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Abstract

Hybrid energy systems are successfully applied in areas where grid extension is practically impossible or uneconomical. This paper reports the results of optimization of hybrid energy system model for electrification of remote village Gobindapur, located at the foot hills of Similipal forest (Latitude 21°55' N and Longitude 86°34' E) of Mayurbhanj district of Odisha in India. The model is developed with the objective of minimizing cost function based on demand and potential constraints. The model has been optimized using HOMER (Hybrid Optimization Model for Electric Renewable) <https://assignbuster.com/india-by-using-homer-engineering-essay/>

software (2. 68 version) package developed by National Renewable Energy Laboratory (NREL), Colorado, USA. From the load demand, the capital cost, cost of energy for different types of resources and optimised configuration of hybrid system are determined. Key words: Hybrid, PV, insolation, HOMER

Introduction

In India, over 80, 000 villages remain to be un-electrified and particularly in the state of Odisha, 9326 villages are still to be electrified. There is difficulty to supply electricity due to inherent problems of location and economy of these places. The costs to install and service the distribution lines are considerably high for remote areas. Also there will be a substantial increase in transmission line losses in addition to poor reliability. Like other developing countries, India is characterised by severe energy deficit. In most of the remote and non-electrified sites, extension of utility grid lines experiences a number of problems such as high capital investment, high lead time, low load factor, poor voltage regulation and frequent power supply interruptions. Solar panels can be used successfully for rural electrification, bringing power to the most remote parts of a region. A recent study by the MNES on comparison of relative cost of electrification of remote villages through conventional grid and solar photovoltaic power basing on net present value of life cost over a period of 20 years reveals that the solar electrification is more economical for villages located beyond 3 kms in hilly areas and 7 kms in plains from the grid [10]. Moreover potential PV Systems when used on a large scale cuts down the need for extending the distribution grids in rural areas. A hybrid energy system consists of two or more energy systems, an energy storage system, power conditioning equipment and a

controller. Examples of energy systems commonly used in hybrid configurations are small wind turbines, photovoltaic systems, micro hydro, biomass, diesel generator and fuel cells. The Hybrid Energy System (HES) has received much attention over the past decade. It is a viable alternative solution as compared to systems, which rely entirely on hydrocarbon fuel. Apart from this, it has longer life cycle. Moreover, for off-grid power supplies, a diesel generator (DG) system is most attractive because of its low capital inspite of higher operation and maintenance cost and higher CO₂ emission [13]. In some cases, diesel generator is not cost effective due to high fuel transportation cost to remote areas. But, the environmental issue is a major concern, particularly emission of carbon dioxide from the DG sets. This led engineers and planners to find a sustainable and environmental friendly solution of meeting power demand through renewable energy sources [1], [3]. For systems employing totally clean renewable energy, high capital cost is an important barrier. However, we can produce green power by adding different renewable energy sources to diesel generator and battery, which is called a hybrid system. Optimization of a hybrid energy system is site specific and it depends upon the resources available and the load demand. Many hybrid systems sizing have been studied and optimized by economic analysis based on system life cycle cost and cost of energy by using HOMER [6],[7],[8],[9]. Odisha receives an abundance of solar radiation throughout the year except for some interruption during the monsoon and winter seasons and has a vast potential for harnessing large amount of solar power of about 8000 MW (Table-1). Similarly wind energy potential is 910 MW and small hydro power project is of 120 MW [11]. Utilizing hybrid power system consisting of solar-wind or solar-wind-hydro (where there is potential of

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hydro power) is the best alternative sources for rural electrification in areas which is far away from grid [4],[12]. This study is for developing a model for electrifying a remote tribal village called Gobindapur (Pithabata) under Kuchilaghathi Panchayat of Samakhunta block which is located at the foothills of Similipal reserve forest, close to Sitakund waterfall. This village is not yet been electrified nor to be electrified in near future. In this village there are 63 tribal families residing and the houses are scattered. They are presently using kerosene lamps in evening and early morning. These models definitely help to supply electricity to this village for lights, radio, television and for using other small appliances. Electric lights can enable these families to extend their days after sunset productively and enjoyable by studying, working, or simply cooking and eating dinner in a well lit home [17]. The proposed model suggested for this village is shown in Fig. 1.

Renewable energy resources at the site

The most important factor in developing a hybrid energy system is its geographical location and availability of renewable resources. This study area located at Gobindapur village have all the wind, solar and hydro energy for generating sufficient power for electrifying this area. For this hybrid system, the meteorological monthly data of solar insolation and wind speed for the area (Longitude 86°34' East and Latitude 21°55' North) are imported from the NASA metrological website [5] for the analysis by HOMER which synthesised daily radiation and hourly wind speed values. Our average wind speed is 2.99 m/s and average daily radiation is 4.88 KWh/m² (Fig. 2 & Table 2).

Load analysis

The proposed hybrid power system is designed to ensure the electric supply to all the 63 households including one agricultural farm with an average energy consumption of 148 kWh/d with a peak load of 23 kW. Fig. 3 shows the daily load profile of the site. The main aim of this study is to identify the most economic and appropriate power supply system for this village. There is one agricultural farm inside the forest having one rest shed. The load demand of the village is given in Table 3. Keeping in view that in future, if each family will have one refrigerator (125W) running on load for 12 hours, then $125 \text{ W} \times 12 \times 63 = 94.5 \text{ kW}$ extra to be consumed. Considering future increase in demand, load of 200, 250 and 300 kWh/d was considered along with present demand of 148 kWh/d for analysis.

System optimisation

In all the simulations, 5% annual maintenance cost (except solar PV), salvage value of 10 % (except battery) and annual nominal interest (Actual interest - inflation rate) of 6% were taken.

Solar-wind-hydro-DG hybrid system (system I)

The system configuration for this model is given below. EquipmentSolar PVWind turbineHydro turbineDGBattery, 24 nosInverterRectifierRated capacity2 kWp5.1 kWp44.1 kWp16 kW200 A12 V5 KW5 KWCost, \$/kW500017001587450\$250/battery10001000The schematic of this model and the cash flow summary of the system are shown in Fig. 4 and 5 respectively while the cost summary of the model at different loads and flow rates with 4.88 kWh/m²/d of solar radiation, 2.99 m/s wind speed and diesel price of \$0.9 /litre is shown in Table 4. It was observed that the levelised <https://assignbuster.com/india-by-using-homer-engineering-essay/>

cost of energy (COE) decreased with increase in load demand from 148 to 300 kWh/day for all the four levels of stream flow rates. The COE of solar-wind-hydro-DG system was found to be highest with all the four levels of flow rates at all the load conditions except at 200 L/s flow rate with 250 and 300 kWh/day load where lowest COE of \$0. 179/kWh and \$0. 156/kWh were found. This indicates that solar-wind-hydro-DG hybrid system is only feasible and viable at higher load demand with higher flow rate of 200 L/s. But at flow rate lower than 200 L/s, neither solar-wind-hydro-DG nor hydro-DG system are capable to supply the energy to meet the higher load of 300 kWh/day. The lowest COE was found with hydro-DG system at all the load conditions except 300 kWh/d load and 200 L/s stream flow rate. At 200 L/s flow rate, only hydro system is capable enough to supply the energy for all the load conditions and the COE with this hydro system was found to be minimum up to 200 kWh/day load. Beyond 200 kWh/day load demand, hydro-DG system is economical with lowest COE of \$0. 167/kWh and \$0. 145/kWh for 250 and 300 kWh/day load respectively. The NPC, excess energy production and annual diesel consumption of solar wind-hydro-DG system at existing resources condition of 4. 88 kWh/m²/d solar insolation, 2. 99 m/s wind speed, diesel price of \$ 0. 9/litre and stream flow rate of 188 litres/sec at different load demand is shown in Table 5 and Fig. 6. It was found that the operating cost increases from \$12, 416/yr to \$16, 544/yr as the load increases from 148 to 250 kWh/day and this may be due to higher amount of diesel consumption at higher loads. The COE decreased from \$0. 375 to \$0. 294/kWh as the load increased from 148 to 250 kWh/day. Also the excess electricity production decreased from 81. 4% to 69. 6% with increase in load from 148 to 250 kWh/day.

B. Only DG system

The schematic of this system with cost summary is given in Fig. 7. For this system, one 16 kW (20 KVA) diesel generator with 24 battery (200 Ah, 12 V) and 15 kW converter is required. The highest cost of energy (\$0. 628/kWh) was obtained for this system with NPC of \$433, 459, operating cost of \$31, 702/yr and annual diesel consumption of 21, 902 litres.

Cost summary of systems

The cost of energy, NPC, operating cost of different systems is presented in Table 6. It was found that: Lowest cost of energy of \$ 0. 357/kWh was observed with hydro -DG system followed by \$ 0. 361/kWh with wind-hydro-DG system. Highest cost of energy of \$0. 628/kWh was observed with only DG system.(System II). Minimum CO₂ production (8865 kg/yr) observed with solar-wind-hydro-DG system (system-I)CO₂ production is reduced by 48811 kg/yr by using solar-wind-hydro-DG system over only DG system. Looking in to economical point of view (COE), hydro-DG system is found to be most economical for electrification of the site at the present load condition of 148 kWh/day. COE of solar-wind-hydro-DG system (system I) is minimum at higher load beyond 200 kWh/day at higher stream flow rate of 200 litres/sec. Looking in to CO₂ production and future load demand, solar-wind-hydro-DG system (system I) may be recommended for installation at the site

Conclusion

Taking in to consideration the load profile of the village, different configuration of equipments were analysed through HOMER and it was found that, least cost of energy (\$ 0. 357/kWh)with lowest NPC(\$246, 295) was observed with hydro-DG system. The highest cost of energy (\$0. 628/kWh)

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with highest NPC (\$433, 459) and operating expenses (\$31, 702/yr) was observed with only DG system. Higher rate of CO₂ production to the tune of 57, 676 kg/yr is observed with only DG system which has very adverse environmental effect. At present load condition (148 kWh/day), though COE of solar-wind-hydro-DG system (system I) is \$0. 018/kWh higher than that of hydro-DG system, minimum CO₂ (8865 kg/yr) is produced in this system I. Looking in to CO₂ production and future load demand, solar-wind-hydro-DG system (system I) may be recommended for installation at the site.