Modelling and Simulation of Distributed Generation System Using HOMER Software

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***Abstract*-A microgrid is an integrated form of Distributed Energy Resources (DERs) which are connected together to serve electrical power to the selected consumers or can exchange power with the existing utility grid under stand alone or grid connected mode. Distributed generators can provide high reliability by providing on-site generation. As a result of this many hybrid systems came in existence 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. 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.**

***Keyword*-PV, Wind, Diesel, HOMER, DER**

I. INTRODUCTION

One of the most recognized terms in today's electricity market is deregulation. To realize the potential of distribution generation, generation and load must be taken as a subsystem. This system may use any combination of generation, load and storage technologies and can operate in grid connected mode or autonomous mode. Some examples of micro power system or microgrid are solar-battery serving a remote load, wind-diesel system serving an isolated village, a grid connected natural gas microturbine providing heat to a factory. Micropower system consists of electric and thermal load, and any combination of photovoltaic modules (PV), wind turbine, small hydro, biomass power generation, microturbines, fuel cells, reciprocating engine generators, batteries and hydrogen storage. The analysis and design of micropower system is challenging due to large number of design options and uncertainty in key parameters such as load size and future fuel price. Renewable energy sources add further complexity because the output may be intermittent, seasonal and nondispatchable and the availability is uncertain. This work is a technical and economic feasibility study of a hybrid generating system, composed of wind, diesel and grid resources feeding a customer with high reliability requirements of electric supply. Penetration of distributed generation across the country has yet not reached the significant levels. These emerging technologies have lower emission and potential to have lower cost. A better way to realize the potential of distributed generation is to take a system approach where load and generation acts as a subsystem called "microgrid". This is a decentralized and bidirectional pattern permits electricity import from the grid and electricity export to the grid. A plant that produces electricity less than 500 kW comes under micro generation technologies. Microgrid sources can produce electrical energy and thermal energy both. Hence, the penetration of distributed energy resources both at low voltages and medium voltages (LV and MV) in utility and downstream networks have been increased in developed countries like USA, Canada, Japan.

II. SYSTEM SCHEMATIC AND COMPONENTS

The ability to generate electricity is a building block of modern society. The utilization of wind turbines to produce electricity is practiced for over hundred years. Similarly, diesel engines have been a technology to produce energy since 1940s. However, the field of engineering concerned with the coupling of PV-Wind-Diesel systems have just begun recently. The following schematic represents basic PV-Wind-Diesel hybrid system. Hybrid power system incorporates more than one piece of equipment for electricity production as well as storage, power conditioning components and system controls.

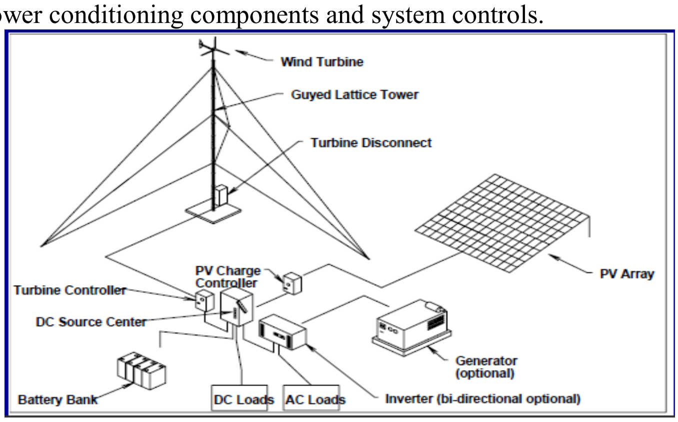

Fig. 1. Basic PV-Wind-Diesel Hybrid System

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A. *Wind Resource*

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. As the ratio of installed wind capacity to the system load increases, the required equipment needed to maintain a stable AC grid increases, forcing an optimum amount of wind power in a given system. So the design of individual components. must be sized properly. In this modeling, 0.4 kW DC rated power is used for the wind turbine. The power curve and cost curve for wind turbine is shown in figures2and3respectively.

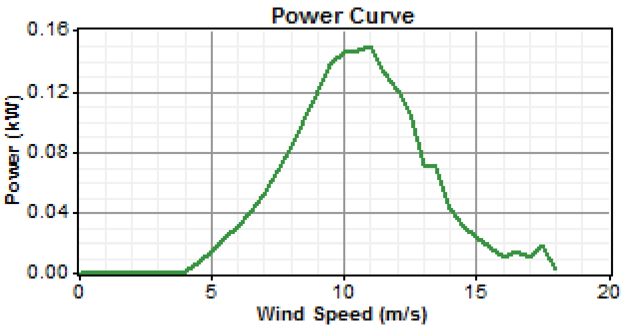


Fig. 2 Power Curve of a Wind Turbine

The life time taken as 15 years and hub height is 25 meters for the wind turbine considered. Figure 4 shows wind resource for a given simulation. The daily average wind speed measured at 25 meters height is 4.5 m/s.

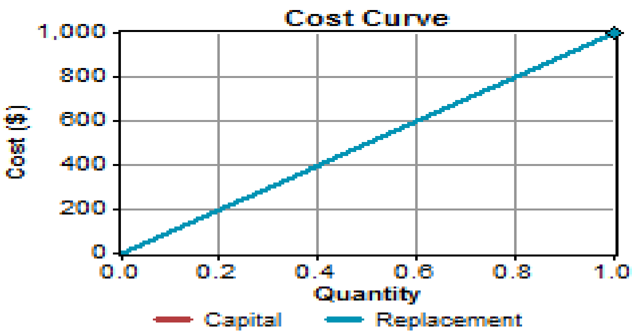
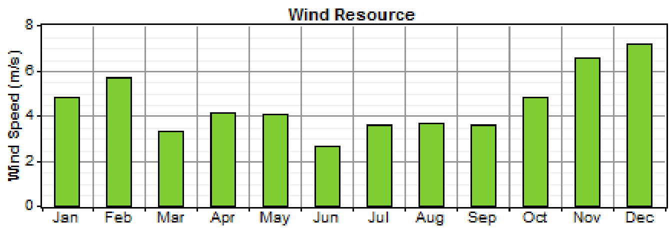
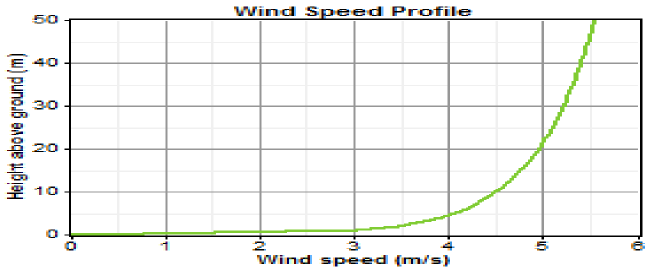


Fig. 3. Cost Curve of a Wind Turbine



(a) Wind Resource



(b) Wind Speed Profile

Fig.4 (a) Wind Resource and (b) Wind Speed Profile

B. *Diesel Engines*

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. They run at a speed defined by the frequency of supply grid. In this modeling 1 kW diesel engine is used alongwith the wind turbine and PV array. Figure 5 shows the cost curve of diesel generator rated for 1 kW.

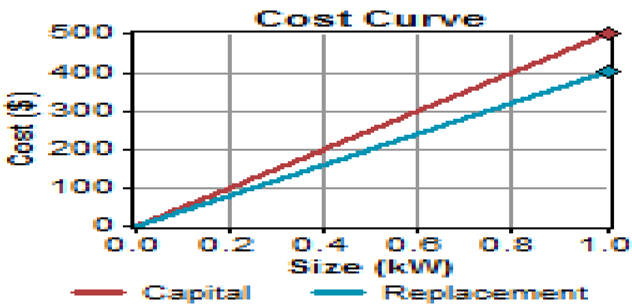


Fig. 5 Cost Curve of 1 kW Diesel generator

In addition to wind turbine, PV and diesel generator, storage battery, a converter and a primary load is used in the modeling of PV-Wind-Diesel hybrid system. A primary load of 910 Wh/day having 144 W peak load is taken for simulation.

C. *Photo Voltaic (PV)*

Photovoltaic systems convert energy from the sun directly into electricity. They are composed of photovoltaic cells, usually a thin wafer or strip of semiconductor material that generates a small current when sunlight strikes them. Multiple cells can be assembled into modules that can be wired in an array of any size. Small photovoltaic arrays are found in wrist watches and calculators; 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.

The PV plant is connected to grid via DC/AC inverters of different technology. PV have explosive growth rate, which is still less than one tenth of wind. Figure 6 and 7 shows the cost curve of PV module and solar resource profile over one year. The solar resource data for Gujarat is obtained from NASA surface meteorology and solar website [9]. The approximate location of the site used is 24.5^0 lattitude and 70.5^0 longitude.

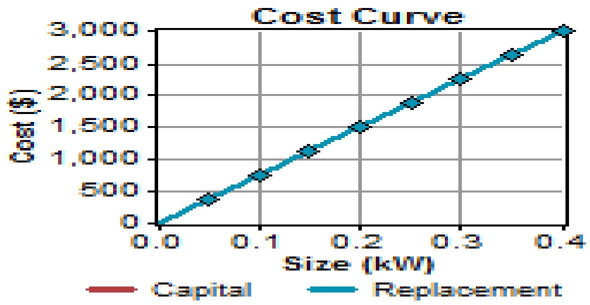


Fig. 6 Cost Curve of PV module

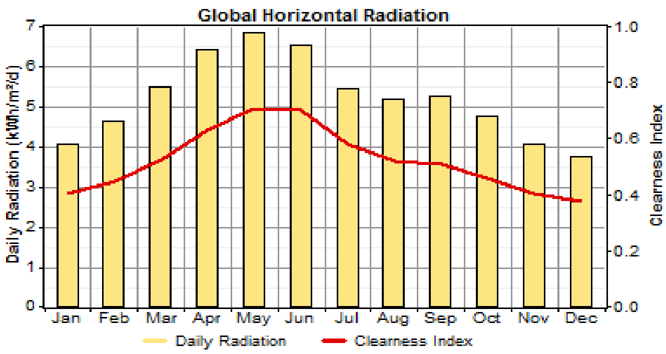
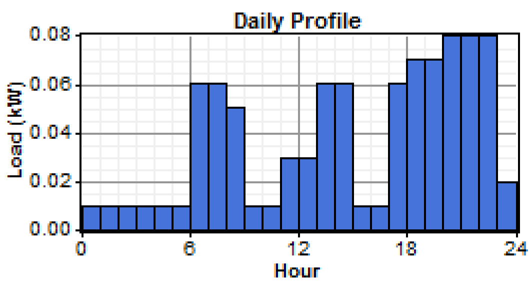


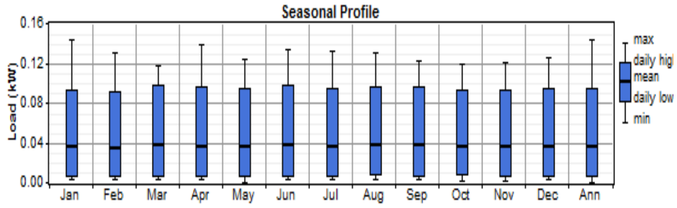
Fig.7 Solar Resource

D. Load Details

The load details for the DG system is shown in figure 8. The load profile is based on a hypothetical building as shown in figure 8. A small base load of 10 W occurs throughout the day and night and small peaks of 80 W occur during evening. The total daily load average is 910 Wh/day [8]. 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

III. MODELLING OF HYBRID SYSTEM

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.

Table 1 displays the values of each optimization variable. It shows set of all possible variables in the system configuration. HOMER simulates all possible configurations and sorts them according to net present cost (NPC). In this simulation, sensitivity variables are PV arrays, wind speed and diesel price. Total number of possible sensitivity variables including converter and battery are 2 and number of simulations are 2880. HOMER simulates Solar, Wind and Diesel as renewable resources. HOMER checks for Emissions, System control variables, Economics and Constrains during the hybrid simulation. The hybrid system simulation shows the optimized system for different system sensitivity variables.

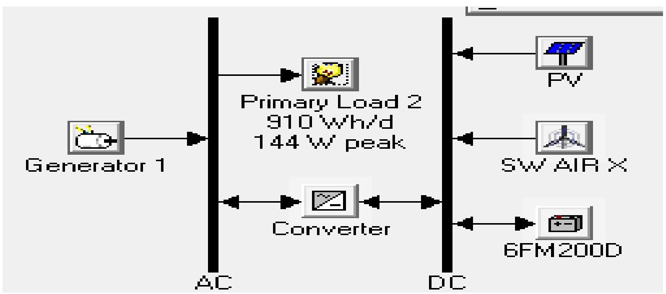


Fig. 9 PV-Wind-Diesel Distributed Generation System

Wind data : Auto correlation factor : 0.893, Hours of peak wind speed : 13, Anemometer height : 10 m, Scaled annual averages : 4.5 m/sec.

Diesel Data : Life time: 1 kW generator : 30,000 hours, life time, Minimum load ratio : 30%

PV Data: Scaled Annual Average : 4.88 KWh/m^2/d

Using the above window, there are 2880 simulation results possible for the designed system. The simulation is completed in 1 minute 39 seconds. The following session shows the simulation results for the optimum system.

Figure 9 indicates the HOMER modeling for PV- Wind-Diesel hybrid system consisting of storage battery, converter and load.

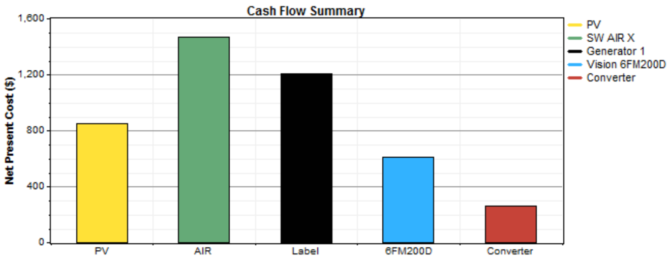
TABLE I

SIMULATION PARAMETERS

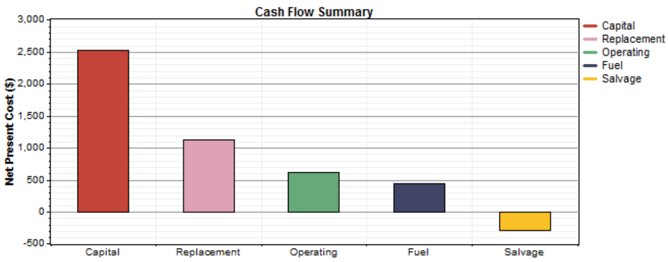
	PV Array (kW)	AIR (Quantity)	Label (kW)	6FM200D (Quantity)	Converter (kW)
1	0.050	0	0.00	0	0.00
2	0.100	1	1.00	1	0.10
3	0.150			2	0.15
4	0.200			3	0.20
5	0.250			4	0.40
6	0.300			5	0.50
7	0.350			6	0.75
8	0.400			7	1.00
9				8	1.25
10					1.50

IV. RESULTS

A. Cost Summary



(a) By Component

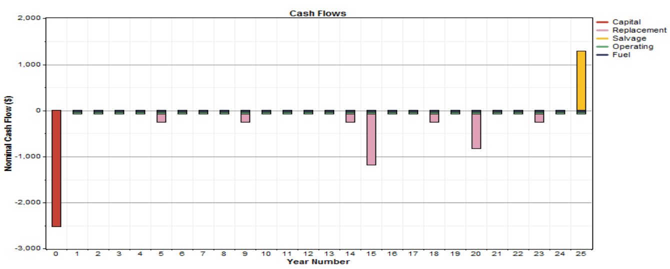


(b) By Cost Type

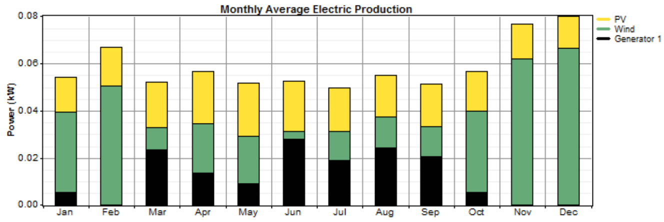
Total NPC: (Net Present Cost) : $4,402

Operating Cost : 147 $/yr

B. Cash Flow Summary



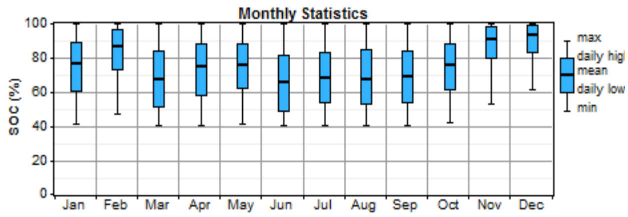
C. Electrical Production



Production	kWh/yr	%
PV array	157	31
Wind turbine	246	48
Generator 1	109	21
Total 513	100	

Renewable fraction: 0.672

D. Battery



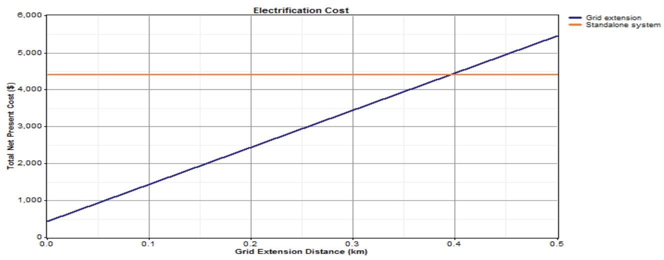
Energy In:	229 KWh/hr
Energy Out:	183 KWh/hr
Losses:	46 KWh/hr
Expected Life:	4.48 years
Nominal Capacity:	2.4 KWh
Average Energy Cost:	0.058$/KWh

E. Emissions

Emissions for different pollutants are shown in table 2.

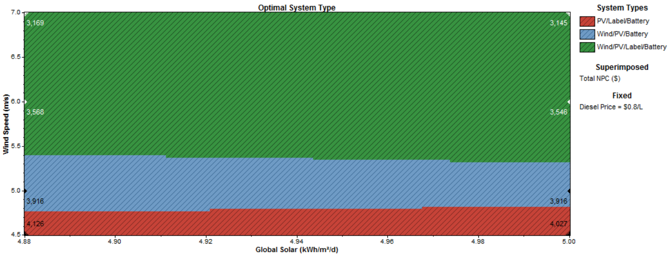
Pollutants	Emissions (kg/yr)
Carbon dioxide :	108
Carbon monoxide:	0.266
Unburned Hydrocarbons:	0.0295
Particulate matter:	0.0201
Sulphur dioxide:	0.217
Nitrogen oxides:	2.38

F. Optimal System Type



Breakeven grid extension distance = 0.396 km

In this hybrid simulation, PV, Wind turbines and Diesel generators are used alongwith battery and converter. Figure below shows the Optimal System Configuration for the used renewable resources for given wind speed and solar radiation.



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. Total Net Present Cost is $3159. From the optimal system type it is clear that at lower wind speeds, PV/Battery/Diesel configuration is optimum, at medium wind speeds Wind/PV/Battery configuration is feasible and at higher wind speeds, PV/Wind/Diesel/Battery configuration shows optimum results. As wind speed increases, the penetration of PV and diesel reduces.

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