Optimization of Wind-Solar-Diesel Generator Hybrid Power System using HOMER

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Abstract— *The amount of the conventional energy sources is decreasing day by day. To avoid energy shortage, the use of renewable energy sources is highly required. A hybrid energy system usually consists of two or more renewable energy sources used together to provide increased system efficiency, but design of hybrid power involves uneconomic and excessive capacities results in excess electric generation. In this study optimization of wind-solar-diesel generator hybrid power system using HOMER Software is used to develop simulation model for BEC Campus. Hybrid Optimization Model for Electric Renewable (HOMER) software is used to carry out the optimization. The main objective is to optimize hybrid system component sizes, minimizing excess electricity generation, and unmet electric load and carry out cost analysis based on life cycle cost. Inputs used for simulation includes real solar radiation data and wind speed data (Averaged to monthly values), taken from weather station installed at Basaveshwar Engineering College and load data details taken for BEC Campus Energy Meter. Based on peak load, hybrid system component sizes considered and various simulation results are obtained.*

Key words—COE, HOMER, Hybrid Energy System, Diesel Generator, Solar Photovoltaic, Wind turbine Generator (WTG).

1. INTRODUCTION

Hybrid renewable energy systems (HRES) are becoming popular as stand-alone power systems for providing electricity in remote areas due to advances in renewable energy technologies and increase in prices of petroleum products. A hybrid energy system usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply. Normally hybrid energy systems use solar, wind, and hydro energy sources, most of the renewable energy available on earth consists of different forms of solar energy. A system with presence of these different sources be the advantage of the balance and constancy. National Renewable Energy Laboratory's (NREL) Hybrid Optimization Model for Electric Renewable (HOMER) software used to carry out the study. HOMER performs economic analysis on hybrid power systems. Inputs to HOMER will perform an hourly simulation of every possible combination of components entered and provides the system results according to Total Net Present Cost[2].

In this paper work simulation of hybrid power system consists of PV, Wind Turbine Generator, Diesel generator with Battery has modeled and power management strategy has designed and simulated.

2. SYSTEM DESCRIPTION

Hybrid power system has designed based on peak load of present location (BEC Campus) and to optimize cost and size of components effectively. While designing the power system solar radiation, wind speed, load profile, cost and size of system components considered are discussed in following sections.

2.1 Solar radiation and Wind speed Data

In the present work, solar radiation and wind speed data were collected for Bagalkot (Latitude 16.1817° N, Longitude 75.6958° E) location from Weather station installed at Basaveshwar Engineering College, Bagalkot, of the year 2013, this data has been averaged to monthly values to evaluate design of hybrid PV/WG/Battery/DG power systems to meet the load requirement of BEC Campus. Fig.1 shows monthly average daily solar radiation ranges from 3.58 to 6.34 (kWh/m2/d).

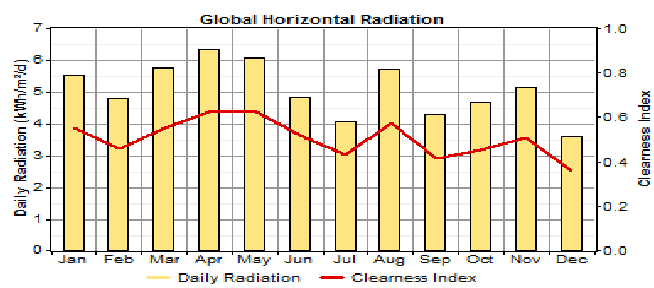

Fig.1: Monthly Average Solar Radiation

Fig.2 shows monthly average daily wind speed ranges from 2.54 to 6.30 (m/s). The red line indicates the clearness radiation is the fraction of the solar radiation that is transmitted through the atmosphere to strike the surface of the Earth. The annual average of solar radiation is 5.07

kWh/m2/day.

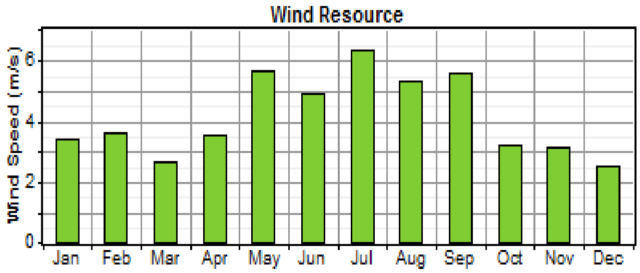

Fig.2: Monthly Average Wind Speed

Wind speeds over a year are presented in a Weibull distribution form shown in Fig.3. The site is considered as low wind regime.

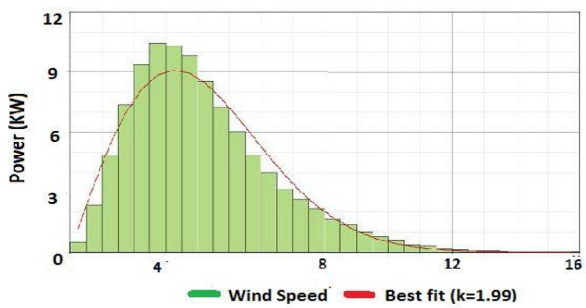

Fig.3: Weibull Distributions of Wind Speeds

2.2 Load Profile

An important consideration any power system is load. HOMER optimizes the system components based on load profiles. In this study load data details have been collected for BEC Campus from HESCOM (Electricity Distribution Company) by downloading through MRI (Meter Reading Instrument) and it is averaged to each hour of the day (24 values) in terms of kW. So the measured annual consumption is considered as 1.516 kWh/d in the present study. The Fig.4 shows Daily average load profile. The peak load used to design simulation model and it decides the size of system components. Here 186 kW is considered as peak load consumption.

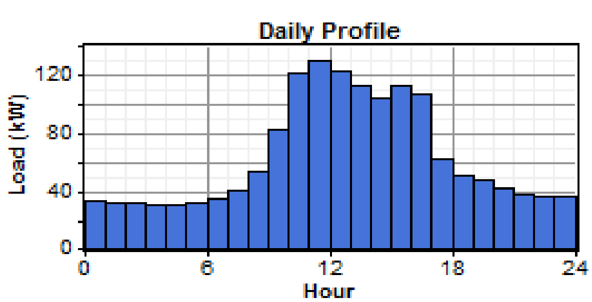

Fig.4: Daily Load Profile

The seasonal load is also an important condition, for that HOMER calculates seasonal load variations by simulating 8,760 hours in a year. The seasonal load profile for entire year is shown in Fig.5.

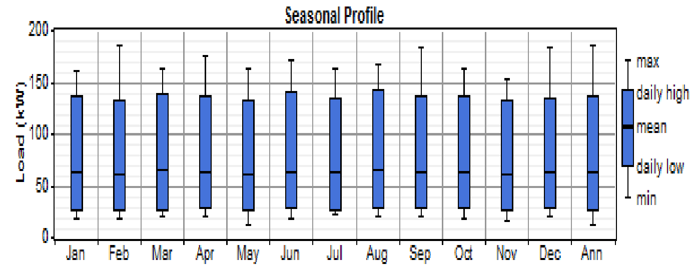

Fig.5: Seasonal Load Profile

2.3 Diesel Generator

The generator used for providing power during night time is of AC type. The generator having capacity 25kW is used in this present study. The capital cost considered is $1500. Lifetime of generator is estimated at 15000 operating hours and price of diesel is 0.9 $/liter.

2.4 Converter

Converter functions both rectifier as well as inverter. Converter having capacity 200kW is used for designing simulation model with capital cost $14,40,000. Lifetime of converter is estimated around 20 years and efficiency of 90% (inverter), 85% (rectifier).

2.5 Battery

The batteries used for designing simulation model are only to reduce excess electricity. Batteries with capacity 2V, 3000Ah is preferred in this study. Minimum lifetime of battery considered is 4 years.

3. HOMER SIMULATION MODEL

In the present work, the selection and sizing of components of hybrid power system has been done using NREL's HOMER software. HOMER is user friendly software. HOMER's fundamental capability is simulating the long-term operation of a micro power system. Its higher-level capabilities, optimization and sensitivity analysis, HOMER can simulate a wide variety of micro power system configurations, comprising any combination of a PV array, one or more wind turbines, and many no of generators, a battery bank, an ac-dc converter. The system can be grid connected or autonomous can serve AC as well as DC loads.

PV Array	
Capital cost	1333 US $/kWpk
O & M Cost	0
Lifetime	20 year
Efficiency	14%
Tracking System	No tracking
Wind Turbine Generator	
Technology	Fuhrlandar 100
Capital cost	216666 $
O & M Cost	0
Life time	20
Technology	Fuhrlandar 30
Capital cost	83333 $
O & M Cost	0
Life time	20
Converter	
Capital cost	24000 $
Replacement cost	24000 $
Lifetime	20 year
Diesel Generator	
Price	0.9 $/liter
Operating hours	15000
Battery	
Capacity	10,196kWh
Nominal Capacity	3000Ah
Voltage	2V
SOC	30%
Capital cost	400 $
Replacement Cost	400 $
Life time	4 year

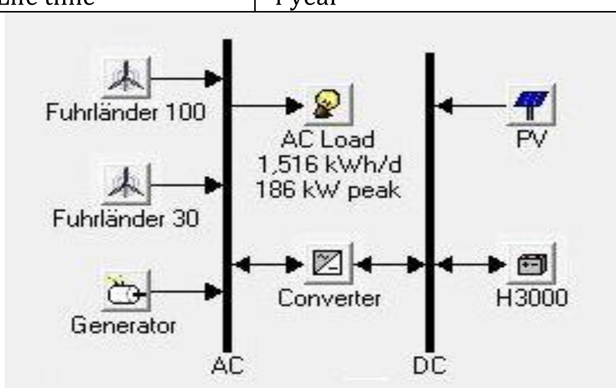

Fig.6: HOMER Simulation Model

The Fig.6 shows Hybrid Power System Design for present location using Homer. It consists of Photovoltaic array, Two Wind turbine generators (Fuhrlander 100 and Fuhrlander 30), converter, Diesel generator, converter and batteries are presented in simulation model. In normal operation, PV and WTG supply the load demand. The excess energy from PV and WTG is stored in the battery till full capacity of the battery is reached. The diesel generator is used as a backup, in the case when supply from PV and wind is unavailable. Converter is used to convert DC to AC (as inverter) and AC to DC (as rectifier). The details of proposed hybrid system components can be found in table-1.

Table-1: Technical Data Details

4. SIMULATION RESULTS

Several simulation results have been obtained by considering different PV capacities and the number of WG. The PV capacity has been allowed to vary from 180 to 320 (kW), and the number of WG has been allowed to vary from 0 to 2. Size of the converter and Diesel generator considered is 200kW and 25kW. The simulation results for 5.07 (kWh/m2/d) solar radiations and 4.15 (m/s) wind speed are presented in table-2 and 3. The first column shows the presence of PV modules, WG(s), Generator and Battery in hybrid system. It can be noticed from these results that the first system consist of PV/DG/Converter/Battery is the most commercial but in this paper the result of the fifth configuration has considered because of presence of all components. The COE of hybrid PV/WG/Battery/DG system (280 kW PV, 30 kW WG system) is 0.144$/kWh, annual capacity shortage has been found to be 0.009.

Table-2: Simulation Results

PV (kW)	FL 100	FL 30	Genr (kW)	Battery	Converter (kW)
320			25	144	200
320			25	120	200
320			25	144	200
320			25	120	200
280		1	25	144	200

Table-3: Simulation Results (Continued)

Initial Capital	Total NPC	COE ($/kWh)	Diesel (L)	Genr (hrs)
$509,769	$699,125	0.142	15,909	2,756
$500,169	$700,356	0.143	16,793	2,912
$509,769	$708,519	0.144	16,524	2,572
$500,169	$710,361	0.145	17,472	2,718
$539,738	$712,005	0.144	14,782	2,642

4.1 Electrical output

The annual electric energy production from system components. Excess electricity, unmet electric load and capacity shortage. Excess electricity is the surplus electrical energy that must be dumped because it cannot be used to serve a load or charge the batteries. Unmet electric load is electrical load that the power system is unable to serve and capacity shortage is a shortage occurs between the required operating capacity and the actual amount of operating capacity. Electric production from various energy sources per year and electrical parameters such as excess electricity, unmet electric load and capacity shortage are discussed in table- 4[4].

Table-4: Electric Production and Electric Parameters

Electrical Production		
Components	**kWh/yr**	**%**
PV array	425,437	83
Wind turbine	46,321	9
Generator	37,991	7
Total	509,749	100
Electrical Parameters		
Excess electricity	29,062	5.70
Unmet electric load	0.564	0.2
Capacity shortage	0.919	0.3

The monthly average electric production from PV, Wind and Generator for entire year is shown in Fig.7.

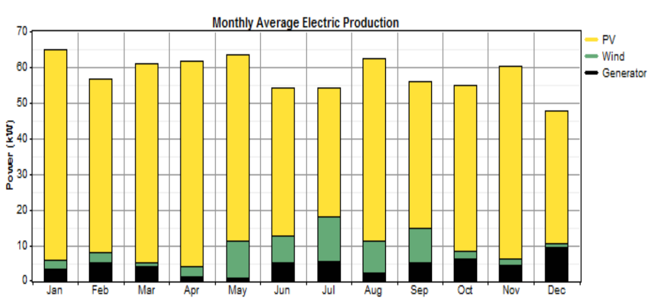

Fig.7: Monthly Average Electric Production

4.2 Cost Summary

The system cost is defined as sum of PV cost (C_{pv}), Wind Turbine Generator cost (C_{WTG}), Generator cost (C_{GENR}), battery cost (C_{BAT}) and converter cost (C_{CONV}) can be calculated using equation (1). Cost summary in terms of component wise and cash wise are shown in Fig.8 and Fig.9 respectively [3].

$$C_{SYSTEM} = C_{PV} + C_{WG} + C_{GENR} + C_{BAT} + C_{CONV} \quad (1)$$

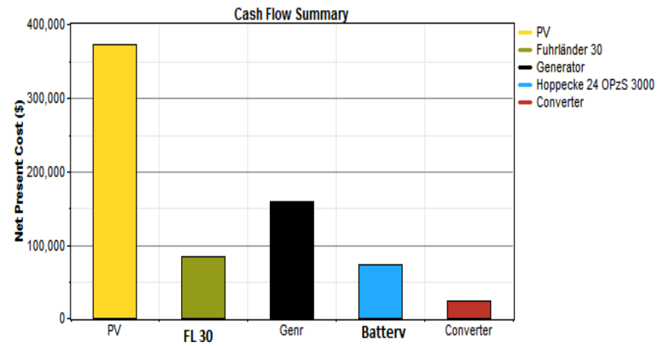

Fig.8: Net Present Cost of each components

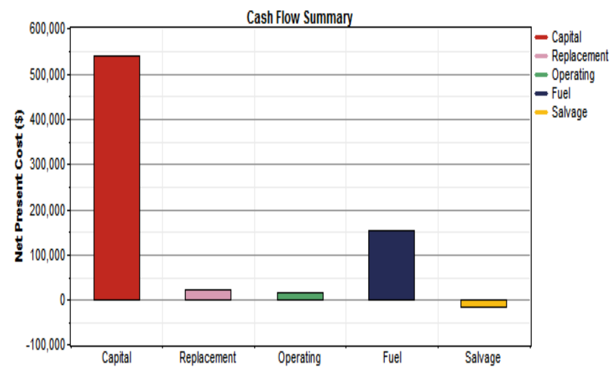

Fig.9: Cash Flow Summary

4.3 Battery

Fig.10 shows the state of charge of battery for entire year is the total amount of energy currently contained in the battery bank. In the present study size of strings is 12, strings in parallel is 12, total number of batteries required id 144 and bus voltage considered is 24V.

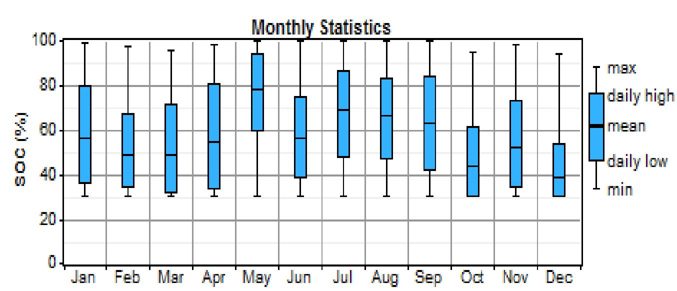

Fig.10: Battery SOC

4.4 Emissions

Table-5 show the total amount of each pollutant produced annually by the power system. Pollutants originate from the consumption of fuel. The annual emission of the hybrid system is tabulated in table-5.

Table- 5: Annual Pollutants

Pollutant	Emissions (kg/yr)
Carbon dioxide	38,925
Carbon monoxide	96.1
Unburned hydrocarbons	10.6
Particulate matter	7.24
Sulfur dioxide	78.2
Nitrogen oxides	857

5. CONCLUSION

Optimization of wind-solar-Diesel generator hybrid power system connected to AC load is presented in this study. HOMER Software is used to carry out optimization procedure. Simulations are carried based on load profiles and available resources. The results obtained in HOMER shows that component sizes, cost summary, cash flow summary, electrical production and cost of PV-Wind-Diesel Generator hybrid system found feasible. It is concluded that, for BEC Campus stand alone system is feasible and economic option.

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BIOGRAPHIES

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