Cost Comparisons of Hybrid Renewable Energy Systems Comprising Different Fueled Generators

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Abstract

Today, the world is very much concerned about the global warming effects due to the increasing pollutant emissions from various sectors of manufacturing industries. They are majorly using coal based power plants for fulfilling their electricity need. The requirement is of switching some partial load on renewable system and finding alternative fuels that can help in reducing green house gases' emissions. This paper presents the cost comparison of hybrid renewable energy systems comprising generators running by petroleum diesel, natural gas, fuel oil and biodiesel. Solar PV, wind, diesel generator and bettery bank are the components of the chosen hybrid system. Here, the effects on operating cost, Net Present Cost (NPC), Cost of energy (COE) and fuel cost has been studies. The optimized hybrid system has been modeled and simulated using Hybrid Optimization Model for Electric Renewables (HOMER) software developed by NREL, USA. The results show that system comprising generator running by bio diesel is most cost effective with respect to NPC and COE whereas system comprising natural gas generator has lowest operating cost. The fuel cost of systems comprising biodiesel and natural gas generators is found same and lowest.

Keywords: Hybrid System, Diesel, Natural Gas, Fuel Oil, Biodiesel

INTRODUCTION

Reduction of pollutant emissions from power generating units has always been an important concern for governement authorities,scientists and researchers. But, from past few years, the whole world has stood up for working towards reducing green house gases' emissions after seeing the effects of increasing global warming phenomenon. The government athorities are putting pressure on manufacturing units to reduce their energy consumption through various innovative projects. They are also emphasising upon use of renewable energy system as a component of their power supply system. Indian renewable energy development agancy has a concrete policy on giving incentives for development of power through renewable energy sources[1]. This article presents the results of work towards proposing an alternative system comprising solar photo voltaic(PV), wind, diesel and battery bank for running a partial load of a cement manufacturing unit located in Durg district of Chhattisgarh, India. Presently this partial load is run by a coal based power generating unit. Moreover, the petroleum diesel has been replaced with natural gas, fuel oil and biodiesel to find further possibility of reducing pollutant emissions. These fuels will be used to run diesel generator with a required modification.

The hybrid systems comprising renewable energy sources and fossile fuel based power generators have been studied earlier for feasibility. Four renewable resources, namely, small-scale hydropower, solar photovoltaic systems, wind turbines and bio-diesel generators were considered by Rohit Sen et al [2]. Using HOMER, they have identified the optimal off-grid option and compared this with conventional grid extension. Alireza Maheri [3] has designed a hybris system comprising wind, PV and diesel as its components and found the optimal system with cost and reliability as optimizing parameters. In [4], Nitin Agarwal et. al. have considered solar-diesel battery

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system for providing a solution to the energy demand of remote village of Uttar Pradesh, India. The hybrid system designed by Shafiqur Rehman et. al. [5], comprises solar photo voltaic, wind and diesel systems for powering a remote village in Saudi Arabia. The proposed hybrid power system was found to be less pollutant as it avoided addition of 4976.8 tons of GHG equivalent of CO_2 gas in to the local atmosphere of the village and saving of 10,824 barrels of fossil fuel annually.

ASSESSMENT OF LOAD AND RENEWABLE ENERGY POTENTIAL

Profile of Electrical Load

The load considered for running from hybrid system power includes plant residential colony, some lighting and HVAC load of manufacturing unit. The monthwise hourly load profile is shown in fig 1.

It is observed that the maximum load on system is in the month of May and it is calculated to be 38 MWh/day and the maximum demand is 2MW.

Assessment of Solar and Wind Energy Potential

The solar radiation and wind energy potential has been obtained from National Aeronautics and Space Administration, USA website[11].

It is found that the average solar radiation in the plant area is found to be 5.07 kWh /m^2 /d and the annual clearness index is 0.542. Fig 2 shows month wise solar radiation. It can be seen that the maximum radiation is in May and minimum in August month.

Durg district average wind speed is found to be low and is equal to 3.39 m/s. The variation of wind speed is shown in fig 3. It is seen that the average wind speed is maximum in March and minimum in September month and it varies from 2.79m/s to 3.8 m/s.

HYBRID SYSTEM COMPONENTS' DATA

There are various data entered in HOMER for modeling of hybrid system. The hybrid system's components are shown in fig.4. The technical and cost details of PV

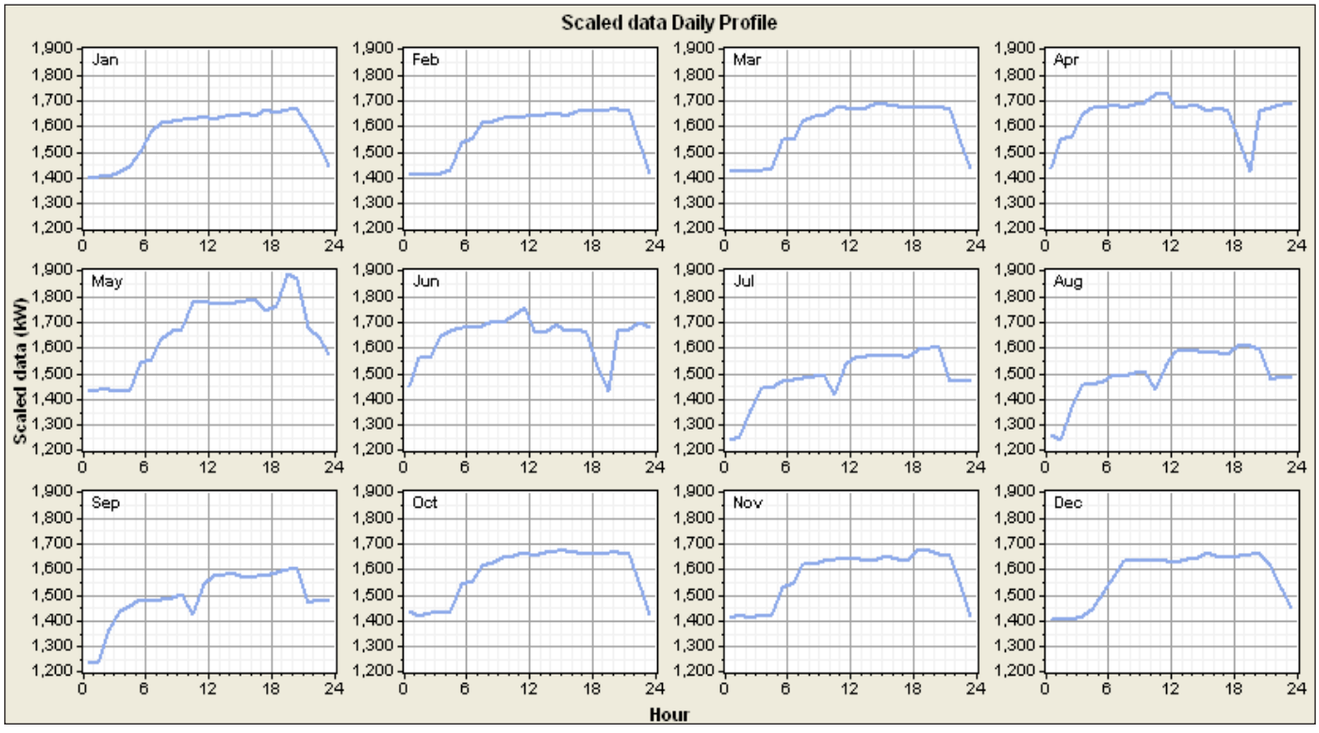

Fig. 1. Load Profile of Partial Electrical Load

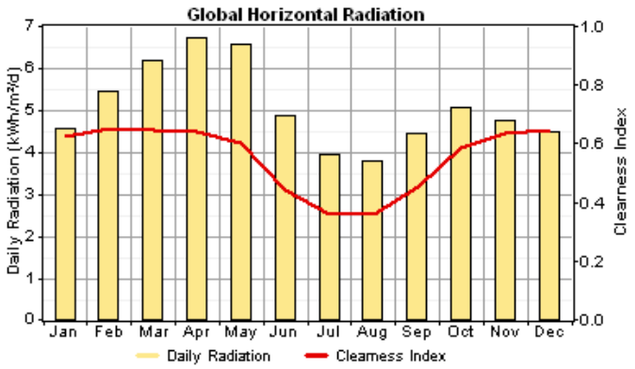

Fig. 2. Monthly Average Solar Radiation and Clearness Index

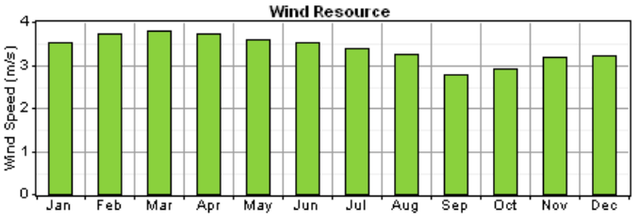

Fig. 3. Wind speed distribution

module, Wind turbine, Diesel generator, Batteries and Converters are detailed ahead.

There are various sizes considered for simulation and finding out an optimal system. The sizes entered according to the load pattern are 0, 5900, 5950, 6000, 6050, and 6100 kilowatts. The capital cost, operation and maintenance (O&M) cost and replacement cost are $6000/7.2kW, $60/7.2kW and $4000/7.2kW respectively.

The wind turbine considered is Sicko Wind Up 48000 [12] which has rated power of 2kW and rated wind speed is 4.9 m/s. Start up wind speed is 1.9 m/s which is the minimum speed required to generate voltage output. Rated output voltage is 24V DC or 270V AC with power generation capacity of 48 kWh/day. The numbers of Wind turbines considered are 0, 1910, 1920, 1930, 1940 and 1950. Capital cost of one wind turbine, replacement cost and annual O & M cost considered are $4939, $4000 and $50 respectively.

Diesel generator considered has zero input capital cost since a 3.2 MW generator already exists in plant premises. The replacement cost and O&M costs are $4000 and $0.017 per hour.

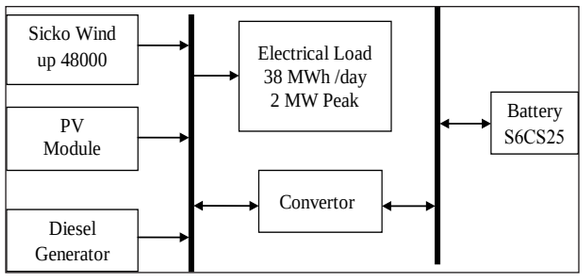

Fig. 4. Configuration of Hybrid PV-Wind-Diesel-Battery System

Converter's size inputs are 1859, 1900 and 1950 kW. Capital, replacement and yearly O&M costs are $700, $550 and $40 respectively. Converter efficiency is considered to be 90%.

Battery used for simulation is Surrette 6CS25P nominal voltage of 6V and ampere-hour capacity of 1156 Ah. Capital, replacement and yearly O&M cost of a battery unit is $1000, $800 and $50 respectively. Battery string size considered is 1950 with 70 batteries per string.

The converter and batteries' data is obtained from previous published articles [3]

The system control is applied with load following strategy where in the generator is operated only when the PV and wind systems are not generating power sufficient enough to run the load.

There are some fixed costs involved in the system implementation. The system fixed capital cost involves constructional cost, administrative costs and project approval cost. It is considered to be $230000 for complete project lifetime. The lifetime fixed operational and maintenance costs are estimated as $5000 per year.

For continuous power supply to the load, the maximum annual capacity shortage is considered as 0% and the minimum renewable energy fraction is taken as 30%.

RESULTS AND DISCUSSIONS

This section presents the results obtained after inputting the data detailed in previous section. After a number of simulations, HOMER presented various optimized systems which had different Operating cost, Net Presents Cost (NPC), Cost of energy (COE) and fuel cost. The top five optimization results based on lowest NPC are shown

Table I. Optimization Results of PV-Wind-Diesel-Battery Systems

PV (kW)	5,950	5,950	6,000	6,050	5,900
No. of Wind turbines	1,940	1,945	1,940	1,930	1,950
DG (kW)	3,200	3,200	3,200	3,200	3,200
Battery numbers	5,428	5,428	5,428	5,428	5,428
Converter (kW)	1,900	1,900	1,900	1,900	1,900
Initial Capital ($)	21,527,994	21,527,384	21,569,660	21,561,936	21,535,716
Operating Cost ($/year)	1,497,209	1,493,696	1,494,439	1,495,198	1,497,253
Total NPC ($)	40,667,348	40,671,836	40,673,608	40,675,588	40,675,636
COE ($/kWh)	0.231	0.231	0.231	0.231	0.231
Renewable Fraction	0.92	0.92	0.92	0.92	0.92
Diesel (Liters)	634,556	630,584	631,107	631,646	634,812
Diesel Hours	1,350	1,343	1,344	1,345	1,352

Table II. Effect of Different Fuels on Various Costs

System	PV-wind-Diesel-battery	PV-wind-Natural gas-battery	PV-wind-Fuel oil-battery	PV-wind-Biodiesel-battery
Operating Cost ($/yr)	1,497,209	1,372,460	1,427,403	1,378,291
NPC($)	40,667,348	39,266,804	39,774,988	38,963,340
COE ($/kWh)	0.231	0.223	0.226	0.221
Fuel Cost($)	8,192,879	6,700,959	7,300,585	6,700,959

in Table I. The most feasible system among these five systems has lowest NPC and COE equal to $40,667,348 and 0.231$/kWh respectively. The components sizes of this system are 5950kW PV array, 1940 wind turbines, 3200kW diesel generator, 5428 batteries and 1900kW power convertor.

If this lowest NPC system is run with different fueled generators then different cost parameters have values shown in table II. It is evident that system comprising generator running by bio diesel is most cost effective with respect to NPC and COE whereas system comprising natural gas generator has lowest operating cost. The fuel cost of systems comprising biodiesel and natural gas generators is found same and lowest.

CONCLUSION

In this study, after various simulations a most feasible renewable energy based PV-wind-diesel-battery hybrid energy system was found. The hybrid system selected for the purpose has lowest NPC and COE among other combinations. Further a cost comparison among systems comprising different fueled generators reveals that system comprising generator running by bio diesel is most cost effective with respect to NPC and COE whereas system comprising natural gas generator has lowest operating cost. The fuel cost of systems comprising biodiesel and natural gas generators is found same and lowest.

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