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Hybrid Solar Power Plant in Saint Martin's Island can Enlarge Tourist Attraction in Bangladesh

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Abstract

Saint Martin's Island is the best tourist spot in Bangladesh and one of the most beautiful tourist places in the world. But the accommodation facilities are not suitable for tourists. The supply of electricity in the hotels is only 4-5 hours from the generator. For the geographical position, the electricity cannot supply from the mainland grid and the cost of electricity is so high and is not favourable to the environment. In this paper, Hybrid system of photovoltaic (PV), diesel generator, battery for generating electricity in the Saint Martin's Island is analyzed for 18 hotels. The main objective of the present study is to determine the optimum size of Hybrid system which can fulfil the requirements of 528 kWh/day primary load with 125 kW peak for 18 hotels in this island. By using HOMER (Hybrid Optimization Model for Electric Renewables) software an optimum model is established for the renewable system. The aim is to configure a renewable system with low interest and low energy cost. The diagrams and tables which show prices and performances of the types of equipment on the optimum model are also presented. The result shows that PV (185 kW), diesel generator (105 kW), converter (96 kW) and 615 piece batteries of the Hybrid system is most commercially reliable and least cost of energy is about 19.48Tk per kWh or \$ 0.253 per kWh (\$1=77Tk) with total net present cost \$ 624,391 or 48,078,107TK. The emission of CO2 is very low in this Hybrid system.

Index Terms: Saint Martin's Island, Bangladesh, Hybrid system, HOMER software, PV cell.

1. Introduction

Saint Martin's Island in Bangladesh is one of the most renowned tourist places which areas are only 8 Km^2 [1]. It located in the northern part of the Bay of Bengal and the position from Bangladesh is roughly between 20°34' - 20°39' N and 92°18' - 92° 21' E and 17 kilometres off Taknaf, the most southern mainland [2]. So it's

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actually quite impossible to provide electricity from the mainland grid. 359MW electric energy needed every year in this island. PDB installed 30-kW diesel generator, but it is not operating. In hotels they use the diesel generator to meet their electricity demand but only for 4-5 hours [3], [4]. The main occupation of the people is fishing. Besides algae collection, tourism services etc are the common profession of the people. People most commonly use kerosene and coconut palm to meet their daily energy demands. In this undeveloped area, small amounts of electricity can free large amounts of human time and labour also contributes to their financial needs. Tourism today has grown significantly in both economic and social importance. The tourism industry includes hotels, motels, food services, transportations and other leisure facilities. Since many of these businesses are served by local residents. At present days because of no reliable and constant electricity supplies, the hotels fail to create comfortable and inviting environments for the tourists. Though Saint Martin's Island is a beautiful tourist spot but it fails to attract the domestic as well as international tourists because the lack of luxury accommodation place. Our proposed Hybrid system of renewable energy can develop the current situation and offer a better accommodation and leisure place for the tourists, also enhance the tourists' attraction.

Energy demands are increasing day by day. The price and consumption of fossil fuels are also increased. According to this prospect, solar energy becomes an important source of renewable energy for Bangladesh. Recently power system faces three serious problems because of the severe energy crisis, limitation of current power systems and reliability issues. On the other hand Hybrid system has an abundance of solar energy, can supply constant power to meet the demand and also less reliability issue. For remote areas like Saint Martin, the long-distance electricity transmission, the fossil fuel transportation is complicated and costly. But Hybrid system can comprise an efficient, low-cost and environment-friendly power supply.

Normally, for using renewable energy a Hybrid system designs with one or more renewable energy sources instead of power generators for generating the electrical power. The generators may use as a backup system but large portions of power are generated by the renewable energy sources. In the proposed model the Hybrid system consists of the diesel generator, PV and batteries. The primary load is 528 kWh/day where the peak is 125 kW. The HOMER software is used for designing which is the renewable energy-based system optimization tool developed by the US National Renewable Energy Laboratory (NREL), was used for the design of electric power systems and applications [5].Here the inputs detail like prices, electrical load, solar radiation data, component technical details etc. are given for the parameters. The total cost- revenue (NPC) and the cost of electricity (COE) should be measured before the installation. The software designs an optimal configuration to serve the desired electric loads. To design the optimum system HOMER performs thousands of simulations. But the system cannot calculate the load for less than 1 hour [6]. So, the proposed design analyzes all the data for exact 1 hour. Economic analysis is essential before installing a Hybrid system to generate power. HOMER makes this economic analysis and ranks the systems according to their net present cost (NPC).

2. Load Data Analysis

A typical load system in table 1 [7], [8], [9], [10] for the single room of a hotel in Saint Martin's Island has been considered for the analysis. The input of Monthly average hourly load demand in Bangladesh perspective has been given in HOMER software and it generates daily and monthly load profile for a year which is showing in figure 1. It has been found that for this system eighteen hotels power consumption 528 kWh/day with a peak demand of 125 kW.

Table 1. Appliances for Single Room

Appliances	Quantity	Capacity (W)	Maximum work hour/day
Florescence Light (bathroom)	1	5	1-2
Florescence Light (corridor)	1	10	6-8
Florescence Light (bedroom)	1	15	6-8
Fan(bedroom)	1	40	7-10
Point for charging	1	3	3-4
TV (14 inch) Model: Daewoo only for luxurious and standard hotel's room	1	39	4-7
AC (Mitsubishi) Model:SRK63ZMA-S only for luxurious hotel's room	1	1760	5-6

From the table 1,

For a single room (luxurious hotel) power consumption = 9.4 kWh/ day

For a single room (standard hotel) power consumption = 0.6 kWh/ day

For a single room (economy hotel) power consumption = 0.4 kWh/ day

In Saint Martin's island, there are 3 luxurious hotels, 5 standard hotels, 10 economy hotels and 15 rooms in each hotel.

Now, 18 hotels the total power consumption 528 kWh/day with peak demand 125 kW.

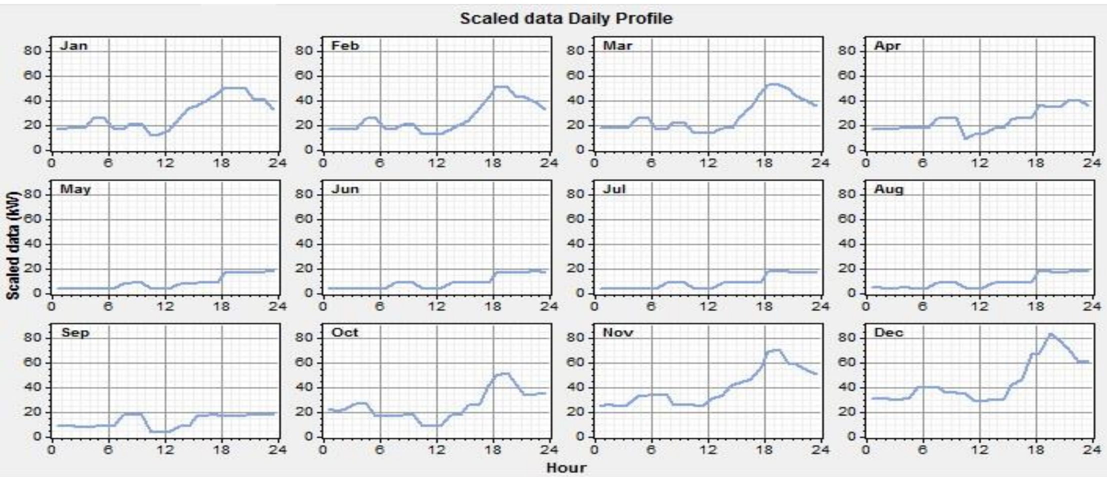

Fig.1. Load Profile for Eighteen Hotels

In the Saint Martin's Island people usually go within November to March, some people go to April but not much as these months. Those months are called the tourist season and the others are called off season for tourist. In the month, June and July climate is not suitable for the tourist because the cyclone, tornado, hurricane etc. happening in those months. So, an imaginary load profile is shown in the above figure 1. The hourly load profiles are not available, that's why load data were analyzed by identifying typical daily load profiles and then adding daily 10% and hourly 15% noise.

3. Solar Energy Resources

The Saint Martin's island is located in 20^0 37' north and 92^0 19' east. This latitude specifies the location on the Earth's surface. It is an important variable in solar calculations because HOMER uses this data for calculating radiation values from clearness indices, and vice versa. The average data of daily radiation were given as input [11].HOMER calculates clearance index automatically from the daily radiation values which are shown in table 2. When the values were given as an input HOMER builds a set of 8760 hourly solar radiation value. HOMER creates the synthesized values using Graham Algorithm [12]. Figure 2 shows that the solar radiation of a year. The average annual clearness index is 0.515 and the average daily radiation is to 4.838kWh/m^2/d.

Table 2. Monthly Solar Radiation Data

Month	Clearness Index	Daily radiation (NASA) (kWh/m^2/d)
January	0654	4.840
February	0.650	5.460
March	0.668	6.410
April	0.616	6.480
May	0.545	5.960
June	0.329	3.600
July	0.331	3.620
August	0.348	3.690
September	0.440	4.340
October	0.541	4.720
November	0.582	4.420
December	0.643	4.540
Average	0.515	4.838

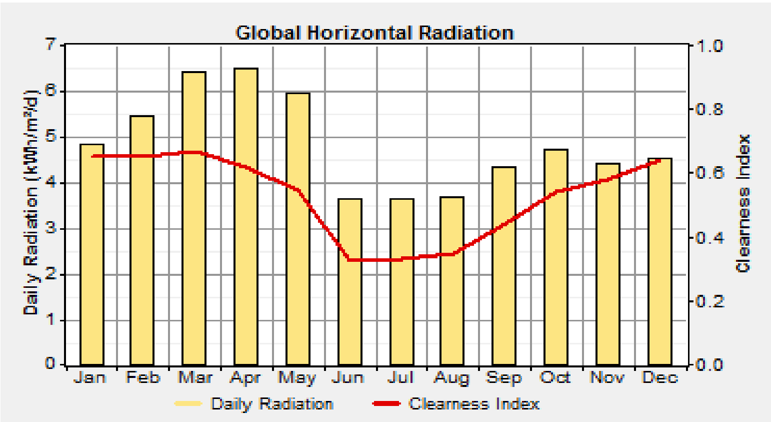

Fig.2. Global Horizontal Radiation

4. Model and Components of Proposed Hybrid System

The main reason for choosing the Hybrid system is it save the fuel up to 50 % and it is lower atmospheric contamination. It will save the maintenance cost and also silent system. The optimized model is shown in figure 3 where the simulated peak demand of primary load is 125 kW and total energy consumption is 528 kWh/day.

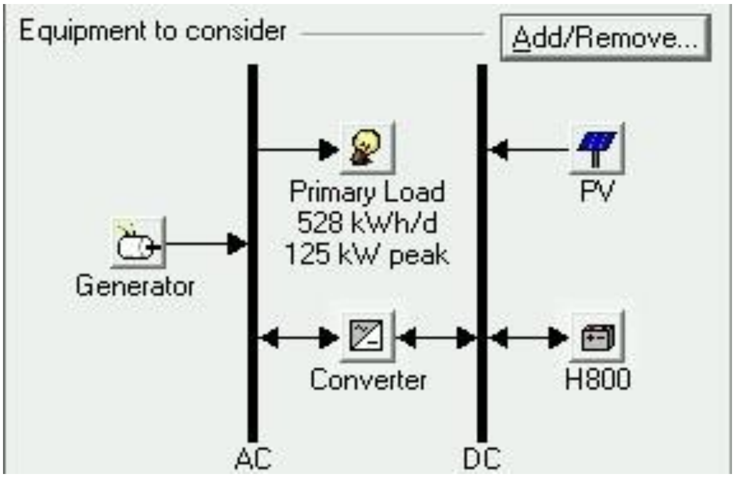

Fig.3.Complete Model of Hybrid System

Considering our model we have designed our Hybrid system with the power source of solar radiation and diesel. Hence, the components of our systems are Photovoltaic array, Diesel generator, Storage device and Converter.

In the Hybrid system, the generator was used as a backup power. If the system was not running by the PV for the reason of fog or rain the diesel generator generated the power. More batteries were used for storing the excess electricity which was generated by PV and generator to fulfil the extra operating demand of appliances. The project lifetime is 25 years and the annual interest 6% taken from the bank as helping money in the capital cost. The specification of the types of equipment which are used in the proposed Hybrid model is given below:

4.1. Photovoltaic array

Size: 185 kW
Output current: DC
Lifetime: 20 years
Derating factor: 90%
Tracking system: no tracking
Capital: 1,169 $/kW or 90,000 Tk/kW [13]
Replacement: 1,039 $/kW or 80,000 Tk/kW [13]

4.2. Diesel generator

Size: 105 kW
Lifetime (operating hours): 15,000
Minimum load ratio: 10%
Fuel consumption: 12,499 Litre/year
Specific fuel consumption: 0.333 Litre/kWh
Fuel price: 0.88 $/Litre or 68 Tk/Litre [14]
Capital: 130 $/kW or 10,000 Tk/kW [5]
Replacement: 104 $/kW or 8,000 Tk/kW [5]
O&M: 0.25 $/hour or 20 Tk/hour [5]

4.3. Storage Device

Battery type: Hoppecke 8 0PzS 800
Nominal specs: 2V, 800 Ah, 1.6 kWh
Quantity: 615
Lifetime throughput: 2,742 kWh
Batteries per string: 1 (2V bus)
Dispatch strategy: Cycle charging
Capital per piece: $91 or 7,000 Tk [5]
Replacement per piece: $78 or 6,000 Tk [5]
O&M per piece: 0.10 $/year or 7.7 Tk/year

4.4. Converter

Size: 96 kW
Inverter inputs,
Lifetime (years): 15
Efficiency: 90%
Rectifier inputs,
Capacity related to inverter: 95 %
Efficiency: 85%
Capital: 194 $/kW or 14,933 Tk/kW [5]
Replacement: 130 $/kW or 10,000 Tk/kW [5]

5. Simulation Result and Discussion

The Hybrid system was designed in HOMER software by setting all the parameters in a different scheme. It was found that 185 kW PV, 105kW generator, 615 piece batteries and 96 kW converter was the most cost efficient from the others where the COE is $0.253 or 19.48 Tk. The production of electricity is individually shown in table 3 where the PV generated 89% comparatively to the diesel generator was only 11%.

Table 3. Electrical Power Generated by the System

Production	kWh/yr	Percentage
PV array	314,921	89
Generator	37,495	11
Total	352,416	100

The PV produced more electricity than the others in the system, that's why it was considered the base energy source for the system. The excess electricity 116,036 kWh/yr was used to fulfil extra demands of the electrical appliances, decoration and security purpose of hotels. In figure 4, an average electricity production was shown where consumption of AC primary load was 192,699kWh/yr.

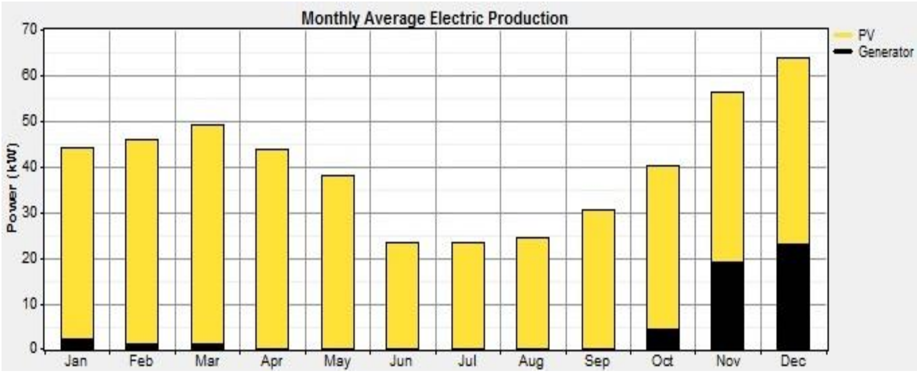

Fig.4. Monthly Average Electric Production of the Hybrid System

The solar PV delivered the maximum power in the Hybrid system. Simulation result of solar PV which is shown in table 4 has been calculated by different values of solar radiation. It is shown the minimum output is 0 kW when the panel is not getting enough solar isolation to produce the electricity.

Table 4. PV Result Obtaining from Simulation

Capacity	Value	Units
Rated capacity	185.0	kW
Mean output	36	kW
Mean output	863	kWh/d
Capacity factor	19.4	%
Total production	314,921	kWh/yr
Minimum output	0.0	kW
Maximum output	205	kW
PV penetration	163	%
Hours of operation	4,363	hr/yr
Levelized cost	0.0603	$/kWh

The batteries are used for storing the generating power which is generated by PV and generator. In figure 5 the simulation results of batteries are shown which capacity was 800 Ah per piece.

Quantity	Value
String size	1
Strings in parallel	615
Batteries	615
Bus voltage (V)	2

Quantity	Value	Units
Nominal capacity	984	kWh
Usable nominal capacity	689	kWh
Autonomy	31.3	hr
Lifetime throughput	1,686,330	kWh
Battery wear cost	0.031	$/kWh
Average energy cost	0.015	$/kWh

Fig.5. Simulation Results of Batteries

The generator is only run when the battery bank fails to supply the demand of electricity. A diesel generator participating in a model with capacity 105 kW and the mean output power 101 kW. The different simulation results obtained for diesel generator system is given below in figure 6 and figure 7 is shown for converter simulation result.

Cost Summary | Cash Flow | Electrical | PV | Gen | Battery | Converter | Emissions | Time Series

Quantity	Value	Units
Hours of operation	372	hr/yr
Number of starts	64	starts/yr
Operational life	40.3	yr
Capacity factor	4.08	%
Fixed generation cost	34.4	$/hr
Marginal generation cost	0.220	$/kWh

Quantity	Value	Units
Electrical production	37,495	kWh/yr
Mean electrical output	101	kW
Min. electrical output	22.2	kW
Max. electrical output	105	kW

Quantity	Value	Units
Fuel consumption	12,499	L/yr
Specific fuel consumption	0.333	L/kWh
Fuel energy input	122,986	kWh/yr
Mean electrical efficiency	30.5	%

Fig.6. Simulation Result for Diesel Generator

Quantity	Inverter	Rectifier	Units
Capacity	96.0	91.2	kW
Mean output	20.3	2.2	kW
Minimum output	0.0	0.0	kW
Maximum output	86.5	80.6	kW
Capacity factor	21.1	2.4	%

Quantity	Inverter	Rectifier	Units
Hours of operation	8,388	355	hrs/yr
Energy in	197,279	22,347	kWh/yr
Energy out	177,551	18,995	kWh/yr
Losses	19,728	3,352	kWh/yr

Fig.7. Simulated Result for Converter

Sensitivity Results | Optimization Results

Sensitivity variables

Global Solar (kWh/m²/d) 4.84 Diesel Price ($/L) 0.88

Double click on a system below for simulation results.

					PV (kW)	Gen (kW)	H800	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Gen (hrs)
					185	105	615	96	$ 303,889	25,072	$ 624,391	0.253	0.81	12,499	372
					195	105	615	96	$ 315,579	24,322	$ 626,492	0.254	0.81	11,941	358
					185	105	600	96	$ 302,539	25,693	$ 630,983	0.256	0.80	12,809	383
					175	105	615	96	$ 292,199	26,609	$ 632,356	0.257	0.79	13,443	403
					195	105	600	96	$ 314,229	24,914	$ 632,714	0.257	0.81	12,264	368
					175	105	600	96	$ 290,849	26,763	$ 632,973	0.257	0.79	13,568	403
					175	130	615	96	$ 295,449	26,646	$ 636,076	0.258	0.79	13,468	326
					185	130	615	96	$ 307,139	25,925	$ 638,553	0.259	0.80	12,935	315
					195	130	615	96	$ 318,829	25,057	$ 639,139	0.259	0.81	12,336	301
					175	130	600	96	$ 294,099	27,144	$ 641,092	0.260	0.79	13,727	333
					185	130	600	96	$ 305,789	26,362	$ 642,779	0.261	0.80	13,191	320
					195	130	600	96	$ 317,479	25,452	$ 642,835	0.261	0.81	12,551	306
					185	105	615	120	$ 308,545	27,680	$ 662,390	0.269	0.79	13,836	418
					144	105	615	96	$ 255,960	31,977	$ 664,738	0.270	0.74	16,930	503
					175	105	615	120	$ 296,855	28,871	$ 665,923	0.270	0.77	14,599	442
					144	105	600	96	$ 254,610	32,308	$ 667,617	0.271	0.73	17,138	507
					195	105	615	120	$ 320,235	27,194	$ 667,864	0.271	0.79	13,388	410
					185	105	615	140	$ 312,425	27,806	$ 667,882	0.271	0.79	13,871	419
					175	105	600	120	$ 295,505	29,221	$ 669,050	0.272	0.77	14,846	446
					175	105	615	140	$ 300,735	28,940	$ 670,688	0.272	0.77	14,599	442
					195	105	615	140	$ 324,115	27,215	$ 672,013	0.273	0.79	13,366	409
					185	105	600	120	$ 307,195	28,548	$ 672,140	0.273	0.78	14,302	434
					195	105	600	120	$ 318,885	27,674	$ 672,648	0.273	0.79	13,689	417

Fig.8. Optimization Result for the Hybrid System

6. Cost Analysis and Payback Calculation

The cost summary of our system is shown in figure 9 and all the equipment vital costs are shown in table 5.

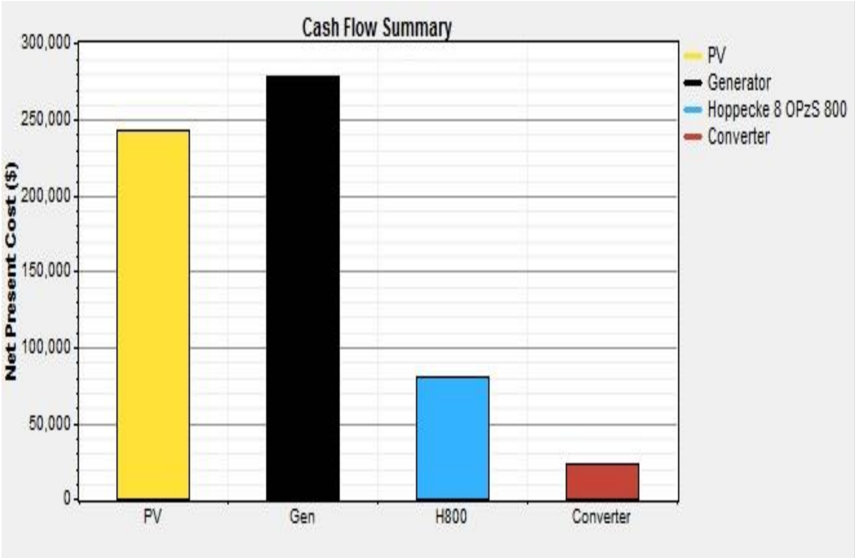

Fig.9. Cash Flow Summary

Table 5. Cost Required for Equipments

Component	Capital($)	Replacement($)	O&M($)	Fuel($)	Salvage($)	Total($)
PV	216,265	59,934	0	0	- 33,589	242,609
Generator	13,650	0	124,830	140,600	-967	278,113
Hoppecke 8 OPzs 800	55,350	35,233	786	0	-10,562	80,807
Converter	18,624	5,207	0	0	-969	22,862
System	303,889	100,374	125,616	140,600	-46,087	624,391

Payback considers the initial investment costs and the resulting annual cash flow. The payback period is usually calculated by the amount of time (usually measured in years) to recover the initial investment. The payback method doesn't account for savings that may continue from a project after the initial investment is paid back from the profits of the project, but this method is helpful for a "first-cut" analysis of a project [15]. Here we have to consider 19.48 taka or $0.253 per kW hour.

Considering 1kWh = 19.48Tk or $0.253

Capital cost of the Hybrid system = $303,889

The capital money will be lent with 6% interest.

So the total capital cost with 6% interest = $322,123

Annual income = $48,753 [As annual consumption of electricity = 192,699kWh]

So, payback period= $\frac{\$322,123}{\$48,753}$ =6.60 years≈ 7 years [13], [15].

7. Conclusions

The Hybrid system has been designed keeping in tourist. As Saint Martin is a popular tourist spot in Bangladesh so most of the tourist come here from around the world. This Hybrid Model will help them for their better accommodation places. In the proposed Hybrid system doesn't hamper the beautiful environment because the system generated electricity from a solar resource that's why it produced low CO_2. This study indicates that for a selected location having annual average global solar radiation (4.838kWh/m^2/d), PV (185 kW), diesel generator (105 kW), converter (96 kW) and 615 piece batteries of the Hybrid system is most economically feasible system for 18 hotels, the total power consumption 528 kWh/day with peak demand 125 kW. It was found from the simulation of the Hybrid system that the cost of electricity (COE) is only $0.253 or 19.48 Tk with its lifetime 25 years, also has lowest NPC $624,391 and the investment will be back for approximately 7 years. Due to the high cost of fossil fuel, only diesel generator based power system is not economically suitable and this system would increase the emission of GHG. The operating hours for diesel generator is only 372, so our proposed Hybrid system is more fuel efficient and more environment-friendly in comparison with only diesel generator based power system.

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