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Design and Simulate the Solar-Wind-Diesel Stand-Alone Systems for an Institutional Area

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ABSTRACT
Hybrid energy source is becoming general because it is composed from two or more energy sources. This combination of two or more energy sources is a competent way of generating energy. The amount of the conventional energy sources is reducing day by day. To avoid energy inaccessibility, the use of renewable energy sources is extremely essential. Hybrid operation raises the reliability of stand-alone system, reduces the production cost and guarantees the availability of power. A new technological energy solution delivered by solar-wind and diesel standalone system is facing a high growth rate in recent days. In this paper we are designing the solar-wind & diesel generator for an Institutional area for providing green energy generation as much as possible. The hybrid system consist solar, wind, diesel generator and batteries with converter. Hybrid Optimization Model for Electric Renewable (HOMER) software is used to design the proposed hybrid renewable energy power system model. The sensitivity analysis was supported out using Homer program. The results are presented to verify the system performance and it has been found that renewable energy sources will replace the conventional energy sources.

Keywords
Renewable energy systems, photovoltaic, wind turbine, diesel generator.

1. INTRODUCTION
The Stand-alone micro grids are energy supply systems that are not connected to the main electricity grid. Stand-alone systems are most common as electrification of areas that are not in proximity to the main grid and where grid extension is too expensive. The most common way of ensuring electrification to such areas has been through installation of diesel generators, although micro grids provide good opportunities to consume locally available energy resources. As renewable energy technologies, mainly Photovoltaic (PV) power, have developed regarding price, efficiency and reliability, these are becoming increasingly popular and affordable for rural areas. At the same time, diesel generators suffer from increasing fuel prices, with the additional costs of transportation to remote locations, and low efficiency at low loads. However, its output can be controlled as disparate to solar power, an intermittent resource which varies both on a daily and seasonal basis. Combining a PV system with a generator in a hybrid micro grid makes it possible to limit some of the disadvantages in both technologies. Depending on the requirements of the energy supply, a micro grid might take in an Energy Storage System (ESS) [1].

The stand-alone hybrid solar-wind power generation system is accepted as a viable alternative to grid supply or to conventional fossil fuel based far-off area power supplies all over the world. There are almost 292 off-grid Canadian isolated communities with a total population of almost 194,281 peopling (2006 Statistics Canada Census); they have significant wind energy potentials [2]. The annual demand is almost 31,477,415 MWh /yr. where fossil fuel generation type is generally diesel. As the operation of diesel generators are highly expensive and contribute in carbon emission a different solution is required to minimize the diesel consumption. In the period of 2008-2011 the annual evolution rate of solar photovoltaic power was 147.3% in Canada. At the same time wind power generation has gained popularity and is estimated to produce 12% of the world's electricity by 2020. Consequently, the idea of hybrid operation is gaining attention among the researchers in electrical power industry.

In this paper, a stand-alone hybrid alternative energy system is proposed for Institutional area in Jaipur, Rajasthan. The currently system works there has a continual use of Kirloskar (KG1-62.5AS) diesel generator running at 1500rpm and M.K 12v battery. Therefore, we recommend taking this system steps further by adding renewable energy sources (wind turbine and photovoltaic). Wind and PV are the primary power source of the system and diesel generator is used as a backup for long-term storage system. On the supplementary hand, the battery is used in the system as a backup for short-term storage system.

2. ARCHITECTURE OF THE SYSTEM
The hybrid energy system architecture designed and simulated in Homer software is shown in figure 1. The projected hybrid renewable energy system involves wind turbine, photovoltaic panel. Diesel generator, battery, and inverter are including as a backup storage system. The system is designed positively for an off grid system for an Institutional area. The homer software is used to realize the greatest optimal sizing and for the system also is used for pre-feasibility study of the system. Sensitivity is considered in design the system.

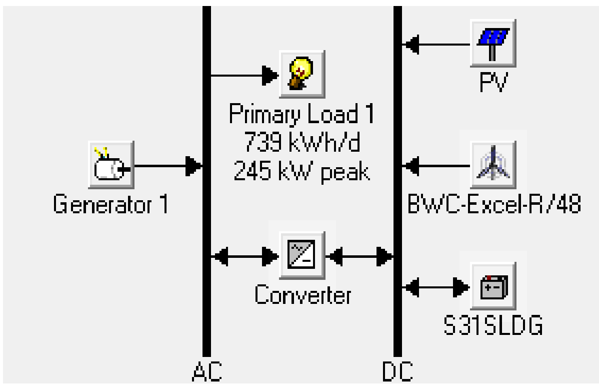


Fig. 1: Solar-wind-diesel stand-alone systems for an Institutional area

2.1 Wind Turbine

BWC-Excel-R/48 is usage in this system. It has rated capacity 7.5Kw and affords 48V DC. Its initial capital cost $23081, replacement cost is $17000, and yearly operation and maintenance cost is $462. The technical factors of wind turbine are shown in Table 1, which we became from (www.bergey.com). The hub and anemometer is located at 50 meters height. Figure 2 displays the power curve of BWC-Excel-R/48 turbine, which expresses the connection between the wind speed and generated power. Wind data for this place still under collection. So, ascending up the wind speed is used to get the estimated wind speed at Institutional site. These data achieved from (http://maps.nrel.gov/swera). Figure 3 shows the wind speed data for Institution with 3.287m/s average wind speed. Three levels of wind speed are excellent for sensitivity analysis.

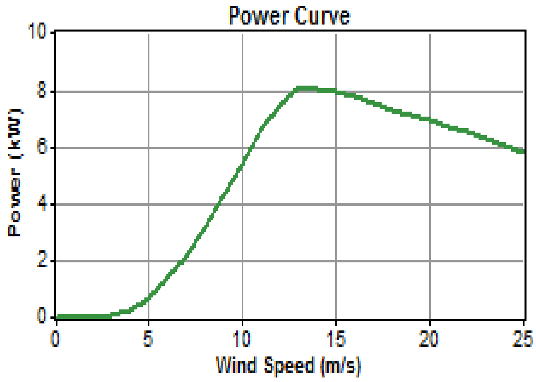


Fig. 2: Wind turbine power curve

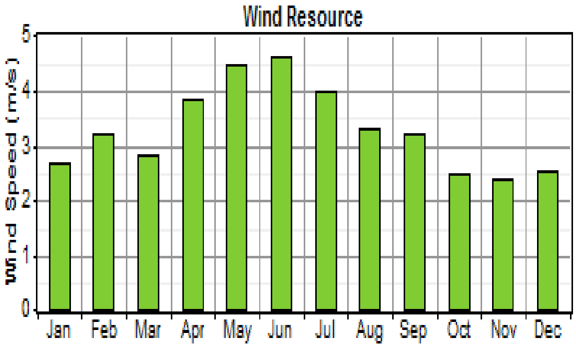


Fig. 3: Average wind speed over a year

Table 1. BWC-Excel-R/48 parameters

Start-up Wind Speed	3.4 m/s (7.5 mph)
Cut-in Wind Speed	2.5 m/s (5 mph)
Rated Wind Speed	12 m/s (27 mph)
Rated Power	7.5 Kw
Type	3 Blade Upwind
Rotor Diameter	7 m (23 ft.)
Generator	Permanent Magnet Alternator

2.2 Photovoltaic Array

The second renewable source implemented in this system is ZT300P solar module. There are several different solar panels are available in the streak, but basis on pieces, size, and rating Zytech ZT300P was chosen. The technical factors of wind turbine are presented in Table 2. Because the DC voltage bus is 24V, two PV sections are connected in series since each element has 12V. There are 7894 PV panels with every has 38W. The initial cost of each two panels attach in series is 200Kw- $111193 & 300Kw-$274277, replacement cost is $95626 & $235878 and operational and maintenance cost is $1112 & $2742. The latitude and longitude of Institute are 26N and 75E separately. The time zone is GMT+5:30 India. The effect of temperature is measured in this system. Figure 4 displays the solar radiation in a year created by HOMER.

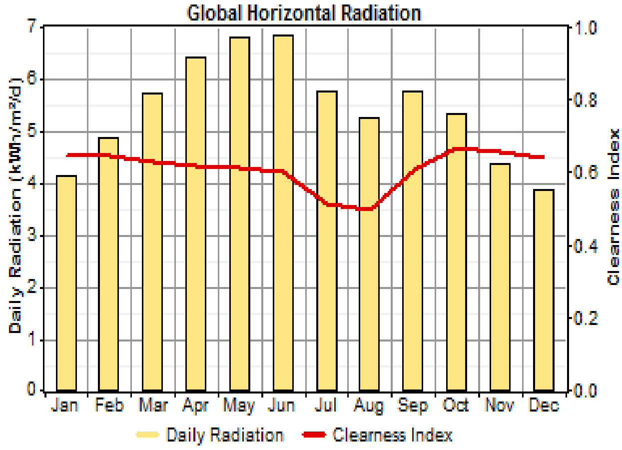


Fig. 4: Monthly solar radiation

2.3 Diesel Generator

Kirloskar KG1-62.5AS diesel generator running at 1500rpm is used to deliver AC power to the system all over the inverter. This generator has capacity of 50kW. Its initial capital cost is $6746, replacement cost is $5559, and operational and maintenance cost is 0.050$/hr. the almost cost of diesel fuel is $0.94 per liter. The manufacture efficiency graph is exposed in figure 5 and fuel consumption data is exposed in table 2.

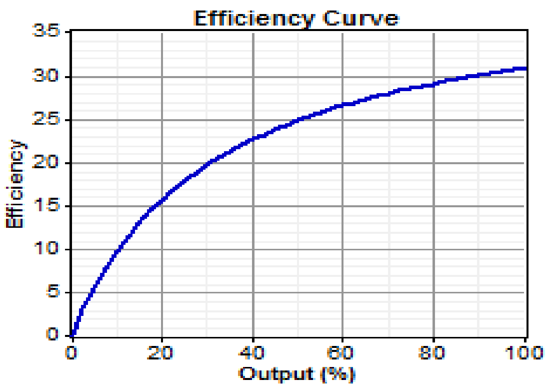


Fig. 5: Efficiency Curve

Table 2. Fuel Consumption Data

Output Power (Kw)	Fuel Consumption (L/hr.)
1.000	0.250
10.000	2.500
20.000	5.000
50.000	12.500

2.4 Battery
Total 200 numbers of batteries of S31SLDG Sealed Gel Cell are used in this system as a backup system and it also continues constant voltage irritated the load. Every battery rate 12V and has a capacity 98Ah with 12V total rating. The initial capital cost of all batteries is $69600 with replacement cost of $55600, and M&O cost is $6. The batteries are talented to handle the constant charging and discharging which tells as deep cycle batteries.

2.5 Converter
A converter can be an inverter (DC to AC), rectifier (AC to DC), or both. The conventional load is DC type, but generated power from diesel generator is AC type. The average load is 200kW and the peak load is 245 kW. The Capital cost of average load is $71428 and replacement cost is $42458 & M&O $714.

2.6 Demand Load
The Institutional site day-to-day average AC load is 739kWh/day. The Institution operates practically the same hourly load during the year. Institution facilities make a small different in the load, especially the air condition. Fig.6 displays a typical load profile for Institutional site produced by HOMER.

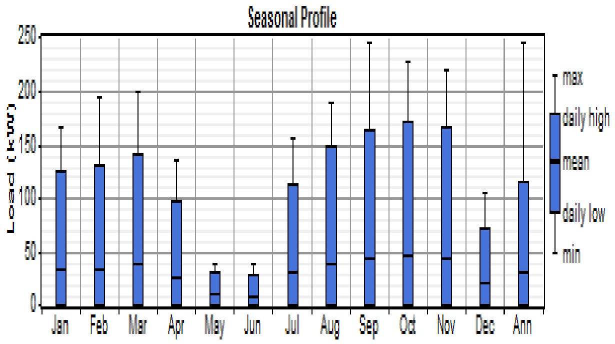
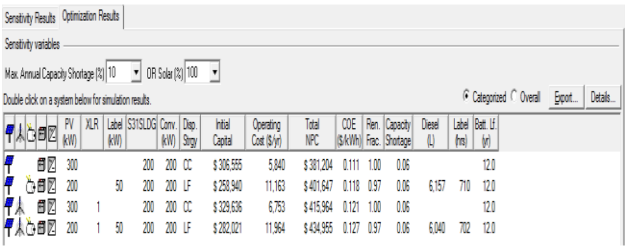


Fig. 6: Load Profile for Institutional area

3. RESULT AND DISCUSSION
HOMER allows the user to define different possible sizes of the PV system, Wind System, battery bank, converter and generators. After each simulation, the optimal solution presented by HOMER is the system that, with the sizes and components available, can cover the load within the given technical constraints at minimum cost.

The simulations in HOMER were performed multiple times for each case. For each simulation, multiple evaluations of the results were made shows Fig. 7.



Sensitivity Results | Optimization Results

Sensitivity variables

Max. Annual Capacity Shortage (%) 10 OR Solar (%) 100

Double click on a system below for simulation results.

Categorized Overall Export... Details...

	PV (kW)	XLR	Label (kW)	S31SLDG	Conv. (kW)	Disp. Strgy	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Label (hrs)	Batt. Lf. (yr)
	300			200	200	CC	$ 306,555	5,840	$ 381,204	0.111	1.00	0.06			12.0
	200		50	200	200	LF	$ 258,940	11,163	$ 401,647	0.118	0.97	0.06	6,157	710	12.0
	300	1		200	200	CC	$ 329,636	6,753	$ 415,964	0.121	1.00	0.06			12.0
	200	1	50	200	200	LF	$ 282,021	11,964	$ 434,955	0.127	0.97	0.06	6,040	702	12.0

Fig. 7: Optimization results with sensitivity variables

On the basis of cost of energy different combinations were obtained by HOMER.

The first combination obtained by HOMER is Solar with battery and converter, Second combination obtained by HOMER is Solar-Diesel with battery and converter, Third combination obtained by HOMER is Solar-Wind with battery and converter and Fourth combination obtained by HOMER is Solar-wind-diesel generator with battery and converter.

On the above different combination most Optimal solution obtained by HOMER is Solar with battery and converter for an Institutional area.

3.1 Solar with battery and converter for an Institutional area

Table 3. System Architecture

Component	Rating
PV	300 Kw
Battery (S31SLDG)	200
Inverter	200 kW
Rectifier	200 kW
Total NPC	$ 381,204
Levelized COE	$ 0.111/kWh
Operating Cost	$ 5,840/yr.

3.1.1 Cost Summary
The Cost Summary tab displays cash flows as either a present value or annualized cost, categorized by component or cost type. Three cost outputs, the total net present cost, levelized cost of energy, and the operating cost appear in the top right corner of the Simulation Results window.

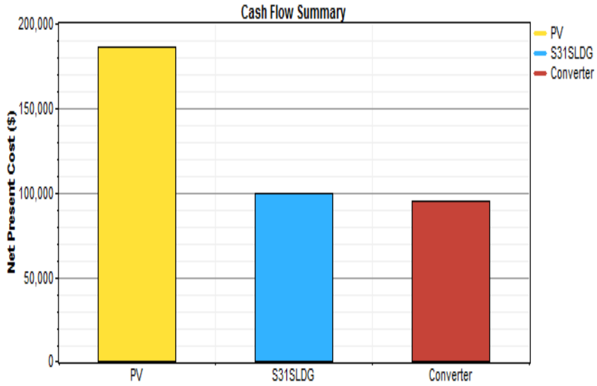


Fig. 8: Net Present Cost V/s different Components

Table 4. Simulation result of Cost Summary

Component	PV	Battery (S31SLDG)	Converter	System
Capital ($)	165,554	69,600	71,401	306,555
Replacement ($)	0	41,364	17,887	59,250
O&M ($)	21,161	77	9,366	30,603
Fuel ($)	0	0	0	0
Salvage($)	0	-11,875	-3,329	-15,204
Total ($)	186,715	99,165	-15,204	381,204

3.1.2 Cash Flow

The Cash Flow tab of the simulation results window shows a graph of the system cash flow. Each bar in the graph represents either a total inflow or total outflow of cash for a single year. The first bar, for year zero, shows the capital cost of the system, which also appears in the optimization results. A negative value represents an outflow, or expenditure for fuel, equipment replacements, or operation and maintenance (O&M). A positive value represents an inflow, which may be income from electricity sales or the salvage value of equipment at the end of the project lifetime.

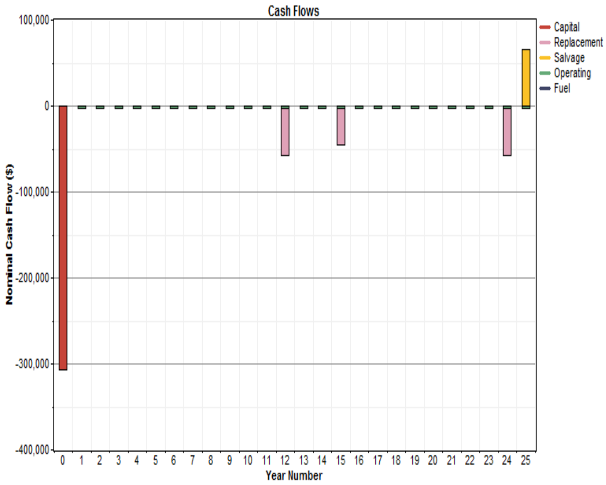


Fig. 9: Nominal Cash Flow V/s Time

3.1.3 Electrical

The Electrical tab of the Simulation Results window shows details about the annual production and consumption of electrical energy by the system.

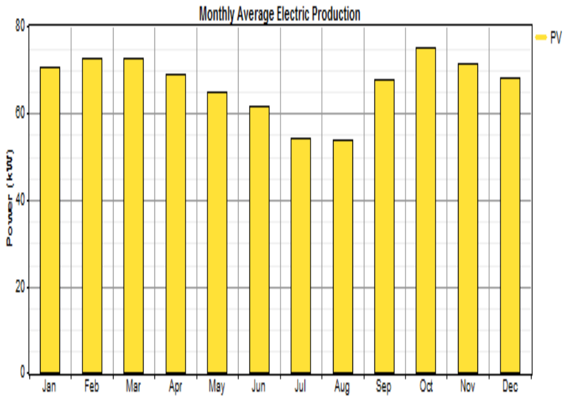


Fig. 10: Power V/s different Time

Table 5. Simulation result of Production (Electrical)

Production	kWh/yr.	%
PV array	584,223	100
Total	5854,223	100

Table 6. Simulation result of consumption

Consumption	kWh/yr.	%
AC primary load	269,094	100
Total	269,094	100

Table 7. Simulation result of Quantity

Quantity	kWh/yr.	%
Excess electricity	276,968	47.4
Unmet electric load	641	0.2
Capacity shortage	16,348	6.1

Quantity	Value
Renewable fraction	1

3.1.4 PV

The PV tab shows details about the operation of the PV array if the system contains one. The PV tab of the Simulation Results window contains the following output variables:

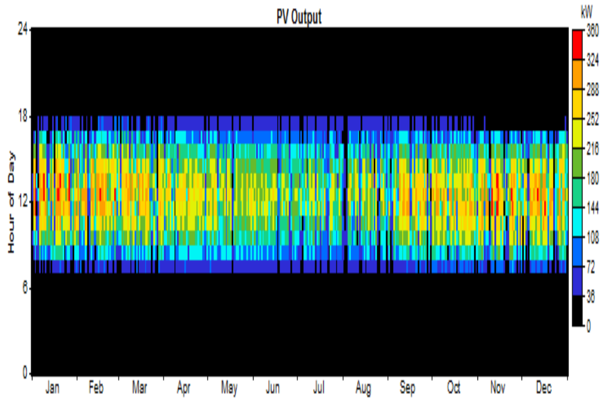


Fig. 11: Hour of Day V/s Months

Table 8. Simulation result of Photovoltaic

Quantity	Value	Unit
Rated capacity	300	kW
Mean output	67	kW
Mean output	1,601	kWh/d
Capacity factor	22.2	%
Total production	584,223	kWh/yr.
Minimum output	0	kW
Maximum output	352	kW
PV penetration	217	%
Hours of operation	4,368	hr/yr
Levelized cost	0.0250	$/kWh

3.1.5 Battery

The Battery tab shows details about the use and expected lifetime of the battery. The Battery tab of the Simulation Results window contains the following output variables:

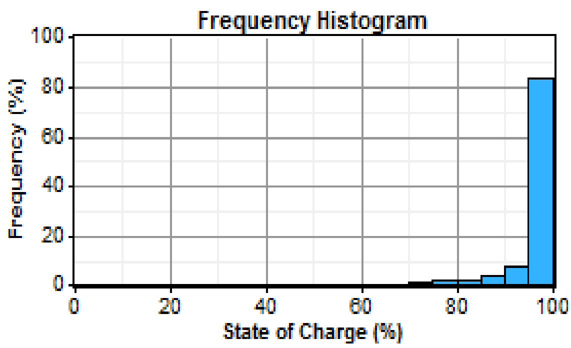


Fig. 12: Frequency V/s State of Charge

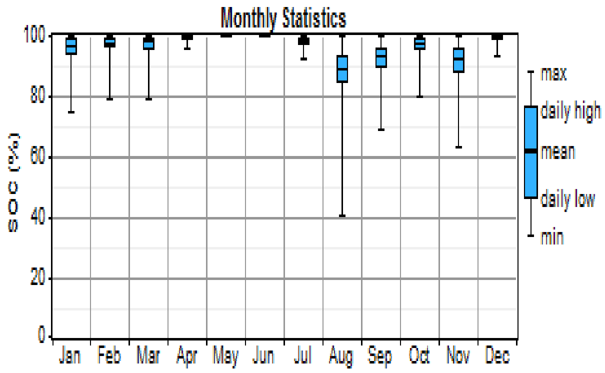


Fig. 13: State of Charge V/s Months

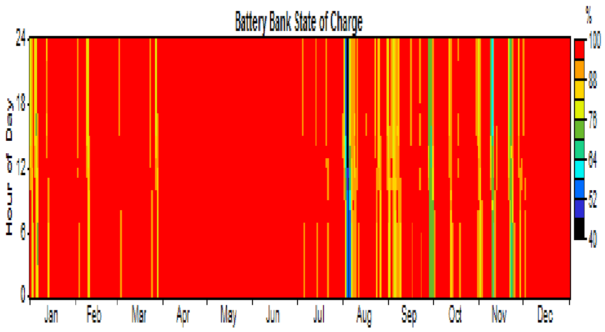


Fig. 14: Hours of Day V/s Months

Table 9. Simulation result of Battery

Quantity	Value
String size	1
Strings in parallel	200
Batteries	200
Bus voltage (V)	12

Quantity	Value	Unit
Nominal capacity	235	kWh
Usable nominal capacity	141	kWh
Autonomy	4.58	Hr.
Lifetime throughput	6,310,598	kWh
Battery wear cost	0.010	$/kWh
Average energy cost	0.000	$/kWh
Energy in	41,361	kWh/yr.
Energy out	33,098	kWh/yr.
Storage depletion	1	kWh/yr.
Losses	8,263	kWh/yr.
Annual throughput	37,004	kWh/yr.
Expected life	12.0	Yr.

3.6 Converter

The Converter tab shows details about the operation of the inverter and rectifier, including capacity, electrical input and output, hours of operation, and losses.

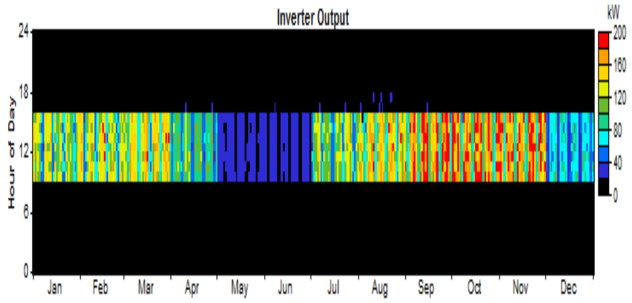


Fig.15: Hour of Day V/s Months

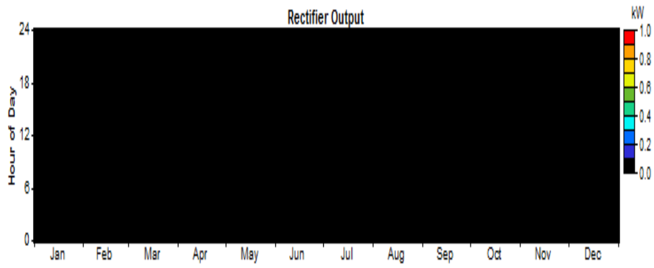


Fig. 16: Hour of Day V/s Months

Table 10. Simulation result of Converter

Quantity	Inverter	Rectifier	Units
Capacity	200	200	kW
Mean output	31	0	kW
Minimum output	0	0	kW
Maximum output	200	0	kW
Capacity factor	15.4	0.0	%
Hours of operation	8,756	0	hrs/yr
Energy in	298,992	0	kWh/yr.
Energy out	269,094	0	kWh/yr.
Losses	29,899	0	kWh/yr.

4. CONCLUSION

This Paper discusses an overview of solar-wind-diesel stand-alone System. The major components of SWDSAS including Photovoltaic, wind, diesel generator, Battery, AC-DC power electronics converter, DC-AC power electronics converter are discussed.

The PV shows the meaningful and optimal result among all four combination in terms of Net Present Cost (NPC) and Cost of Energy (COE) generated by simulation model of solar-wind-diesel stand-alone System. NPC and COE of optimal combination is $ 381204, 0.111 $/kWh respectively.

5. ACKNOWLEDGEMENT

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