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COMPARISON OF PERFORMANCE AND COST OF WIND AND SOLAR HYBRID SYSTEM FOR SAINT-MARTIN ISLAND USING HOMER SOFTWARE

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Abstract- *Saint-martin island is a small isolated island of Bangladesh, with an area of almost 8 km^2 and almost 7000 people live in this small island. It is the main tourist spot of Bangladesh. According to a study performed in 2016, it was found that almost 528 thousand of international tourists visit this beautiful island per year which is increasing every year* [1]. *There is no feasible source of power to fulfill the demand of electricity fully. So, it is very important to provide a feasible solution to the increasing demand for electricity. A renewable energy system can be the proper solution to meet the energy crisis. In this paper a comparative study is done among three possible solutions which are as follow: a) Stand-alone photovoltaic (PV) power generation system, b) stand-alone wind turbine power generation system and, c) wind-photovoltaic hybrid system (WPHS). The cost analysis and cost of energy (COE) was found for these three cases and compared to get the best feasible solution using HOMER software. This paper also shows the usefulness of hybrid solar wind system over stand-alone solar and stand-alone wind system.*

Keywords: Wind-photovoltaic hybrid system (WPHS), photovoltaic (PV), HOMER software.

1. INTRODUCTION

Saint Martin Island lies between 20°37.4′ N to 92°19.4′E. It is in the Cox's Bazar district which is in the division of Chittagong, Bangladesh**.** It covers an area of 8 sq. km. About 4000 population live on the island [1]. To meet the electricity demand of population along with thousands of tourists every year in Saint Martin Island, currently produced by fossil fuels such as natural gas, coal etc. As the arrival of tourist is increasing every year, the demand for electricity is also increasing. So, fossil fuels consumption is also increasing. The only solution for this problem is to utilize renewable energy as they are environment friendly. A wind solar hybrid system is a source of renewable energy system as here solar and wind energy is used. Only wind power or only solar is not a consistent source of energy throughout the year. In this paper, a comparative study has done among standalone wind power energy, standalone photovoltaic (PV) energy and a wind-photovoltaic hybrid system (WPHS). Here, HOMER software is used to determine the net present cost, maintenance cost and cost of energy for the three possible systems mentioned above, considering monthly solar radiation and average wind velocity in the required location [2]. After the comparative study among three possible solutions, it is found that the hybrid system has a more economical alternative for standalone solar and standalone wind system. It is also found that the hybrid system is more efficient and less cost consuming than standalone solar and standalone wind system.

2.HOMER

The HOMER is the global standard for optimizing microgrid design in all sectors, from village power and island utilities to grid-connected campuses. Originally developed at the National Renewable Energy Laboratory, and enhanced and distributed by HOMER Energy, HOMER (Hybrid Optimization Model for Multiple Energy Resources) nests three powerful tools in one software product, so that engineering and economics work side by side [3]. By using HOMER one can get a model with inputs that describe technology options, component costs, and resource availability. These inputs are used to simulate different system configurations or combinations of components and generate results that one can view as a list of feasible configurations. Many possible system configurations can be evaluated and compared the results by HOMER. The operation of the system is simulated by making energy balance calculations in each time step of the year. HOMER also displays simulation results in a wide variety of tables and graphs that help us to compare configurations and evaluate them on their economic and technical merits. The tables and graphs can also be exported using this software for future evaluation and presentation.

3. SOLAR POWER

By using Solar panels solar power is converted into electrical power. Solar panels can directly alter the energy or can heat the water with the induced energy in the process. Photo-voltaic cells (PV) are made from semiconductors and their structures are the same as in modern computer technologies. The PV cells generate DC electricity when sunbeams fall on these solar cells. The monthly average solar global horizontal irradiance (GHI) data is generated in the HOMER software (source: National renewable energy lab database) as shown in figure 1 below:

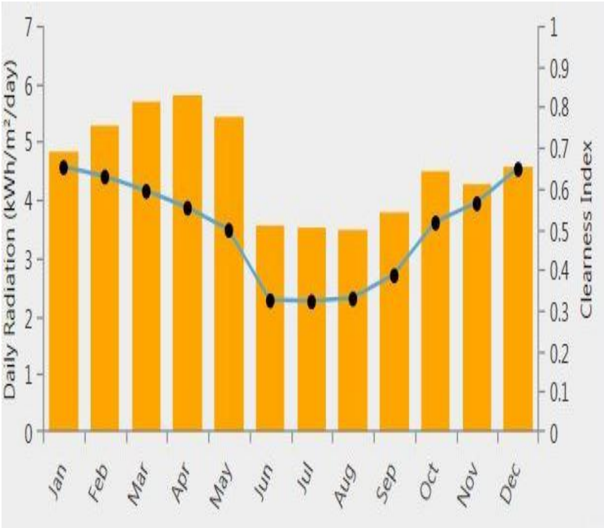

Fig. 1: Monthly global horizontal irradiance (GHI) at Saint-Martin island

4. WIND POWER

The variations in air pressure create the wind system over the earth's surface. Wind is simply the movement of air from one place to another different place. The wind turbine can capture the winds kinetic energy with the help of a rotor containing two or more blades mechanically coupled to an electrical energy generator. Usually, the turbine is placed on a tall tower and hub to enhance energy capture [4]. The monthly average wind speed data is generated in HOMER software (source: NASA surface meteorology and solar energy database) which is shown in figure 2. The scaled annual average was found 4.85 m/s from the gathered data.

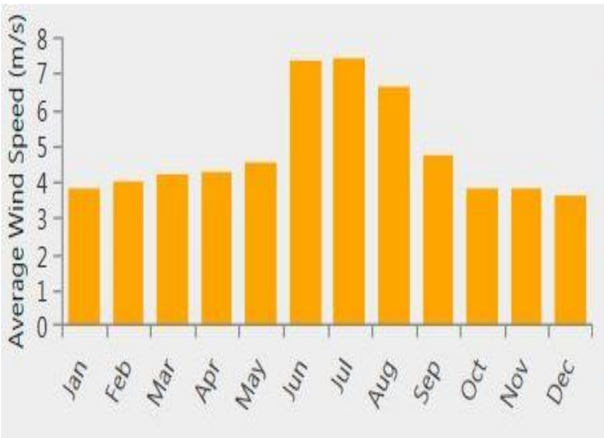

Fig. 2: Monthly average wind speed of saint-martin island

5. HYBRID SOLAR-WIND SYSTEM

Renewable energy resources like solar and wind can be fresh and economically good replacements to conventional power generation, in locations where high wind speed and high solar radiation are available. Renewable energy resources such as solar and wind energy which change arbitrarily are individually less reliable sources of power. So, in many areas, when solar and wind resources are combined for power production, they balance each other by means of daily and seasonal variations [5]. Uniting these two renewable energy sources can make the system more reliable, and the system costs can be slightly reduced depending on the regional conditions. The schematic of the wind-solar hybrid system is shown in figure 3**.**

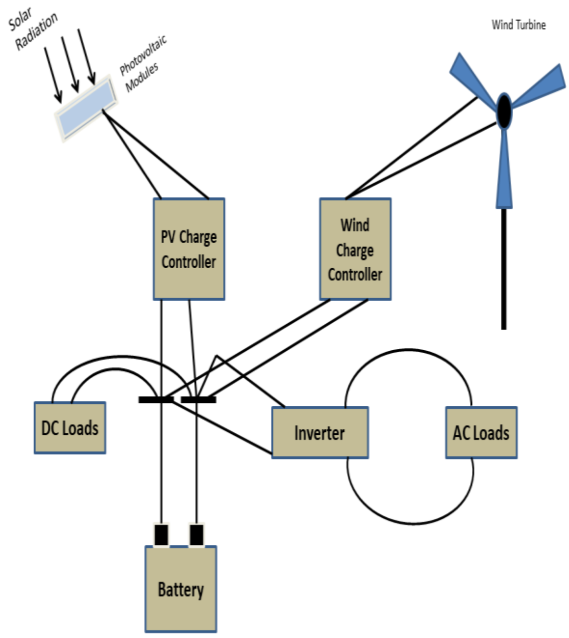

Fig. 3: The schematic of the wind-solar hybrid system

6. SIMULATIONS FOR THREE DIFFERENT COMBINATION

Different simulations are performed using HOMER software for three possible combinations of standalone wind power, Standalone solar power and a wind-photovoltaic hybrid system (WPHS). A.C primary load of 30 KW/day is considered with a 4.02 kW peak for simulation at the desired location. Figure4 shows the modeling of a standalone solar system in HOMER software. The different three combinations of simulations used for standalone wind system, solar system, and WPHS are as follows.

6.1 Stand Alone Wind Turbine System

For simulation 1.5 KW AWS wind turbine is used with a rated power of 1.5 KW DC and its expected lifetime is 20 years. Along with that in simulation hub height is used of 25 m. As a storage device, Generic 1kWh Lead Acid [ASM] is used. A converter is used here to convert DC to AC power.

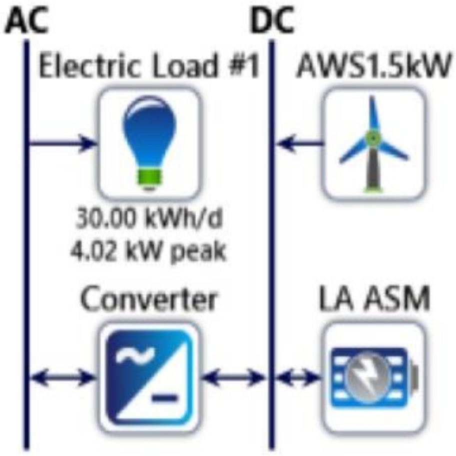

Fig. 4: Modeling of the standalone wind system

The result of the simulation for the stand-alone wind turbine is shown in the following table:

Table 1: Simulation output for a stand-alone wind system

Component	Name	Size	Unit
Storage	Generic 1kWh Lead Acid [ASM]	182	Strings
Wind turbine	AWS HC 1.5kW Wind Turbine	15	ea.
System converter	System converter	7.74	KW

In table 1 the best feasible output found in the simulation is given and it contains the different sizes and units needed to ensure the needed power generation only by using wind as a resource.
In figure 5, the cost summary of the standalone wind power system is shown. Where by three colors three different cost components are indicated. Such as the cost of wind turbine indicated by purple color, the system converter cost is indicated by red and the lead-acid is indicated by the rest color. It can be seen that the maximum cost is capital cost and its maximum for a wind turbine, operating cost is very less than the capital cost. Here is also replacement cost along with some salvage value which can be regained after a period. In this simulation, it is found that the Levelized Cost of Energy (COE) is about $1.10 $/kWh.

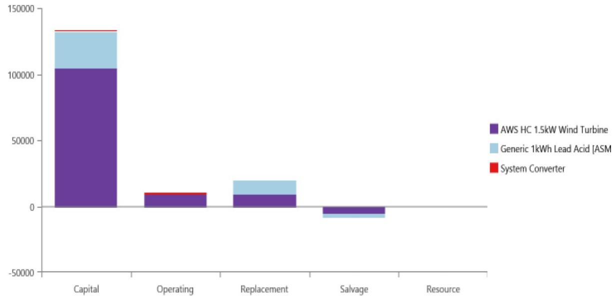

Fig. 5: Cost Summary of standalone wind turbine

In figure 6, the output of the AWS 1.5 KW wind turbine is shown and it can be seen that the output is maximum during 150th to 250th day of the year.

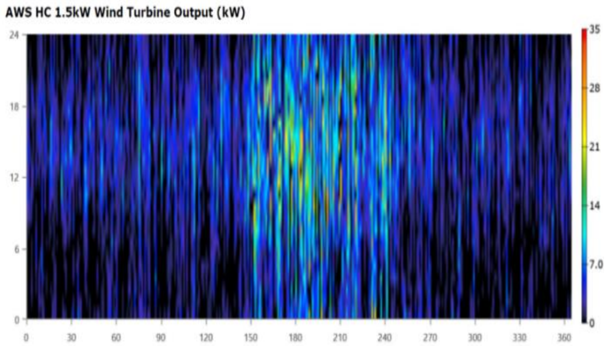

Fig. 6: AWS 1.5 KW wind turbine output

6.2 Standalone PV System

For simulation generic flat-plate PV is used with rated power of 1 KW and its expected lifetime is 20 years. As a storage device Generic 1kWh Lead Acid [ASM] is used here. A converter is used to convert DC to AC power.

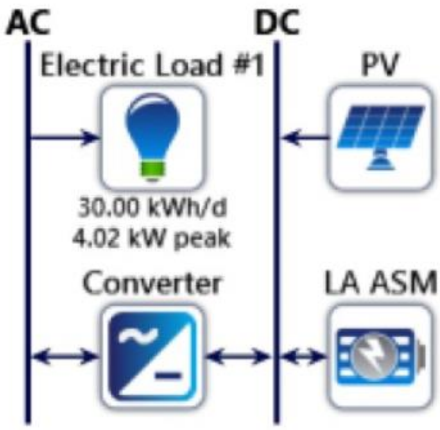

Fig. 7: Modeling of the stand-alone solar system

The result of simulation for the stand-alone solar system is shown in table 2. In table 2 the different component sizes and needed units are shown.

Table 2: Simulation output for the stand-alone solar system

Component	Name	Size	Unit
PV	Generic flat-plate PV	16.7	kW
Storage	Generic 1 kWh Lead Acid [ASM]	15	Strings
System converter	System Converter	7.74	kW
Dispatch strategy	HOMER Cycle Charging		

In figure 8, it can be seen that the cost summary of stand-alone PV system where by three colors three different components are indicated such as a generic Lead-acid battery (ASM) is indicated by purple color, system converter is indicated by red and the flat plate PV is indicated by the rest color. It can be seen that the maximum cost is capital cost and its maximum for flat-plate PV. Operating Cost is very less than the capital cost. Here is also replacement cost along with some salvage value which can be regained after a period. In this simulation, it is found that the Levelized Cost of Energy (COE) is about $0.6888/kWh.

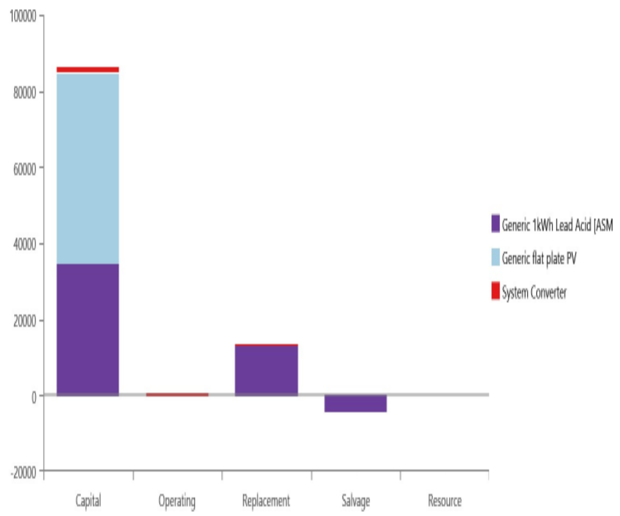

Fig. 8: Cost Summary of standalone PV System

In figure 9, the output of generic flat-plate PV is shown and here output is maximum during 0 to 140th day and 250th to 365th day of the year.
By the performed two types of discussed simulation results it can be seen that, when there is low output in wind turbine, there is high output in PV Solar cells at different times of the year and vice versa. So, for this a combined system is generated and simulated to get the cost of energy for the hybrid system.

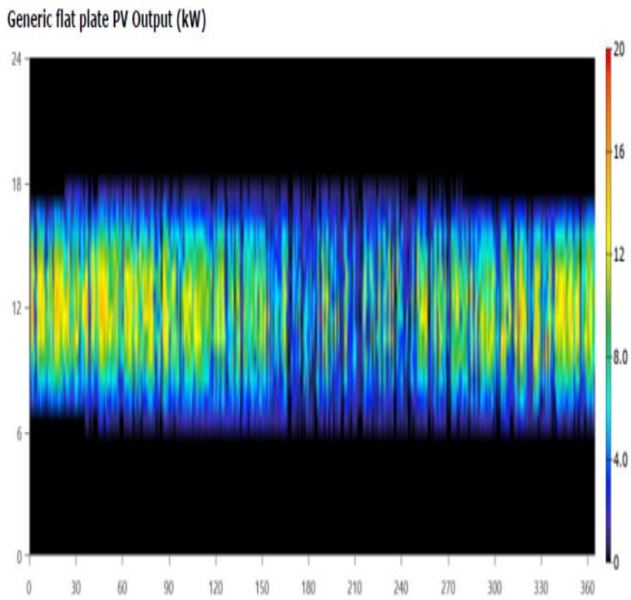

Fig. 9: Generic Flat PV output

6.3 Wind-PV Hybrid System (WPHS):

In this part of the simulation, a combined wind and PV system was designed and analyzed for the same amount of load used in previous simulations. The schematic of the hybrid system is given in figure 10**.**

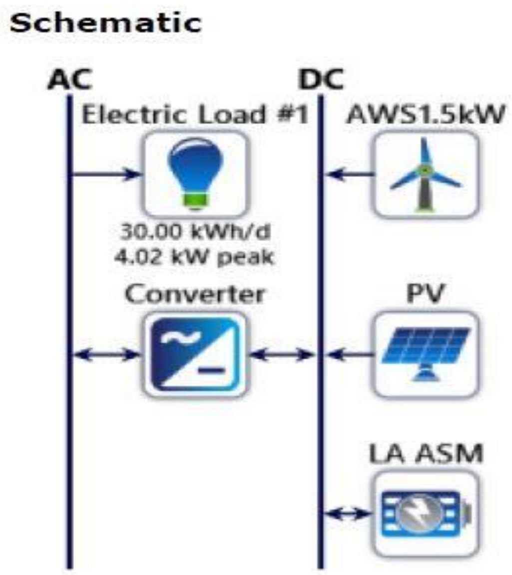

Fig. 10: Modeling of Wind-PV Hybrid System.

For the simulation of Wind- 1.5 KW AWS wind turbine is used with a rated power of 1.5 KW DC and its expected lifetime is 20 years. Along with that in simulation hub height is used of 25 m. As a storage device, Generic 1kWh Lead Acid [ASM] is used here. Generic flat-plate PV is used with a rated power of 1 KW and its expected lifetime is 20 years. A converter is used to convert DC to AC power.

Table 3: Simulation output for WPHS system

Component	Name	Size	Unit
PV	Generic flat-plate PV	7.32	KW
STORAGE	Generic 1kWh Lead Acid [ASM]	109	Strings
WIND TURBINE	AWS HC 1.5Kw Wind Turbine	3	ea.
SYSTEM CONVERTER	System Converter	3.70	KW

Here, from the best feasible simulation result shown in table 3, we can see that, 7.32 KW PV and 3 ea. Of wind turbine as well as 109 strings of lead-acid (ASM) needed to generate the desired load at our desired location.

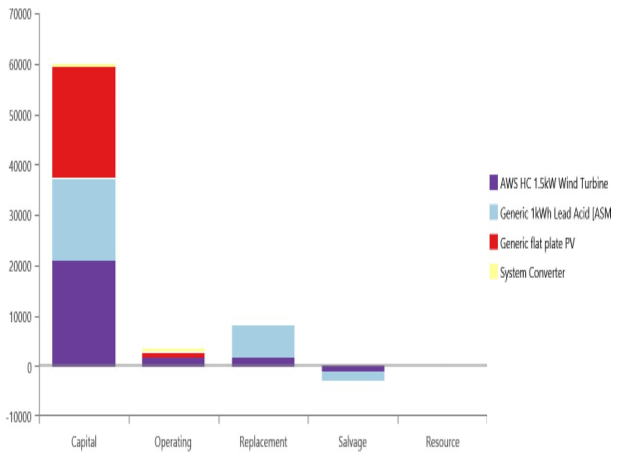

Fig. 11: Cost Summary of WPHS

From figure 11, we can see the cost of flat-plate PV and wind turbine cost is almost equally distributed and other salvage and system cost is also shown. Most importantly the cost of energy is reduced than the previous two systems in this WPHS type of energy generation. The cost of energy is reduced to 0.484 $/kWh. Again, the total Net Present Cost is $68,503.63.

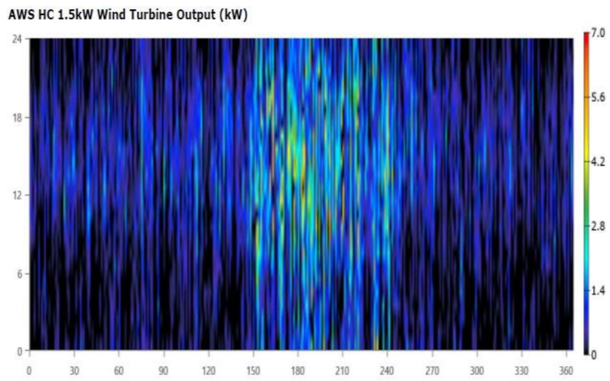

Fig. 12: 1.5 KW wind turbine output while used in WPHS

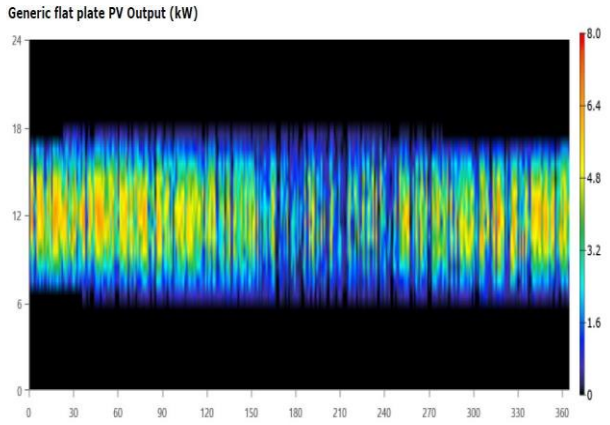

Fig. 13: Generic flat-plate PV output while used in WPHS

In figure 12 and figure 13, we can see the output of the flat-plate PV and wind turbine over the year. It can be seen that the combined use of the solar and wind power generation system has better output result than the previous two systems.

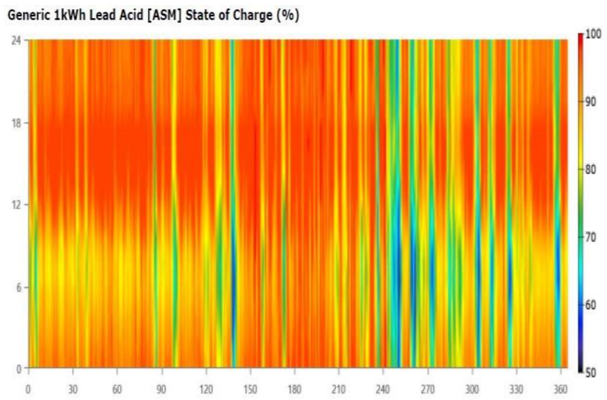

Fig. 14: Generic 1kWh Lead Acid [ASM] State of Charge

The percentage of charge of lead-acid (ASM) battery over the year is shown in figure14. Again, in figure15, the system converter output is shown for a year range.

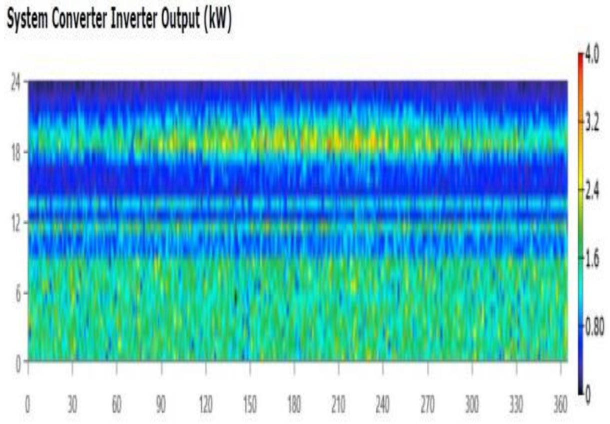

Fig. 15: System converter output

7. COMPARISON OF COST FOR THREE DIFFERENT SYSTEMS CONSIDERED

The results optimized from the simulation are shown in table 3.

Table 3: optimized result for three systems

system	Capital cost	Operating cost	Total NPC ($)	Cost of energy ($/kW)
Solar power system	86452	1269	97383	0.688
Wind power system	133383	1734	155803	1.10
Solar-wind Hybrid system	59828	3364	68503	0.484

Table 3 shows the cost of energy per kWh, net present cost, capital cost, operating cost for all three systems considered. From the result, it can be noticed that the cost of energy is lowest for the solar-wind hybrid system which is only 0.484 $/kWh.

Table 4: production summary of WPHS

Component	Production (kWh/Year)	Percent
Generic flat plate PV	10,487	64.3
Aws HC 1.5Kw Wind Turbine	5,825	35.7
Total	16,312	100

From the above table 4, we can see the percentage of energy production for the hybrid system. The PV system contributes to 64.3% energy production and wind turbine contributes the rest 35.7% energy production.

7. CONCLUSIONS

The results optimized from the simulation show the cost of energy for the stand-alone wind system is the largest and is 1.10 ($/kW). The stand-alone solar system is more efficient and its cost of energy is 0.688 ($/kW). The most efficient system is found to be the hybrid system and its cost of energy is only 0.484 ($/kW). So, we can say that using a wind-solar hybrid system can reduce the cost and can be a source of green energy for the saint-martin island people. It can reduce the energy problem of that island as well as can reduce the emission of harmful gases. Hence this study shows the absence of main grid current can be fulfilled with hybrid system.

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