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RESEARCH ARTICLE

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COST EFFECTIVE AND HIGHLY EFFICIENT HYBRID RENEWABLE ENERGY SYSTEM FOR KUTUBDIA ISLAND OF BANGLADESH

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ABSTRACT

Kutubdia is one of the coastal islands in Bangladesh. There is no availability of all types of fuels except diesel, kerosine and wood in this island. Hybrid sources such as wind and solar are the only options for fulfilling the energy demand. Hybrid optimization software which is called HOMER, is used for representing and scrutinizing hybrid power systems. HOMER software has been used to find out the best technically viable renewable based energy efficient system for different number of households. Additionally, HOMER contains a powerful optimizing function that is used in determining the cost of various energy project scenarios.

Key words: HOMER, PV-Wind energy, DLR ,GHI(Global Horizontal Insulation), Weibull factor

INTRODUCTION

Kutubdia is located at 21.8167°N 91.8583°E. It has 14,463 households and total area 215.8 square kilometers (83.3 sq mi). Actually, Kutubdia Island is famous for its light house and the magnificent beauty of sea shore though it is very small in size; it has the ability to lead all the huge land by its Natural Beauty. The kutubdia beach is one of the most attractive beach in the world and It is no way less attractive than Cox's Bazaar Sea Beach. The scenery of Sun-set and Sun-rise are obviously stunning for all natural beauty lovers. The impressive and unimaginative way of producing and manufacturing Salt is very interesting to the visitors, actually foreigners . There are windmills beside the shore which may also be a point of attraction for the tourists. From recent survey, Kutubdia has a population of 95055. Males constitute 51.66% of the population, and females 48.34%. This Upazila's eighteen up population is 41755. and recorded that where most of them are fisherman and they belong to 1178 families.

Kutubdia is an isolated island. Normally, electricity is generated by kerosene, diesel generators in this remote island. Predominately, this process is highly risky and time consuming to transport diesel to this isolated island and also very expensive, difficult. We are trying to replace diesel and kerosene with the energy generated by the Hybrid Renewable energy (solar and wind) Project. When we supply electricity at 11KV levels or more levels, the diesel generators are stopped completely. Till to date, more than 240 MWh. electrical energy is supplied to the consumers of the Kutubdia islands. One kWh electricity from diesel is costing more than Tk.40.00 here in Kutubdia. So, by using this project, we can be saved diesel and kerosene of Tk.89,00,000.00. BPDB has earned Tk.21,00,000.00 by selling power to the consumers. Moreover, it will be possible to save

Green House Gas Emissions (Carbon-Di-Oxide) for preserving it's natural beauty .

The Island has a good potential of solar and wind energy resources. But till now, for the political turmoil and lack of awareness and publicity , there has no such activity to use these resources. Therefore HOMER (Hybrid optimization Model for Electric Renewables), a software developed by National Renewable Energy Laboratory (NREL), USA for micro-power optimization model, has been used to find out the best energy efficient renewable based hybrid system options for the Island. It contains a huge number of energy consumption models and evaluates suitable technology options based on cost and availability of resources in this island. Finally, Analysis has been done for single home user as well as combination of 20, 40 and 60 home users to get the most economic and technical viable options.

AVAILABILITY OF ALTERNATE ENERGY SOURCES

There is no ground measurement data of solar radiation for the Island. But according to NASA satellite, it has been found that the annual solar insulation is 6.12 kwh/m^2/day [6]. An estimation of solar insulation on horizontal surface has been done by using well known Angstrom Correlation and the sunshine hour data of Teknaf, Bangladesh Meteorological Department, the nearest meteorological station .Also a method has been developed by DLR, Germany which is a combination of DLR / SUNY –model output for Global Horizontal Insulation (GHI) is sampled for 10 km spatial resolution, and the calculated data has been collected from the SWERA Geospatial Toolkit for Bangladesh, developed under the SWERA project [7]. Table 1 shows the values of monthly solar insulation on horizontal surface for Kutubdia, observed from NASA for the period of 10 years (1983 – 1993) and estimated values from Teknaf sunshine data, also for 10 years (1992 – 2001). DLR method used three years (2010, 2011, 2012) satellite data for cloud cover, aerosol optical depth, water vapor to calculate GHI.

In Bangladesh, adequate information on wind speed over the country and particularly on wind speed at hub heights of wind machines is not available. A number of previous studies showed that the wind monitoring stations of Bangladesh Meteorological Department (BMD), situated in built up areas, measure low wind speed near the ground level at height of around 10 meter but the seacoast and coastal islands hould have a good many locations with prospective wind speed. For Wind resources information, Bangladesh Council for Scientific and Industrial Research (BCSIR) has measured wind speed for the period of three years (2010-2013) at a height of around 32 meters above the ground level. Table 2 shows the monthly averaged measured wind speed at 32 m height and the NASA values for the same location at 10m height for terrain similar to airport. It has been found that wind speed goes to maximum and minimum at around 9:30 o'clock in the night and morning of local time respectively.

Seven tidal gauge stations were set up by Bangladesh University of Engineering and Technology (BUET) for the feasibility study of tidal energy . But the result was not in favor. So, only the solar and wind sources have been considered to find out the best hybrid options of renewable based efficient system.

Table 1: GHI values for Kutubdia's Island

Month	NASA	Estimated (from sunshine)	DLR
Jan	4.92	4.23	4.74
Feb	5.60	4.62	5.17
Mar	6.53	5.37	5.62
Apr	6.48	5.87	6.47
May	6.12		5.08
June	3.83	4.13	3.55
Jul	3.80	3.97	3.51
Aug	3.77	4.10	3.90
Sept	4.50	4.26	4.18
Oct	4.72	4.43	4.38
Nov	4.56	3.80	4.62
Dec	4.60	3.85	4.27
Annual	4.84	4.40	4.50

Table 2: Wind Speed data for Kutubdia's Island

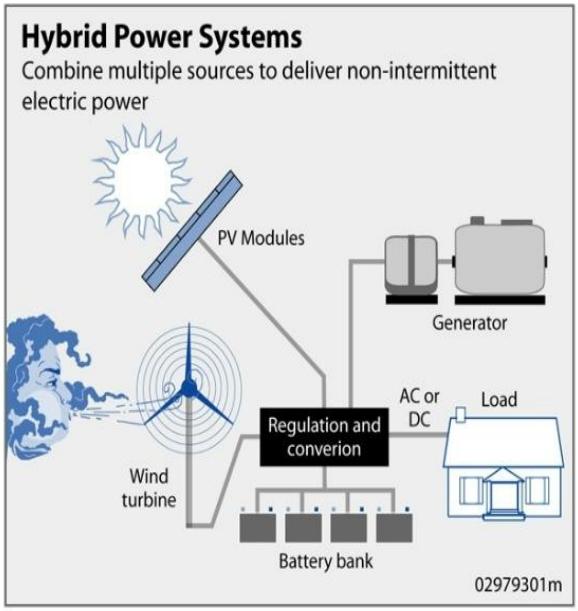
Month	NASA (10m)	Measured (30m)
Jan	3.41	5.23
Feb	3.49	4.93
Mar	3.66	4.42
Apr	3.76	3.98
May	4.02	5.19
June	6.50	6.37

Jul	6.53	5.73
Aug	5.46	5.87
Sept	4.20	4.63
Oct	3.27	4.11
Nov	3.43	3.89
Dec	3.10	4.33
Annual	4.41	4.91

HYBRID OPTIONS ANALYSIS FOR ENERGY EFFICIENT SYSTEM

A hybrid energy system generally consists of a primary energy sources working in parallel with standby secondary energy storage units. HOMER has been used to optimize the best energy efficient system for Kutubdia considering different load and wind – PV combination. Figure 1 shows the schematic diagram of a (a) hybrid energy system for power generation and (b) reflects the propose scheme as implemented in HOMER simulation tool. HOMER simulates the operation of a system by making energy balance calculations for each of the 9,540 hours in a year. For each hour, HOMER compares the electric and thermal demand in the hour to the energy that the system can supply in that hour, and calculates the flows of energy to and from each component of the system. For systems that include batteries or fuel-powered generators, HOMER also decides for each hour how to operate the generators and whether to charge or discharge the batteries.

HOMER performs these energy balance calculations for each system configuration that anybody wants to consider. It then determines whether a configuration is feasible, i.e., whether it can meet the electric demand under the conditions that have been specified, and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel and interest.



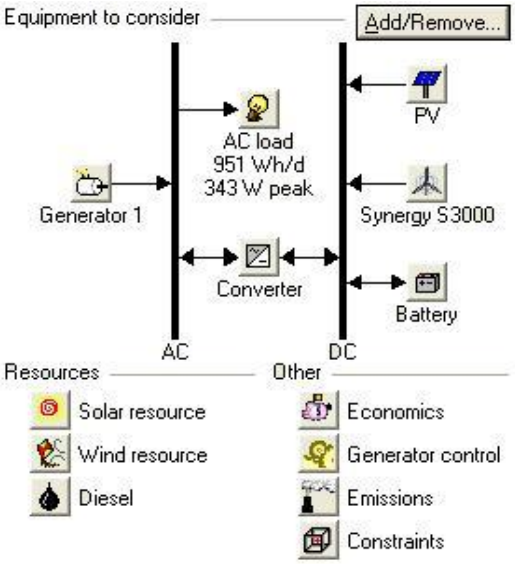


Figure 1: (a) Schematic diagram of hybrid energy system (b) proposed hybrid system in HOMER

Table 3:Speed comparison with other islands in Bangladesh

Locations	**Months**	**Avgerage wind speed** (m/s)	**Theoritical Available power(W/m2)**
Kutubdia	Jan to Dec	6.19	90.90
Teknaf	Jan to Dec	3.23	89.74

sandwip	Jan to Dec	5.23	54.74
Kuakata	Jan to Dec	3.48	74.75

From the Table .it is clear that Kutubdia is best place for establishing Hybrid renewable energy and Information about the load, resources, economic, constrains, controls and other component that have been used in HOMER are given below;

Electric Load

A typical load system (table 3) for single home in the remote areas has been considered for the analysis. Monthly averaged hourly load demand (Bangladesh perspective) has been given as an input of HOMER and then it generates daily and monthly load profile for a year (figure 2). It has been found that for this system each home user consume energy around 350 Wh/day with a peak demand of nearly 118 W.

Table 3: Appliances for single home user

Appliance	Quantity	Capacity (W)	Maximum use hour / day
Florescence Light	5	12	5
B / W TV	1	16	4
Radio / Cassette Player	2	10	8

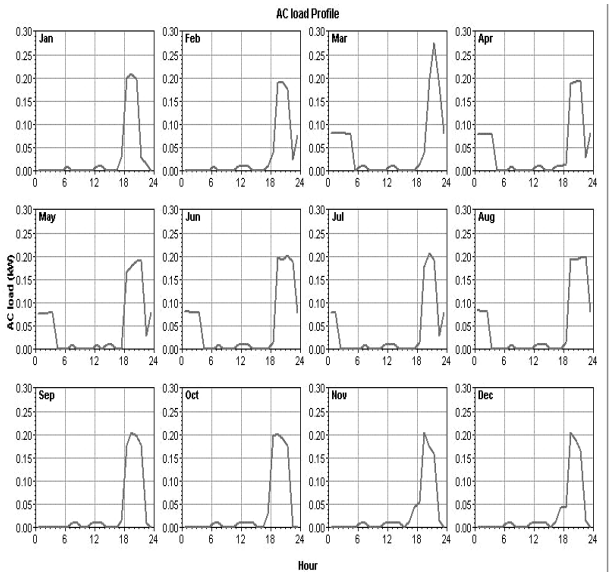


Figure 2: Monthly averaged hourly load profile for a single home user

Renewable Resources

As hourly data is not available therefore monthly averaged global radiation data has been taken from NASA. HOMER introduces clearness index from the latitude Information of the selected site (figure 3). HOMER creates the synthesized 8954 hourly values for a year using the Graham algorithm [9], which results in a data sequence that has realistic day-to-day and hour-to-hour variability and autocorrelation.

For wind monthly averaged (2010-2013) measured data from BCSIR have been used along with the information of height = 30m, elevation = 3m asl, surface roughness = 0.04m. HOMER synthesized these monthly average data based on the other parameters such as Weibull factor "k" = 1.8, Autocorrelation factor (randomness in wind speed) = 0.90, Diurnal pattern strength (wind speed variation over a day) = 0.25, Hour of peak wind speed = 22 to generate hourly data for a year. Figure 4 shows averaged hourly wind speed for 1 year.

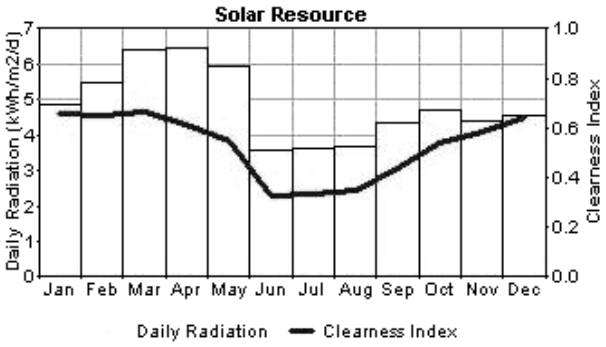


Figure 3: Monthly average global radiation data

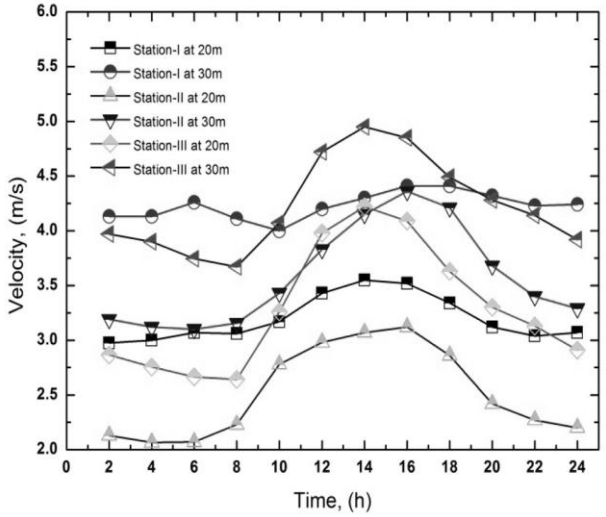


Figure 4:daily Wind Speed for Kutubdia

Hybrid System Components

Photovoltaic Module:

The cost of PV module including installation has been considered as 220 BDT / W for Bangladesh. Life time of the modules has been taken as 25 years and these are tilted at 21 degree with no tracking mode. (1 USD = 78.7 BDT, 2014)

Wind Generator:

The load demand is very low for a single home system and the price per KW turbine cost is very high for low capacity wind turbine compare to that of high capacity ones. Also low capacity wind turbine is not much available. Now a day, research and development are going on to improve the technology and designing low capacity turbine with low cut-in speed at around 2.7 m/s. For these analysis a Synergy S 3000 turbine with a capacity of 0.5 KW has been considered. The cost of the turbine with tower and installation has been considered as 98000 BDT / turbine. For the load higher than 1 KW, turbine from Southwest Windpower, (model: W175, capacity: 3.3 KW) has been considered at the cost of 220000 DBT/ turbine with tower and installation.

Options analysis was done for only PV and Only Wind also.

Battery with Controller:

As the system considered the DC load only, battery and controller were also as a main part of the system. Battery from GATCO Company has been used at a cost of 10,000.00 BDT / battery with charge controller.

Economics and Constraints:

The project life time has been considered to be 25 years and the annual real interest rate has been taken as 4%. As the system has been designed for single and also for multiple home users like 40, 60, 80 and 100 but the load consumed by the user is low so operation and maintenance cost has been taken 500 BDT / year. There is no capacity shortage for the system and operating reserve is 14% of hourly load. No cost subsidy has been taken.

Analysis

Analysis shows that the cost of energy (KWh) is low for the system which is the combination of 100 homes. Table 4 shows the load demand for each combination of homes with system architecture and financial summary. A detailed analysis and system architecture for the 100 homes system has been given figure 5

Table 4: HOMER analysis and results

Home	**Load**	**PV module** (KW)	**Wind Generator** (quantity)	**Battery** (quantity)	**Initial Cost** BDT	**Total NPC**
Single	338 Wh/day 115 KW Peak	0.15	0	2	51,890	93,470
40	6.8KWh/day 2.3 KW peak	1.0	1	16	580,000	841,480
60	10.1 KWh/day 3.5 KW	2.0	1	24	878,890	1,263,300
80	13.5 KWh/day 4.6 KW	2.5	2	24	1,188,330	1,599,590
100	16.9 KWh/day 5.8 KW	3.5	2	8 (Surrette 6CS25P)	1,567,220	1,840,985

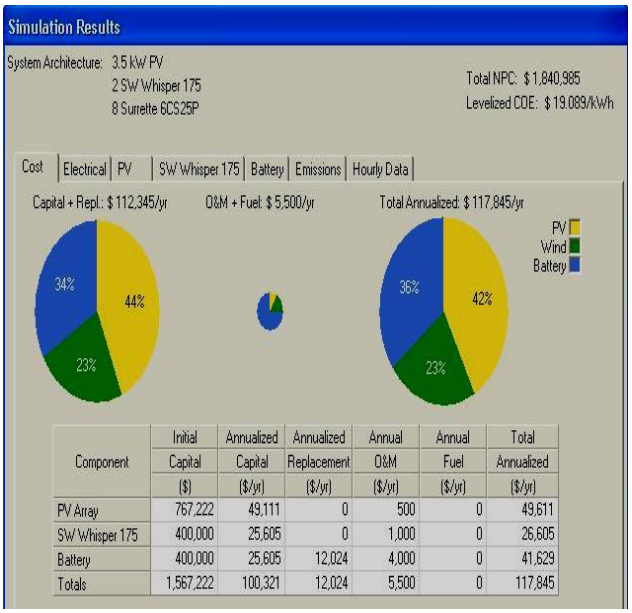


Figure 5: Simulation results for the 100 homes system

CONCLUSION

Energy is the backbone and key instrument for development ,but, severe scarcity of power in

Bangladesh has become a threat to the economical and industrial development. Using of hybrid power generations came forward due to high prices of generating power from oil and also due to the limited availability of such kind of non-renewable sources. Renewable energy systems are very much site specific and designing so that such a system is complicated. So that we can be can be drawn a picture that there is huge potential of hybrid wind-solar power generation in Bangladesh and could be summarized from the analysis that it will be better to use wind-solar combination system for 100 homes instead of single home system. Actually the total cost of energy would be low if the solar cell and turbine cost decreases.

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