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Renewable Energy-based BTS for Remote Locations in Bangladesh

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Abstract: In this paper, energy efficient renewable energy-based Base Transceiver System (BTS) for an isolated location, such as Saint Martin's Island, has been proposed. Saint Martin's is one of the most beautiful tourist islands in Bangladesh where grid connected electric system for the residents and for the telecommunication system will not be possible to launch even in future. Thus the telecommunication network coverage does not exist. The residential consumers use diesel, kerosene and wood for fulfilling their energy demand. Solar and wind resources are the hybrid options for the island. HOMER, a software for optimization of renewable energy-based hybrid systems, has been used to find out the finest technically, economically and environmentally viable renewable energy-based efficient system. Analysis has been done for operating a BTS which consumes a constant power of about 1.5 kW all the days of the year.

Key words: Solar and wind resources, hybrid system, solar radiation, wind generator, photovoltaic and base transceiver system (BTS).

Introduction

Global warming from greenhouse gases, mainly CO_2, is one of today's most important environmental issues. Electricity production is often a source of CO_2 emissions, for instance when fossil fuel is combusted in power plants. Electricity has a direct cost associated with it and the global price of electricity has increased steadily during the last decades. In some parts of the world there is still no electricity available or it is unreliable. In these situations the benefits of telecommunication cannot reach to all. Thus remote telecommunication systems present a special energy supply challenge, because they require reliable, unattended power system operation in locations where grid power is not available. In this paper, the best suited hybrid power system is proposed for operating a BTS so that the population of Saint Martin's as well as tourists do get the coverage of telecommunication network.

The advantages the telecommunication can bring to education, commercial, medical and government activities are too numerous to mention; suffice to say that its expansion plays an important role in the economic and social development of a country. One important benefit of a penetrative telecom infrastructure is that it can enhance instant communication between Bangladeshis and people in distant places around the globe.

Saint Martin's Island is located on the southern-most tip of Bangladesh, roughly between 20° 34′ - 20° 39′ N and 92° 18′ - 92° 21′ E and 17.2 kilometres off Taknaf, the most southern mainland of Bangladesh. The Island is flat and just only about three metre high from the sea level. The island is very much resourceful with enormous biological diversity such as existing fauna and flora—coral, mollusk, fish, amphibian, turtle, snail, bird and mammals. Besides above, coconut tree is the important cash crop (Biodiversity and Eco tourism Project, 2004).

Recently the Government has taken decision to formulate a master plan for development and protection of bio-diversity of St Martin's Island and also to build several establishments for the tourism development at St Martin's Island (News from Voice of America, 2005).

A survey was done by the Sustainable Rural Energy (SRE) Programme of Local Government Engineering Department (LGED) in 2004 and recorded that the population of the Island is 5196 where most of them are fishermen and they belong to 778 families. The annual electric energy demand was found to be about 359 MWh (LGED, 2004). There is a 30 KW diesel generator in St. Martin's Island installed by PDB (Power Development Board), but it is not running (Hossain, A., 2001). People meet their energy demand through kerosene, coconut palm or by other biomass plants. All these mentioned sources are generating greenhouse gases. The island has a good potential of solar and wind energy resources. But till now 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 renewable energy-based hybrid system options for the island. It contains a number of energy component models and evaluates suitable technology options based on cost and availability of resources (HOMER, V – 2.14). Analysis has been done for operating a BTS which consumes a constant power of about 1.5 kW all the days of the year (NASA, released 5.1).

Availability of Alternate Energy Sources

The average solar insulation over St Martin's is 4.84 kwh/m^2/day as found from the NASA satellite data (SWERA project, 2005). An estimation of solar insulation on horizontal surface has been done by using well known Angstrom Correlation and the sunshine hour data of Teknaf, Bangaldesh Meteorological Department, the nearest meteorological station from St Martin's. Also a method has been developed by DLR, Germany which is a combination of DLR and 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 (Saiful Islam, 2005; SWERA project, 2005). Table 1 shows the values of monthly solar insulation on horizontal surface for St Martin's, 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 (2000, 2002 and 2003) satellite data for cloud cover, aerosol optical depth and water vapour to calculate GHI.

For wind resources information, Bangladesh Council for Scientific and Industrial Research (BCSIR) has measured wind speed for the period of three years (1999–2001) at a height of around 30 metres above the ground level. Table 2 shows the monthly averaged measured wind speed at 30 m height.

Seven tidal gauge stations were set up by Bangladesh University of Engineering and Technology (BUET) for the feasibility study of tidal energy (Graham, V.A. et al., 1990). But the result was not in favour. So, only the solar and wind sources have been considered to find out the best hybrid options of renewable energy-based efficient system.

Table 1: GHI values for St Maritn's Island

Month	*NASA*	*Estimated (from sunshine)*	*DLR*
Jan	4.84	4.00	4.63
Feb	5.46	4.44	5.04
Mar	6.41	5.37	5.62
Apr	6.48	5.87	6.47
May	5.96	5.43	4.94
June	3.60	4.10	3.39
July	3.62	3.87	3.31
Aug	3.69	3.95	3.78
Sept	4.34	4.09	3.96
Oct	4.72	4.21	4.28
Nov	4.42	3.72	4.54
Dec	4.54	3.75	4.16
Annual	4.84	4.40	4.50

Table 2: Wind speed data for St Martin's Island

Month	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Annual*
Measured (30 m)	5.03	4.70	4.24	3.79	5.07	6.17	5.56	5.78	4.47	4.11	3.53	4.11	4.71

Hybrid Options Analysis for Energy Efficient System

A hybrid energy system generally consists of primary energy sources working in parallel with standby secondary energy storage units. HOMER has been used to optimize the best energy efficient system for St Martin's considering different load and wind—PV combination. Figure 1 shows the schematic diagram of (a) a hybrid energy system for the power generation of a BTS and (b) reflects the proposed scheme as implemented in HOMER simulation tool. 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.

Information about the load, resources, economic constraint, controls and other components that have been used in HOMER are given below.

Power Requirement of a BTS

The operating power of BTS is about 1.5 kW (Nortel UMTS BTS) which has been considered for the analysis. Monthly averaged hourly load demand 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 the primary load is about 36 kWh/day with 2.3 kW_P.

Renewable Resources

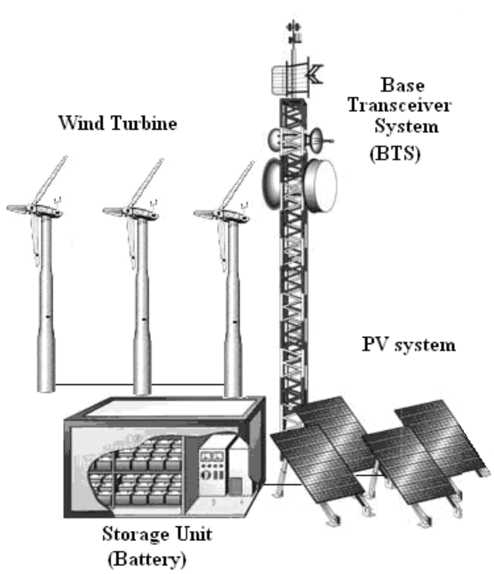
As hourly data is not available, monthly averaged global radiation data has been taken from NASA. HOMER introduces clearness index from the latitude information of the selected site (Figure 3). HOMER creates the synthesized 8760 hourly values for a year using the Graham algorithm (Graham, V.A. et al., 1990), which results in a data sequence that has realistic day-to-day and hour-to-hour variability and autocorrelation.

For wind, monthly averaged (1999–2001) measured data from BCSIR have been used along with the information of height = 30 m, elevation = 3 m asl and surface roughness = 0.01 m. 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 (a) the wind speed probability distribution function and (b) averaged hourly wind speed for one year.

Hybrid System Components

Photovoltaic Module

The cost of PV module including installation has been considered as 300 BDT/W for Bangladesh. Life time of the modules has been taken as 25 years and these are



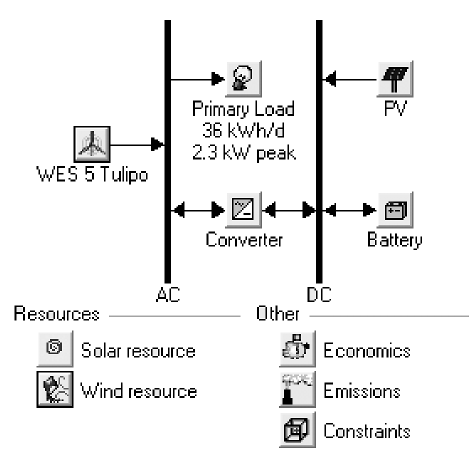


Figure 1: (Left) Schematic diagram of hybrid energy system; (Right) proposed hybrid system in HOMER.

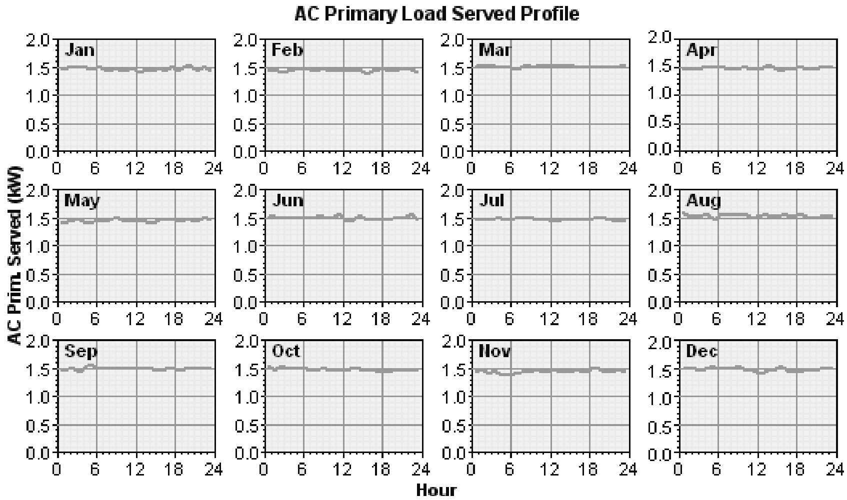


Figure 2: Monthly averaged hourly load profile for a BTS.

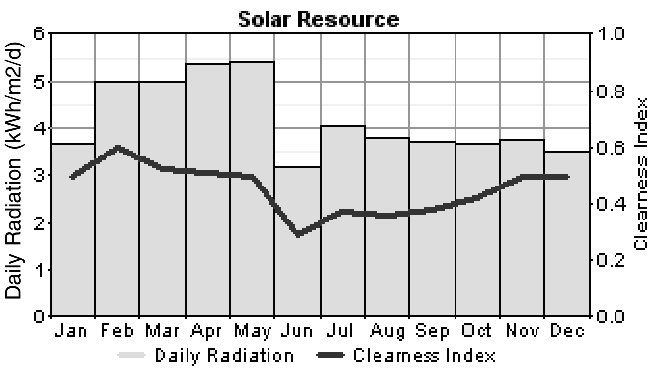


Figure 3: Solar resources of the selective surface.

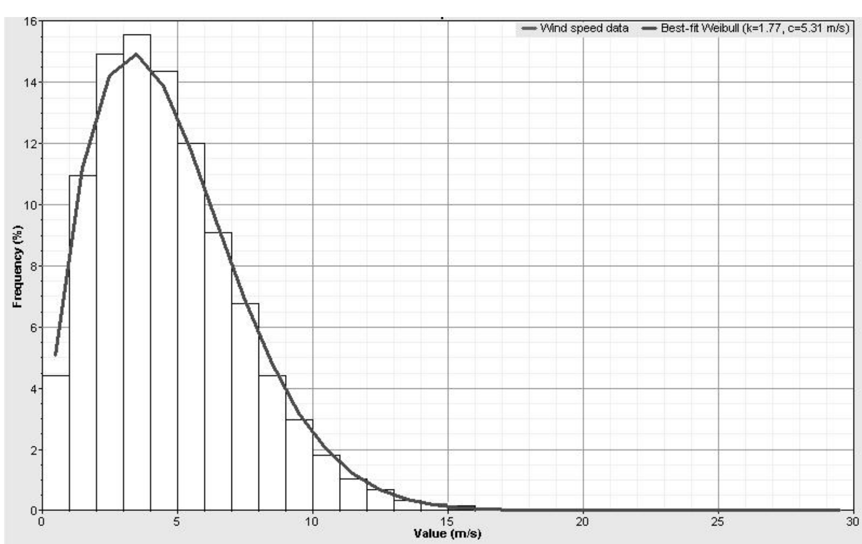
tilted at 21 degree with no tracking mode. Figure 5 shows the scatter plot of PV power and incident solar radiation for the selected solar panel (1 USD = 70 BDT, April 17, 2006).

Wind Generator

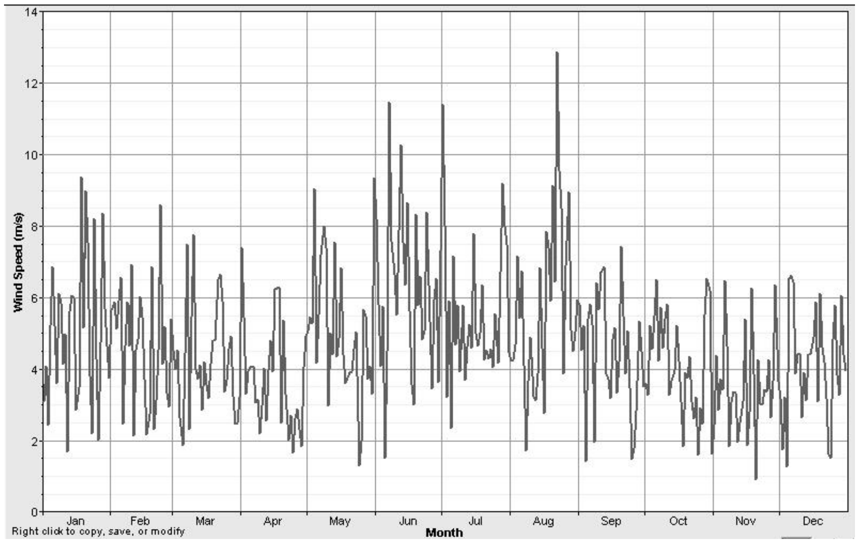
The load demand is very low for a single home system and the price per KW turbine cost is very high for low capacity wind turbine compared to that of high capacity ones. Also low capacity wind turbine is not much available. Now-a-days, research and development are going on to improve the technology and designing low capacity turbine with low cut-in speed at around 2.5 m/s. For this analysis, a WES 5 Tulipo has been considered. The cost of the turbine with tower and installation has been considered as 96,000 BDT/turbine. Figure 6 shows the power curve of the selected turbine.

Battery with Controller

As the system considered the DC load only, battery and controller were also main parts of the system. Battery from Trojan Company (Model: Trojan T-105, nominal



(a)



(b)

Figure 4: (a) Wind Speed Probability density function; (b) daily wind speed for St Martin's.

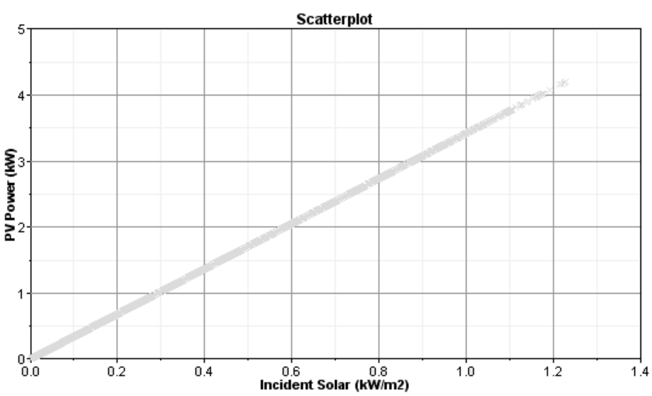


Figure 5: Scatter plot of PV power and incident solar radiation for the selected solar panel.

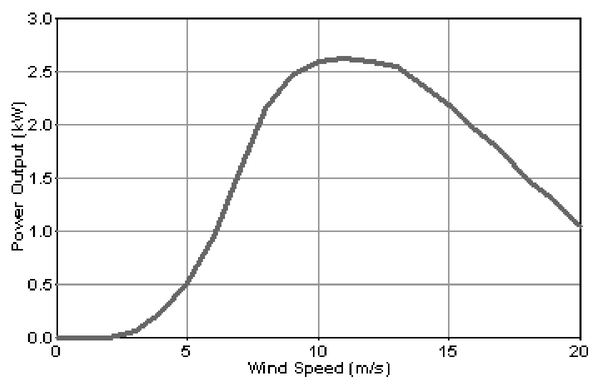


Figure 6: Power curve of a WES 5 Tulipo.

V: 6 Volt nominal capacity: 225 Ah) has been used at a cost of 10,000.00 BDT/battery with charge controller. Figure 7 shows the detailed description of the selected battery.

Economics and Constraints

The projected life time has been considered to be 25 years and the annual real interest rate has been taken as 4%. There is no capacity shortage for the system and operating reserve is 10% 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 PV wind and battery hybrid system. Table 3 shows the best suitable option to fulfill the power requirement of the BTS and the financial summary. A detailed analysis and system architecture for the best combination of PV-Wind power system for BTS has been given in Figure 8. The demand and generation curves of this power system are shown in Figure 9.

Conclusion

It could be summarized from the analysis that it will be better to use Wind-PV hybrid system for powering the BTS in remote location such as Saint Martin's. It is not only economically feasible if this hybrid power system is compared with the traditional diesel generator system but also such hybrid system is environment friendly. But the overall cost of energy would be low if the turbine cost decreases.

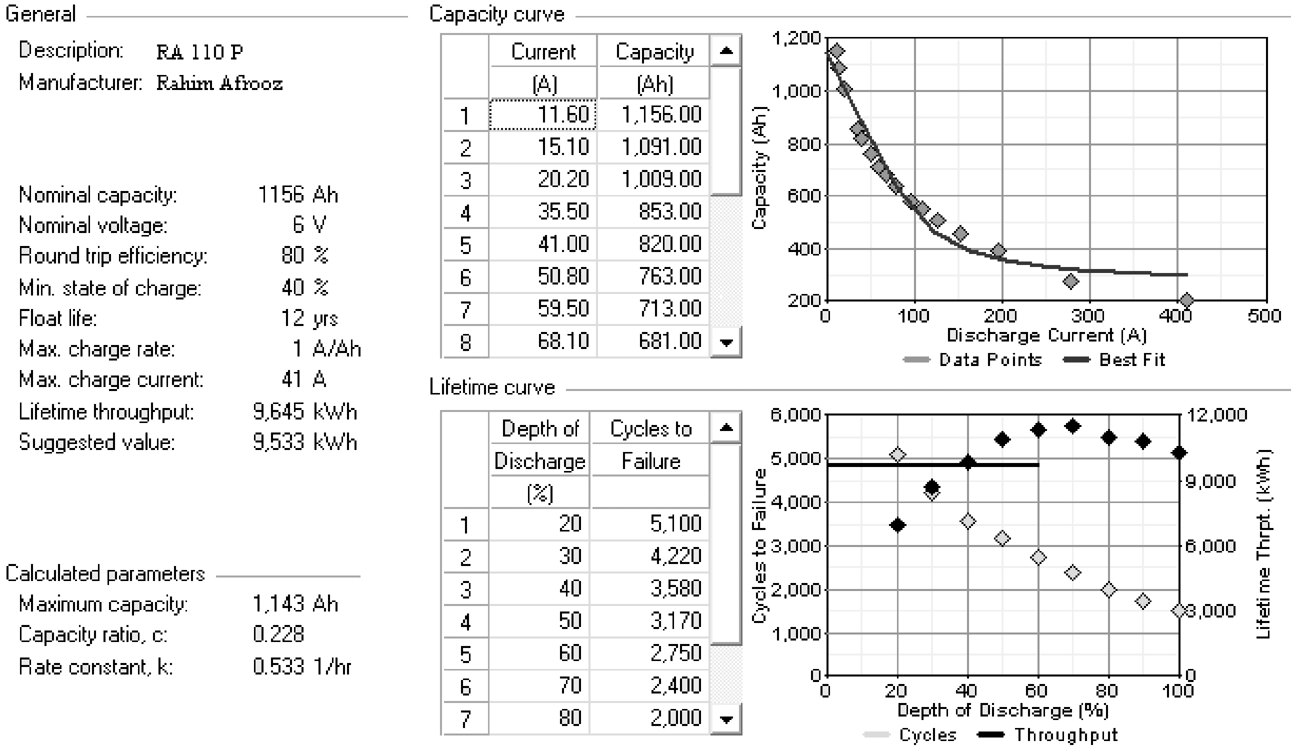
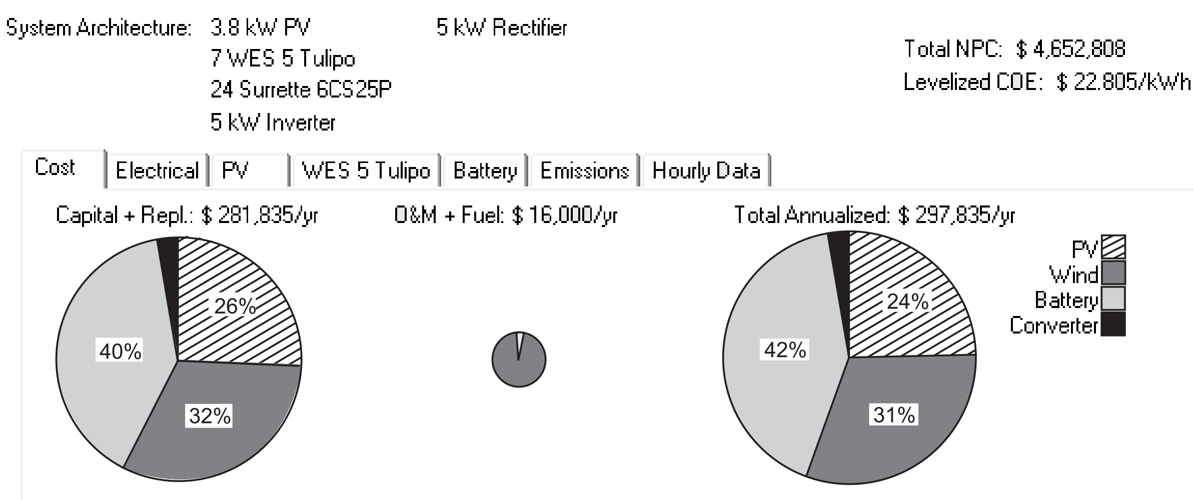


Figure 7: Description of the selected battery.



Component	*Initial capital (Tk)*	*Annualized capital (Tk/yr)*	*Annualized replacement (Tk/yr)*	*Annual O&M (Tk/yr)*	*Total annualized (Tk/yr)*
PV Array	1,140,000	72,974	0	500	73,474
WES 5 Tulipo	1,400,000	89,617	0	3,500	93,117
Battery	1.200.000	76,814	36,072	12,000	124,887
Converter	54,000	3,457	2,902	0	6,358
Totals	3,794,000	242,861	38,974	16,000	297,835

Figure 8: Simulation results for the optimum sized power system for the BTS.

Table 3: HOMER analysis and results

PV (kW)	*WES5*	*Battery*	*Converter (kW)*	*Initial capital*	*Total NPC*	*COE ($/kWh)*	*Renewable fraction*
3.8	7	24	5	Tk3,794,000	Tk 4,652,808	22.805	1
4.5	6	24	5	Tk 3,804,000	Tk 4,654,997	22.817	1
4	7	24	5	Tk 3,854,000	Tk 4,712,808	23.091	1
5.5	8	16	5	Tk 4,104,000	Tk 4,720,289	23.138	1
3.8	7	24	10	Tk 3,844,000	Tk 4,745,306	23.258	1
5.5	5	24	5	Tk 3,904,000	Tk 4,747,186	23.261	1
3.8	8	24	10	Tk 4,044,000	Tk 4,953,117	24.264	1
4.5	7	24	15	Tk 4,104,000	Tk 5,047,803	24.728	1
3.5	5	36	10	Tk 3,954,000	Tk 5,215,178	25.563	1
0.8	7	48	5	Tk 4,094,000	Tk 5,703,797	27.963	1
4.5	6	36	10	Tk 4,454,000	Tk 5,722,989	28.036	1

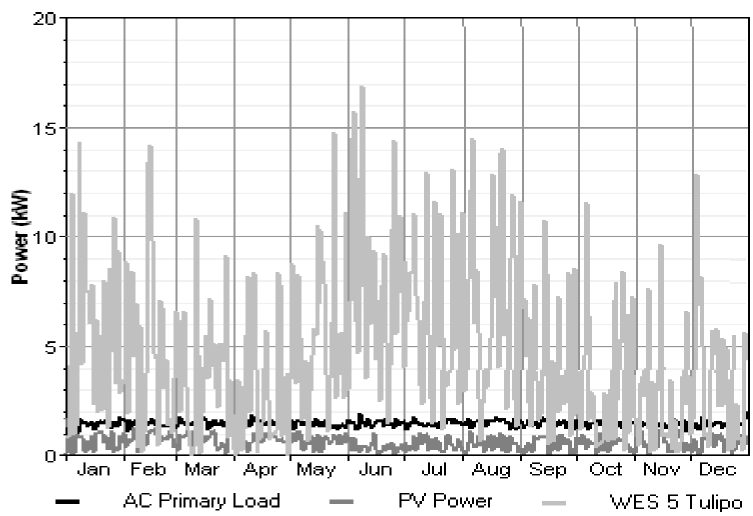


Figure 9: The demand and generation curves of power system.

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