dc. Our peak load is 34 kW. So bus current for 120V bus voltage is 34kW/120V = 283.33A. This 283.33A is distributed into 5 parallel cables and each contains 56.67A current at 120V. This 56.67A current is fed to feeder. There are about 180 household under each feeder.

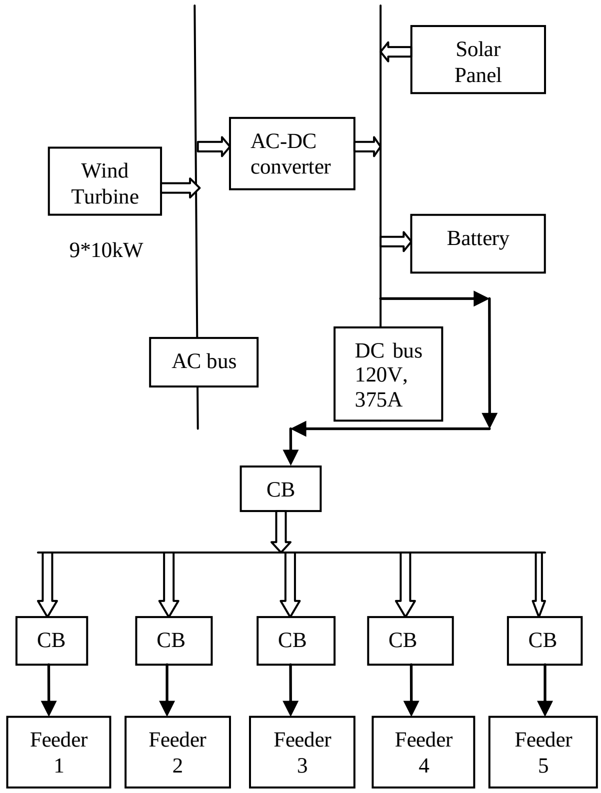

Fig. 2 Block Diagram of Overall System

IV. LOAD CALCULATION

We have considered following loads for different households:

Light (L1): A 15W CFL light

Light (L2): A 5W LED lamp

DC Fan (F1): A 20W 26 inch ceiling fan

Mobile charger (M1): A 5W mobile charger

We choose 20 houses randomly to calculate demand factor. A total of 6 combinations of active loads have been selected and are shown in table III. To calculate demand factor, we have distributed these 6 combinations to 20 houses according to relative weight.

Table III
Various Combinations of Loads

Combinations	On-off state				Total Loads (W)
	L1	*L2*	*F1*	*M1*	
C1	√	√	√	√	45
C2	√	√	√	×	40
C3	×	√	√	×	25
C4	×	√	√	√	30
C5	×	√	√	√	30
C6	×	√	√	×	25

In summer season, consumers are compelled to use fan (F1). So we considered it for all combinations. Consumers can use L2 lamp than L1 to save electricity bill. We choose LED lamp for energy saving purposes.

Average household demands = (6×C1+2×C2 +4×C3+ 5×C4+ 2×C5+ 1×C6) ÷ 20 = 33.75W

Demand factor = 33.75÷45

= 75%

Here we considered to supply electricity to 500 houses. For peak value of 45W, the plant capacity is 45×500=22.5 kW.

V. HOMER SIMULATION

HOMER, the micropower optimization model, simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications [6-7]. According to our system model, the system configuration in HOMER is shown in fig. 3.

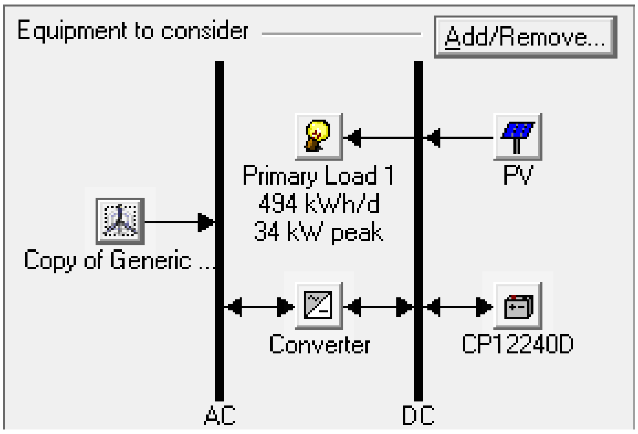

Fig.3 System Configuration in HOMER

For energy balance calculation, costs of various components are given in table IV.

Table IV
Input Parameters for HOMER Simulation

Parameter	Capital cost ($/kW)	Replacement cost ($/kW)	O&M ($/yr.)
PV module	4615	3692	8
Wind turbine	2000	1540	8
Converter	420	350	1
Battery	30	28	1

Here, the nominal voltage of battery is 12V and nominal capacity is 24Ah (0.288 kWh) and lifetime throughput is 103kWh.
Using above data we get HOMER optimization results which are shown in table V.

Table V
Cost Analysis of Optimization Result

Initial capital $	Operating cost $/yr	Total NPC $	COE $/kWh
162900	15.634	362753	0.187

From the above optimized result, we can see that it has contribution from both energy sources.
Here we get all (100%) of the generation from renewable sources as shown in table VI.

Table VI
Analysis of Optimized Result

Production	kWh/yr	%
PV array	133569	60
Wind turbine	88292	40
Total	221862	100

VI. COST ANALYSIS

We assume that the lifetime of the project will be 25 years. Optimized cost analysis is shown in table VII. From the table we can see that although renewable sources have high capital cost they have low replacement and operation and maintenance (O&M) cost and no fuel cost [8].

Table VII
Analysis of Optimized Cost

Component	Capital ($)	Replacing Cost($)	O&M ($)	Fuel ($)	Total($)
PV	92300	0	2045	0	85743
Wind turbine	16000	0	818	0	16818
Battery	54000	193984	23010	0	259573
Converter	600	0	18	0	618
System	162900	193984	25892	0	362753

VII. Conclusion

Our designed system is suitable for a remote locality where grid connection is not available. It includes DC modeling system and omits costly inverter reducing transmission loss. This is an off grid energy efficient system which is very suitable for a developing country like Bangladesh. In our proposed system the cost of energy is 0.187$/kWh or 15.33tk/kWh. Diesel based power plant generally cost more than 20tk/kWh in our country. So our designed system is more cost efficient.

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