Simulation and Optimization of Solar Photovoltaic-Wind stand alone Hybrid system for a Residential Load

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Abstract-An alternative renewable energy sources such as solar-photovoltaic/Wind is an integrated form which are connected together to produce electrical power to the consumers under standalone system. Distributed generators can provide high reliability by providing on-site generation. As a result of this many hybrid systems like PV cells, fuel cells, micro turbines, wind, diesel and small hydro systems. The distributed generation system having Photo Voltaic (PV), wind turbine and diesel generator is simulated and analyzed. This paper gives simulation results of PV-Wind-Diesel hybrid system under standalone conditions. HOMER (Hybrid Optimization Models for Energy Resources) power optimization software by NREL (National Renewable Energy Laboratory) is used to simulate and analyze the PV-Wind-Diesel hybrid system.

I. INTRODUCTION

With rapid escalation of fossil fuel prices as well as sharp increase in the capital cost of new central generating plants, there is a focused attention on alternate generating system with higher efficiency of energy use. Under deregulation and restructuring of power systems, electricity market becomes highly competitive. The main alternate energy sources include solar, water, wind, geothermal and waste material. Solar power is available for use almost anywhere. In the new millennium many countries have taken serious initiatives to tap solar energy resources which are abundant and environment friendly. High quality of research will bring down the cost of manufacturing as well as enhance the efficiency of the allied equipments for tapping solar radiation. And additionally public awareness will increase the market demand of these equipments. Thus the equipments will be sold out at the economy of scale [1],[2].The cost of PV has declined steadily since the first solar cells were manufactured, and the levelized cost of electricity (LCOE) from PV is competitive with conventional electricity sources in an expanding list of geographic regions**.** Utilizing wind mills for various reasons is a practice for several years. Now many nations recognize the shortage of fossil fuels and importance of wind energy. The wind energy has re-emerged as an important source of sustainable energy resource worldwide. The energy available in the wind depends on the density and velocity. The density changes with the temperature and pressure. The need to integrate the renewable energy like wind into power system is to make it possible to minimize the environmental impact on conventional plant. Today more than 28,000 wind generating turbines are operating successfully all over the world [3].A battery converts chemical energy into electrical energy through a reduction-oxidation (redox) process between its active elements. These elements are the anode, the cathode, and the electrolyte, where the anode and the cathode serve as the negative and positive electrodes respectively. During charging conditions, charge is injected into the battery On the one hand, if the redox process is reversible (i.e. the battery is rechargeable), the injected charge is absorbed and stored by the battery. In this case, the battery is referred to as a secondary cell. There are four parameters used to describe a battery: the state of charge (SoC), the capacity (C), the nominal voltage ($Vnom$), and the rated maximum voltage ($Vmax$). SoC describes the battery status and is represented in percentage, where 100% describes a fully-charged battery and 0% describes a fully-depleted battery [4]**.** Diesel generators and combustion engines are mainly used for off-grid generation. Low installed capacity, high shaft efficiency, suitable for start-stop operation, and high exhaust heat are some of the advantages of combustion engines. These engines convert heat from the combustion into work via rotation of shaft. The shaft is directly coupled to the generator and electricity is produced [3]. This paper presents an analysis for a standalone PV system for a residential house in Chennai (Tamil Nadu).System optimizations are studied under standalone conditions. Sensitivity analysis tells the best feasible solution out of different options. The system is simulated and optimized using HOMER. The rest of the paper is organized as follows. Section II describes the System model. Simulation Results are provided in Section III, Finally in conclusion Section IV.

II. SYSTEM MODEL

The proposed model consists of solar PV module of 18 kW PV system, Wind power of 1Kw, Generator10kW a Standalone capacity with Trojan T-105 battery storage of 12V and a converter of 5kW. The system is designed to have a life time of 25 years so the PV panels will not be replaced. The proposed system is shown in Fig.1.

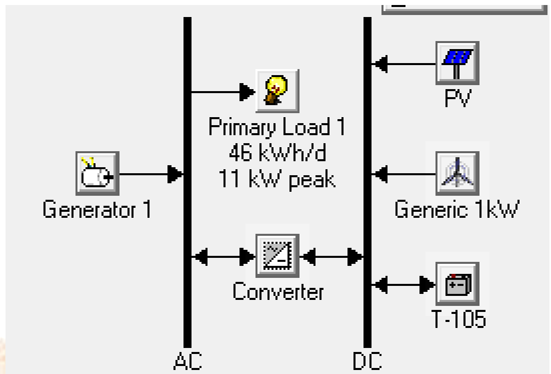


Fig.1 PV-Wind-Diesel Distributed Generation System

In this paper, Standalone hybrid power system models have been done using HOMER to evaluate and determine the cost of different models. HOMER simulation software the input data to evaluate the optimization value for different combinations. After the system components and the equations, Modeling and simulations of the micro power system is carried out. HOMER [5], an optimization model is used to simulate the system. Large number of options are available for different sizes of the components used, components to be added to the system which make sense, cost functions of components used in the system. HOMER's optimization and sensitivity analysis algorithms evaluated the possibility of system configuration. Range of different fuel prices and different wind speeds are considered for modeling. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel and interest [3].

Table 1 displays the values of each optimization value. It shows set of all possible variation in the system configuration. HOMER simulates all possible ways and sorts them according to net present cost (NPC). In this simulation, sensitivity variables are PV arrays, wind speed (m/s) and diesel price. Total number of possible sensitivity variables including converter and battery are 2 and numbers of simulations are 1536.HOMER simulates Solar, diesel and wind as Alternate renewable energy resources. HOMER checks for System control variables, Constraits and Economics during the hybrid simulation. The hybrid system simulation shows the optimized system for different system sensitivity variables.

Wind data: Auto correlation factor: 0.85, Hours of peak Wind speed: 15, Anemometer height: 10 m, Scaled annual averages: 2.2 m/sec.Diesel Data: Life time: 1 kW generator: 15,000 hours, life time, Weibull k: 2

PV Data: Scaled Annual Average: 4.5 KWh/m2/d

Using the above window, there are 1536 simulation results possible for the designed system. The following session shows the simulation results for the optimum system.

2.1. Photo Voltaic (PV)

Photovoltaic systems convert sun's energy directly into electricity. They are composed of semiconductor photovoltaic cells, usually a thin wafer or strip of semiconductor material which produces a small current when sunlight strikes them. Multiple cells can be form into modules which forms an array of any size. Small photovoltaic arrays are found in calculators and wrist watches; the largest arrays have capacities in excess of 5 MW. Photovoltaic systems are cost-effective in small off-grid applications, providing power, for example, to rural homes in developing countries, off-grid cottages and motor homes in industrialized countries, and remote telecommunications, monitoring and control systems worldwide. Figure 2 and 3 shows the cost curve of PV module and solar resource profile over one year. The solar resource data for Chennai, Tamil Nadu is obtained from NASA surface meteorology and solar website [4]. The approximate location of the site used is *13° 04'N* latitude and ***80°** 17' E* longitudes.

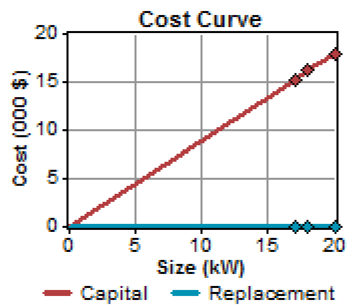


Fig. 2 Cost Curve of PV module

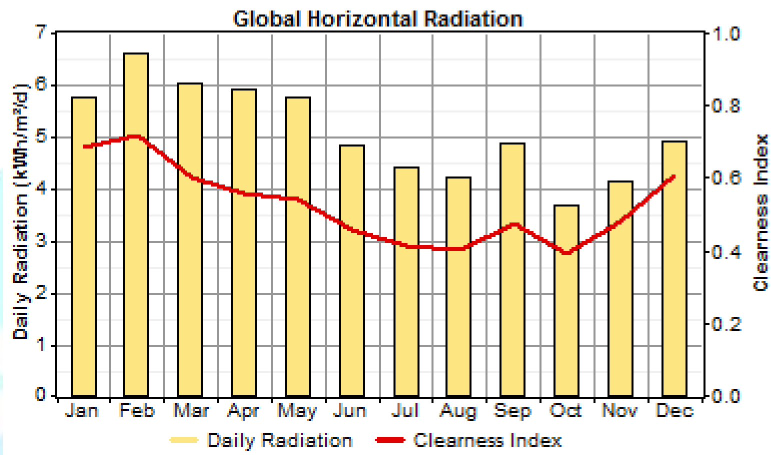


Fig.3 Solar Resource

TABLE I PARAMETERS OF PV PRODUCTION

Quantity	Value	Units
Rated capacity	17.0	kW
Mean output	2.7	kW
Mean output	65.2	kWh/d
Capacity factor	16.0	%
Total production	23,783	kWh/yr

Quantity	Value	Units
Minimum output	0.0	kW
Maximum output	14.3	kW
PV penetration	139	%
Hours of operation	4,375	hr/yr
Levelized cost	0.0502	$/kWh

Table 1.indicates the different parameters of total PV production, where the total production is 3,783kWh/yr.The maximum output taken from PV production is 14.3Kw

2.2. Wind Resource

A wind turbine is a device that converts the wind's kinetic energy into energy. Wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels. Wind was shown to have the "lowest relative greenhouse gas emissions, the least water consumption demands and... the most favourable social impacts" compared to photovoltaic, hydro, geothermal, coal and gas **[5].** In this modelling, 1 kW DC rated power is used for the wind turbine. The power curve and cost curve for wind turbine is shown in figures 2 and 3 respectively.

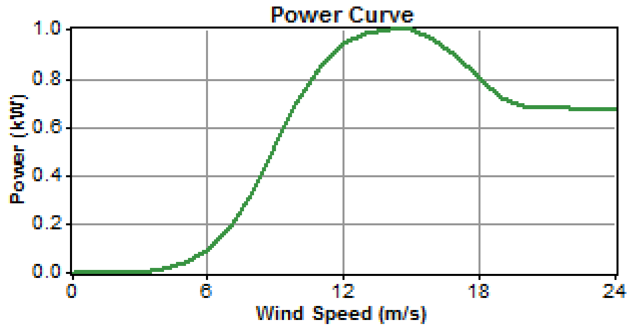


Fig. 4 Power Curve of a Wind Turbine

The life time taken as 15 years and hub height is 10 meters for the wind turbine considered. Figure 6 shows wind resource for a given simulation. The daily average wind speed measured at 10 meters height is 4.5 m/s.

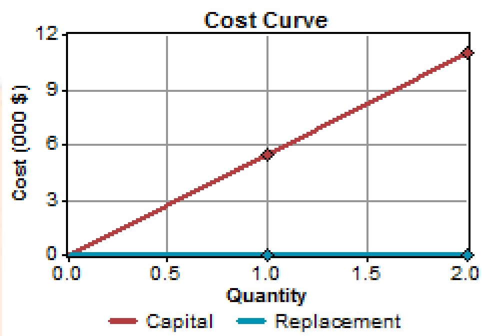
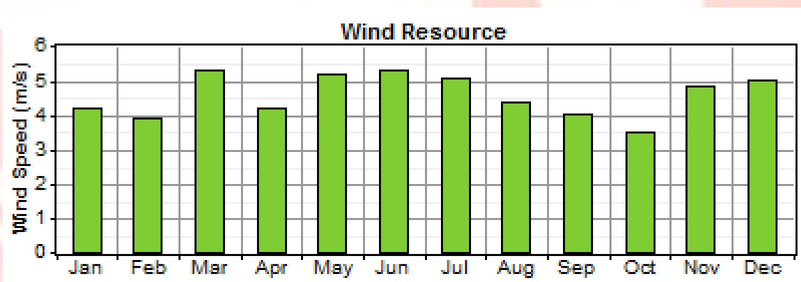
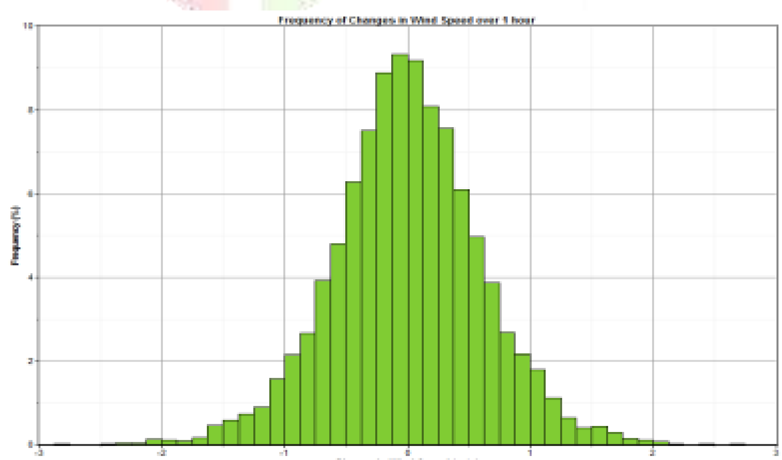


Fig. 5. Cost Curve of a Wind Turbine



(a) Wind Resource



(b) Wind Speed Profile

Fig.6 (a) Wind Resource and (b) Wind Speed Profile

2.3. Diesel Engines

The diesel engine (also known as a compression-ignition or CI engine), named after Rudolf Diesel, is an internal combustion engine in which ignition of the fuel which is injected into the combustion chamber is caused by the elevated temperature of the air in the cylinder due to mechanical compression (adiabatic compression). Diesel engines work by compressing only the air. This increases the air temperature inside the cylinder to such a high degree that atomised diesel fuel that is injected into the combustion chamber ignites spontaneously. This contrasts with spark-ignition engines such as a petrol engine (gasoline engine) or gas engine (using a gaseous fuel as opposed to petrol), which use a spark plug to ignite an air-fuel mixture. In diesel engines, glow plugs (combustion chamber pre-warmers) may be used to aid starting in cold weather, or when the engine uses a lower compression-ratio, or both. The original diesel engine operates on the "constant pressure" cycle of gradual combustion and produces no audible knock. [6]. In this modeling 10 kW diesel engines is used along with the wind turbine and PV array. Figure 7 shows the cost curve of diesel generator rated for 10kW.

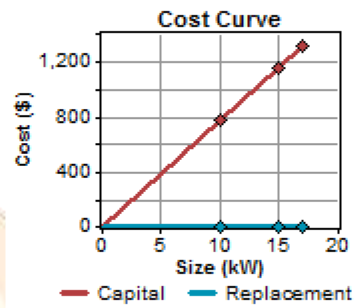
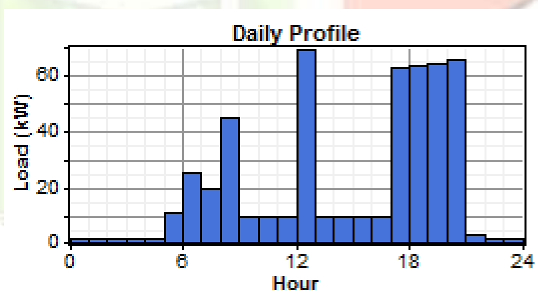


Fig. 7 Cost Curve of 1 kW Diesel generator

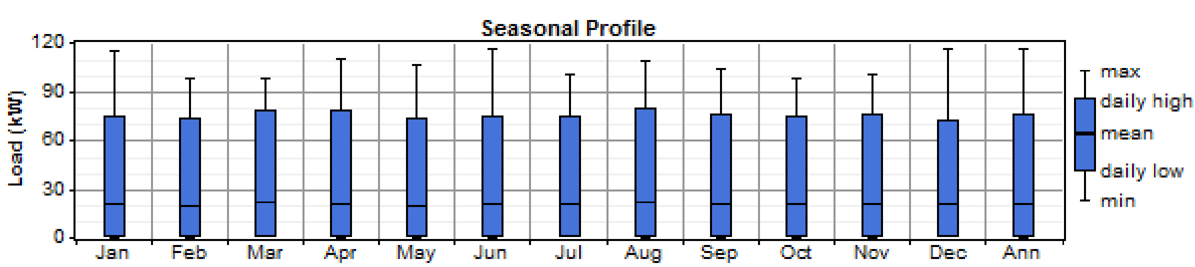
In addition to wind turbine, PV, diesel generator, converter, storage battery and a primary load is used in the modelling of PV-Wind-Diesel hybrid system. A primary load of 46000 Wh/day having 11k W peak load is taken for simulation.

III. LOAD DETAILS

The load details for the Diesel Generator (DG) system are shown in figure 8. The load profile is based on a average wind speed as shown in figure 8. A small base load of 10 kW occurs throughout the day and night. Figure 8 (a) shows the daily load profile and 8 (b) shows the seasonal load profile.



(a) Daily load profile

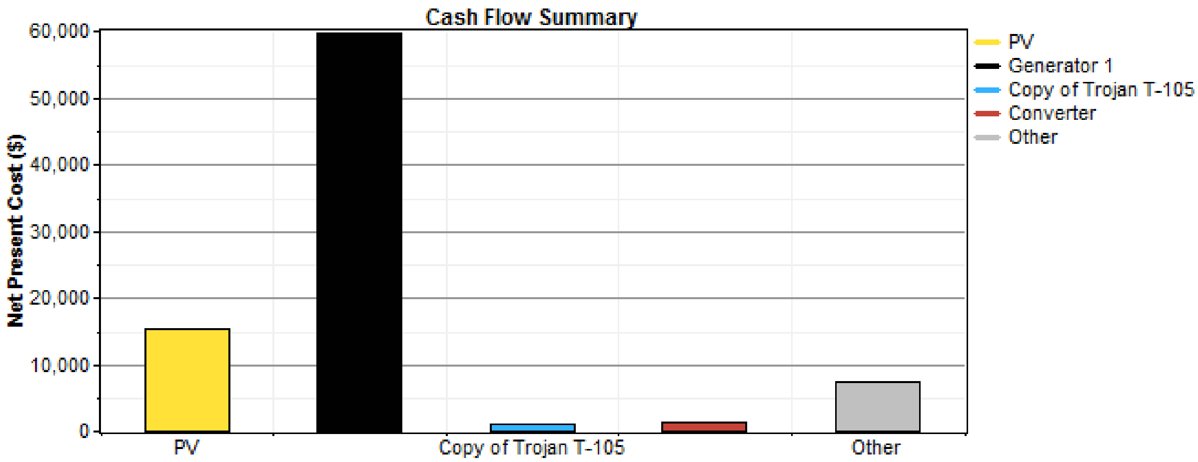


(b) Seasonal load profile

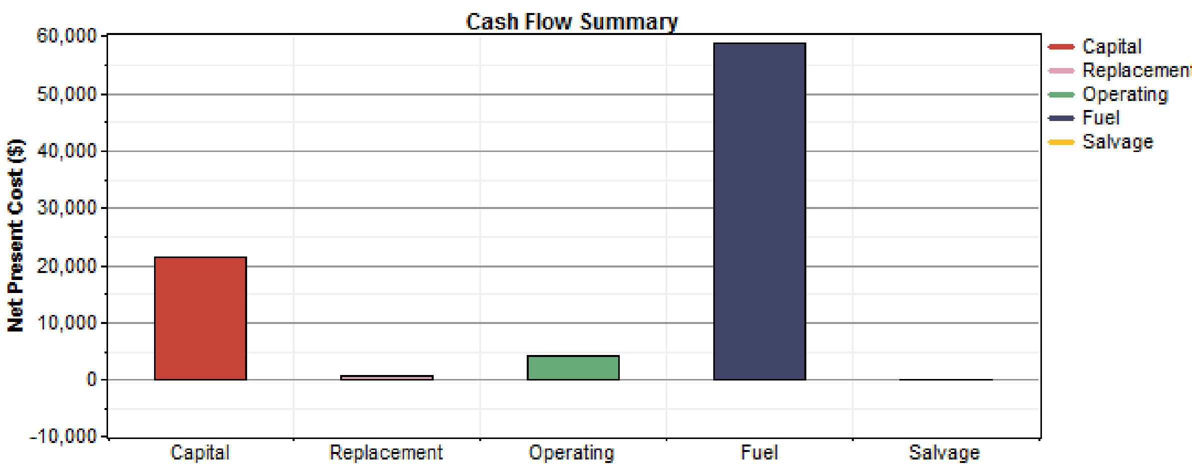
Fig. 8 Load Details for hybrid PV-Wind-Diesel System

IV. RESULTS

4.1 Cost Summary



(a) By Component



(b) By Cost Type

Fig. 9 *(a)* By Component *(b) By Cost Type*

Total NPC: (Net Present Cost): $84,468

Operating Cost: 4.951 $/yr

4.2. Cash Flow Summary

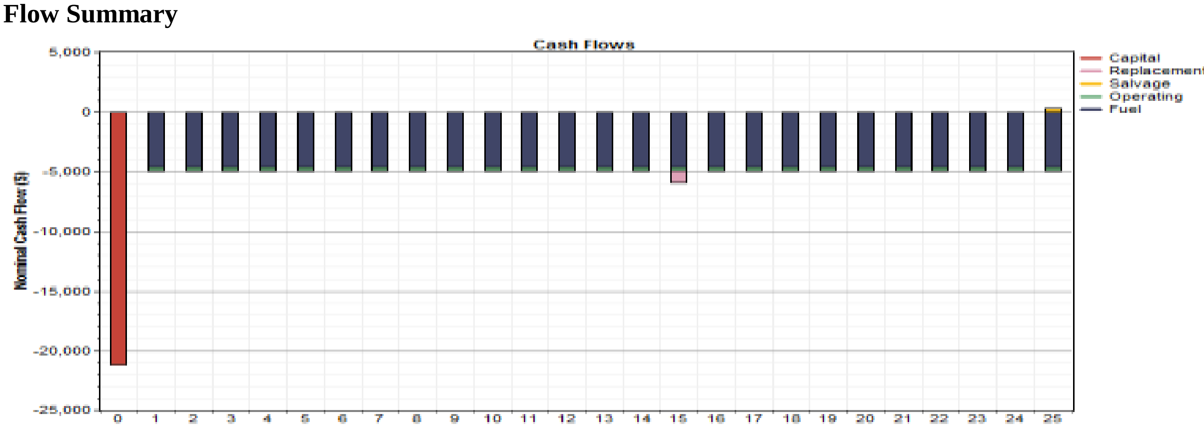


Fig. 10 *Cash Flow Summary*

4.3. Electrical Production

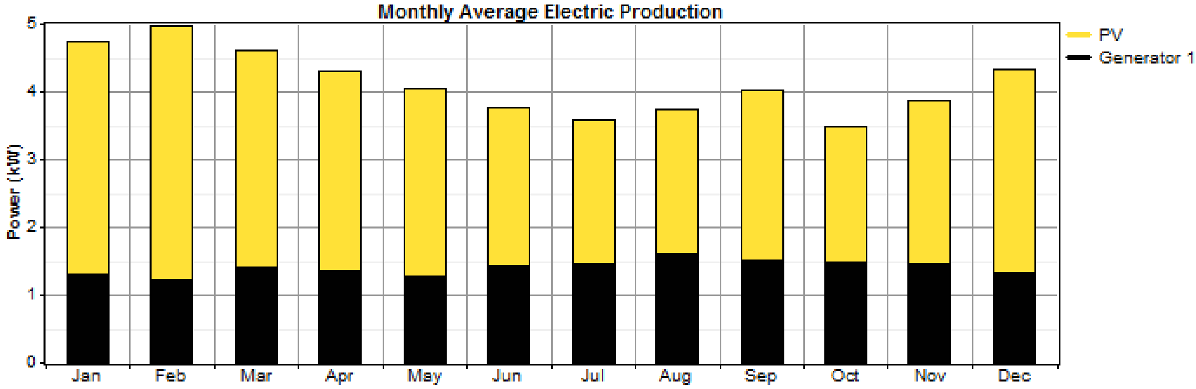


Fig. 11 .Monthly Average *Electrical Production*

TABLE II .Electrical Simulation Results

Quantity	kWh/yr	%
Excess electricity	16,210	44.9
Unmet electric load	3.42	0.0
Capacity shortage	14.3	0.1

Quantity	Value
Renewable fraction	0.658
Primary energy savings	48.3 %
CHP fuel input	56.6 MWh/yr
CHP electrical production	36.1 MWh/yr
CHP thermal production	0.00 MWh/yr
CHP electrical efficiency	63.8 %

4.4. Battery

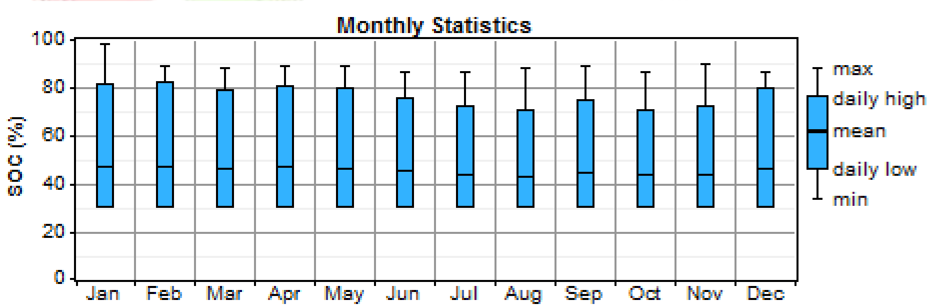


Fig. 12 .Monthly Statistics of Battery

TABLE III Battery Simulation Results

Quantity	Value	Units
Energy in	3,634	kWh/yr
Energy out	3,099	kWh/yr
Storage depletion	11	kWh/yr
Losses	524	kWh/yr
Annual throughput	3,361	kWh/yr
Expected life	3.02	yr

Quantity	Value	Units
Nominal capacity	16.2	kWh
Usable nominal capacity	11.3	kWh
Autonomy	5.94	hr
Lifetime throughput	10,140	kWh
Battery wear cost	0.000	$/kWh
Average energy cost	0.000	$/kWh

4.5. Emissions

Emissions for different pollutants are shown below.

Pollutants Emissions (kg/yr)

Carbon dioxide: 14,728

Carbon monoxide: 36.4

Unburned Hydrocarbons: 4.03

Particulate matter: 2.74

Sulphur dioxide: 29.6

Nitrogen oxides: 324

4.6. Optimal System Type

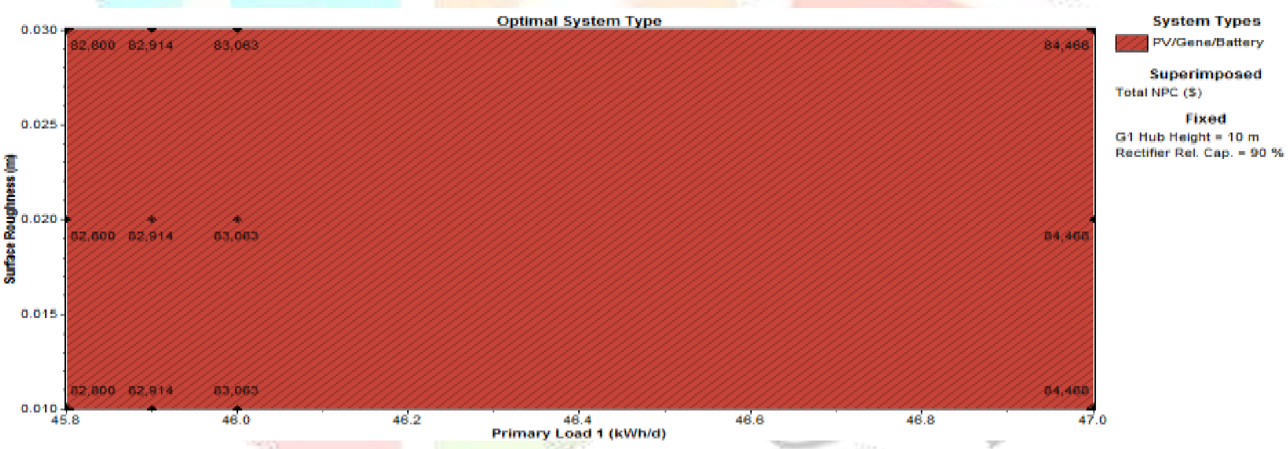


Fig. 13. *Optimal System Type*

V. CONCLUSIONS

The results of HOMER modeling shows that the cost summary, cash flow summary, electrical production or emissions and cost of PV-Wind-diesel hybrid system is feasible. From the proposed model it is clear that PV/Battery/Diesel configuration is optimum without wind energy. Total Net Present Cost of the optimum system type is $82, 800, Cost of energy is $0.388, while Renewable fraction is 0.67 .At higher wind speeds, and PV/Wind/Diesel/Battery configuration shows optimum results, with cost of energy is $0.425

VI. REFERENCES

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