Indian J.Sci.Res. 17(2): 151-155 ISSN: 0976-2876 (Print)
ISSN: 2250-0138(Online)

ANALYSIS OF PV/DIESEL HYBRID ENERGY SYSTEM FOR A SCHOOL IN GORAKHPUR: A CASE STUDY

[1]Manish kumar,[2]Dheerandra Singh
[1,2]Department of Mechanical Engineering, Madan Mohan Malaviya University of Technology, Gorakhpur Uttar Pradesh

Abstract: The supply of continuous electricity in rural areas, where grid connection is not available, is major issue. For the fulfilment of continuous energy demand in rural areas, an alternate energy system is needed. In this case study, a PV/diesel hybrid energy system, is considered for continuous supply of electricity to a school of village Baghar, district Gorakhpur (Uttar Pradesh, India). The daily average load demand for school is 10.89 kWh/day with peak load of 2.23 kW. HOMER simulation software is used for optimization and technical &economic analysis of this hybrid energy system. Sensitivity analysis is done to consider the impact of diesel fuel price and solar radiation data. Technical and economic analysis of the optimum system has been used for comparative study of economic feasibility of solar photovoltaic (PV)/ generator hybrid energy system with a standalone diesel generator system. This load demand is fulfilled by using 5 kW solar PV and 2.5 kW diesel generator capacity. This system canreduce CO_2 emission by about 42 tons/year as compare to diesel generator system. Simulation result shows that solar PV-Diesel system is most cost efficient and environmental friendly over the standalone diesel generator system.

Keywords: Hybrid Energy System; HOMER; Photovoltaic; Diesel Generator

I. Introduction

Electrification is a vital factor for sustainable development of any country [1]. The rural areas which are isolated from urban areas are not connected to electricity gridbecause ofhuge investment and much time is required for electrification [2]. For the Electrification of rural villages, schools, and hospitals there are different technological approach available, in which renewable energy systems are very common. Another option is diesel-power generator which isused to supply electricity. It provides a simple solution and can be designed for different capacities, for fulfilling electricity demand. Infrastructure, operation & maintenance cost of diesel generator is the major problems for the application of diesel generator in rural areas electrification. To overcome these difficulties,use of renewable energy like solar photovoltaic, wind energy as an energy resource for isolated areas is very beneficial. However, major problems by using standalone energy system like solar & wind energy is discontinuousenergy supply, resulting in intermittent supply of power and creating problems if continuous supply is required. Use of hybrid energy system can improve this problem.

Hybrid energy system combines two or more than two energy conversion devices or two or more than two fuels for generation of power [3]. Main purpose of Integration of renewable energy resources in a hybrid energy system is to supply continuous electricity and save fossil fuel. Therefore, diesel generator is used as a backup.

In this case study solar Photovoltaic/Diesel Hybrid System is used in whichHOMER software [4] has been used toanalyse the energy system.HOMER is an optimization and simulation software tool by which Systems sizing and Techno - economic comparisons can be done with the other possible systems.

In this case study a school in Baghar is considered which an isolated village of Gorakhpur and it is not connected to grid. Therefore, a hybrid energy system is considered which can supply electricity required and excess energy will supply to village electrification like street lighting etc.

I.II. Location of School

The proposed system is considered for a school in village Baghar, district Gorakhpur (U.P., India), about 55 km from district head quarter in south direction. The Latitude is 26°26.7' N and Longitude is 83°6.0' E.

II. Literature Review

Hrayshat et.al [5] has done a technical &economic analysis of Photovoltaic-diesel hybrid energy system by the application of HOMER simulation and optimization software to calculate load demand of off grid home located in Jordan. Shafiqur Rehman et.al [6] has performed study of a solar Photovoltaic-Diesel hybrid energy system of an isolated area near Rafha, Saudi Arabia by using HOMER software tool. Deepak Kumar Lal et.al [7] had used the

[1]Corresponding Author

HOMER software for the optimization and simulation of Photovoltaic-wind-micro-hydro-diesel hybrid energy system. Tamer Khatiba et.al [8]had analysed the solar PV-Diesel hybrid energy system. Ismail et.al [9]has performed an economic analysis and a design a hybrid energy system which consists of Photovoltaic-panels, a diesel generator used for backup and a battery is used for supplying electricity in Palestine. Benjamin et.al [10] has analysed life cost of PV-Diesel hybrid energy system in Nigeria.Bhandari et.al [11] has concluded that there are many types of renewable energy resources are used to supply electricity in rural and urban areas.Kamalapur et.al [12] has studied feasibility of photovoltaic solar home system for rural electrification in India. Daud et.al[13] has studied the design of hybrid energy system for minimizing the pollutants emission and cost. Twaha et.al[14] has concluded that Photovoltaic hybrid energy system is more accepted than other renewable energy system. Girma et.al [15] has performed technical and economic analysis for optimization of hybrid energy systemfor electrification of isolated areas in Ethiopia. Kandpal et.al [16] has analysed a techno economic comparison between solar home system and PV micro grid in India.Ranaweera et.al [17] has studied technical &economic analysis of hybrid energy system in Sri Lanka. Khan and Iqbal et.al [18] has analysedprobability of hybrid energy system by using hydrogen as energy option in Newfoundland. Karakoulidis et al [19] has performed analysis of hybrid energy system. Türkay et.al [20]has performed analysis of hybrid energy system. Bilala et al. [21] has studied a PV-wind-diesel energy system. R.K., Rajkumar et al. [22] has modelled the PV/wind energy system by using Adaptive Neural- Fuzzy Inference System. Kaldellis et.al [23] has studied a PV-diesel hybrid energy system for a telephone exchange.

III. Methodology

To analyze Photovoltaic/diesel hybrid energy system by using an optimization software HOMER, some inputs must provide such as hourly load profile, monthly solar radiation value of PV system, initial cost of component like PV, diesel-generator, power-converter, storage-battery and cost of diesel fuel, project life time, etc. The solar radiation data of project location were taken from online data of NASA meteorological department [24]. The capital cost of each equipment taken from online marketing site and adjusted to local value by including transportation and other costs. Simulation of systemoperation by using energy-balance calculation every hour for every of 8760 hours of one year by using HOMER. It displays a list of sorted architecture based on the Total Net Present Cost. Total net present cost represents the life cycle cost of the system. The calculation assesses total costtaking place in project-lifetime, as well as capital cost, replacement cost, maintenance, and fuel cost. But, the system arrangement based on TNPC is wide-ranging depending on the sensitivity variable that has been selected by the author. Therefore, the software repeats the optimization procedure for eachvariety of sensitivity variables. In this paper monthly solar radiation and diesel fuel price has been used as sensitivity variables. The final bestresult of a hybrid energy system refers to lowest total net present cost.

IV.System Input

IV.I Load demand of school

In this case study, school energy load demand is calculated. The estimated load demand for school is usually for light and fans of school.The load demand of school is 10.89kWh/day with peak load of 2.23 kW.

IV.II. Solar Radiation

One-year solar radiation data is used for Baghar, Gorakhpur at Latitude 26°26.7' N and Longitude 83°6.0'E is takenfrom NASA. The annual average clearance index is 0.60 and the daily average radiation is 5.31kWh/m^2/day. This is suitable for installation of photovoltaic system.

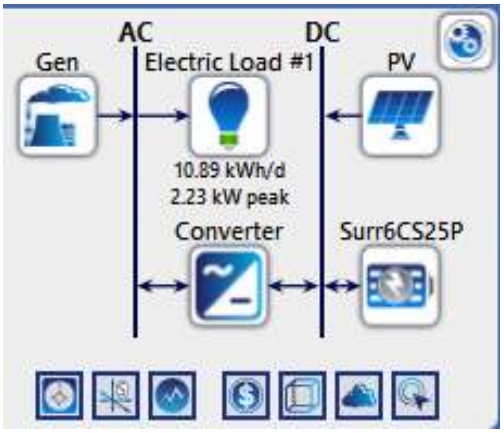

Fig.1.Hybrid system schematic diagram.

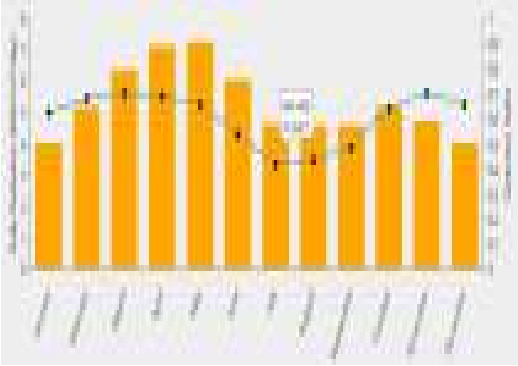

Fig.2. Average solarradiation and clearness index.

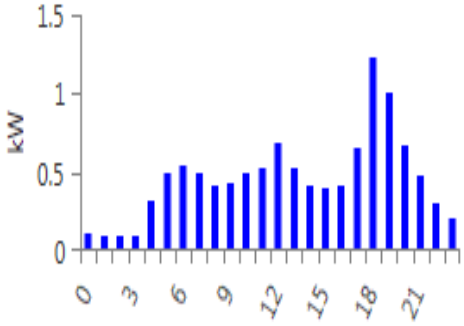

Figure .3 Daily Load variations.

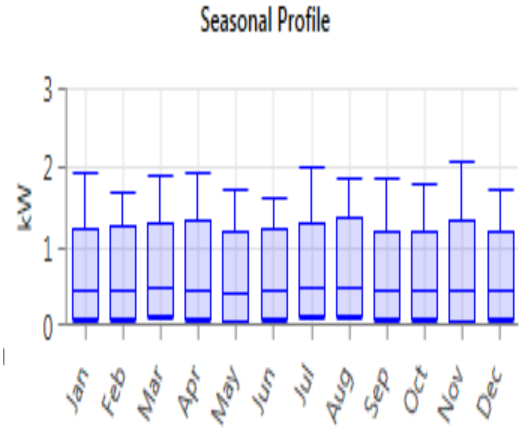

Figure.4 Monthly Load variations.

V. System Components

Photovoltaic/Diesel hybrid energy systems consist of Solar Photovoltaic panels, Diesel generator, Power Converter & Batteries. Direct current is generated form PV panels, Converter changes DC power into AC power and fed to load centre. Extra energy is stored into Batteries.

V.I Solar Photovoltaic

Capital cost of PV module is considered as Rs.50000 for 1kw with Rs. 35000 replacement cost of Photovoltaic panels.Rs. 500/year is taken as operation & maintenance cost. Life time of the panels is taken as 25 years with Derating factor of 80 [25].

V.II. Diesel Generator

Capital cost of diesel generator is considered as Rs.55000/kW and the operation and the maintenance cost is taken as Rs. 60/hr with replacement cost of Rs. 44000. The Diesel fuel price is taken as for sensitivity study is Rs. 58.94/litre. Life time of generator is taken as 15000 hours [26].

V.III.Power Converter

Capital cost of powerconverter is taken as Rs. 65000/kW and Rs. 45500/kW is considered as replacement cost. Operating and maintenance cost is considered as 1000/year with efficiency of 90%. The lifetime of system is considered as 10 years [27].

V.IV.Battery

The Surrette 6CS25P storage of 6V having nominal capacity 1156 Ah is considered for utilisation in this project. Capital cost of battery is taken as Rs.75000 with replacement cost is Rs.52500 with operation & maintenance cost of Rs.1000/year. Minimum state of charging for battery is 40% with efficiency of 80%. Lifetime of battery is considered as 20 years with capacity of 6.94kWh [28].

VI.Results & Discussions

The optimization results for solar radiation parameters 5.3 kWh/m^2/day and diesel price Rs. 58.94/litre are illustrated in the Table [1]. It is seen that there are three system architecture PV/battery, PV/battery/generator & Gen/battery and for continuous supply PV/battery/generator system is optimal solution for that school. A PV/Diesel hybrid energy system is economically more realistic with a minimum (Cost of energy) COE of Rs. 31.21/kWh and least Net present cost (NPC) of Rs. 1585812. The hybrid energy system consists of 5 kW PV panels, a DG with a rated power capacity of 2.5kw and 10 storage-batteries with adding to 2 kW power converters are found to be most practical system. Table [2] shows the details related to energy generated by PV Panels and diesel generator.This system generates 99.9% power from PV system and 0.102% from diesel generator and renewable fraction is 99.8% is used. Total energy generation 46.8% is

excess energy. Total hour working of Diesel generator is 14 hr./year. Excess power can be used for other purpose like street lighting of road in village etc. Table [3] shows the optimization result for diesel generator system at fuel price Rs.58.94 and load scaled average of 10.89kWh/day.

Table.1. Optimization results of system

Parameter	PV/Diesel /battery hybrid system	Diesel/Battery system	PV/Battery system
PV (kW)	5	0	5
Generator (kW)	2.5	2.5	0
Battery	10	10	10
Converter (kW)	2	2	2
Initial capitalRs.	1290000	1020000	1160000
Operating cost Rs. /year	22944.82	444774.30	22546.22
Total NPC	1585812	6703208	1443216
COE (Rs. /kWh)	31.21	131.92	28.41
Renewable fraction	99.8	0	100
Diesel (L)	4.36	1632	0
Generators (hours/year)	14	2117	0

Table.2. Electricity generated by system.

PV array energy production	8589 kWh/year	99.9 %
Diesel generator energy production	8.75 kWh/year	0.10 2%
AC primary load	3975 kWh/year	100 %
Excess electricity	4027 kWh/year	46.8 %
Capacity shortage	0.000 kWh/year	0.0 %
Renewable fraction	99.8 %	

Table.3. Optimization Result of Diesel System.

System	Diesel generator system
DG Size	2.5kW
Initial capital	Rs.1020000
Operating Cost	Rs. 444774.30/Year
Total NPC	Rs. 6703208
LCOE	131.92/kWh
Diesel consumption	1632 L
DG Operation hours	2117year/ hrs

VII. Sensitivity Results

Two sensitivity variables have been taken into accounts for variation of these variables in the future. The two variables are amount of solar radiation of the project location and the price of diesel fuel. It is assumed that these two variables highly affect the cost of the system. This analysis helps to analyse which system is optimal for the different values of these two parameters. Sensitivity variables show that PV/Diesel hybrid energy system is optimal system. In our study sensitive analysis is done on different values of fuel cost and different values of solar radiation data. This study is done because fuel cost is increases day by day and in future contribution of solar radiation will be also increases or decreases.

VIII.Emission

The optimal PV/Diesel hybrid energy system reduces CO_2 emission about 4259.6 Kg/yr. as compare to diesel generator system. Optimal system also reduces emission of SO_2 is about 10.47 Kg/yr. and NO is about 25.235 kg/yr. as compare to standalone diesel generator system shown in. Emission of unburned hydrocarbon and particulate matter is also reducing as compare to diesel generator system. Table [4] shows the comparison between emissions of optimal PV/Diesel hybrid system with standalone Diesel generator system.

Table.4. Comparison of gas emission.

Pollutants	PV/Generator Hybrid system Emission (Kg/yr.)	Diesel Generator system Emission (Kg/yr.)
Carbon dioxide	11.4	4271
Carbon monoxide	0.0719	26.9
Unburned hydrocarbons	0.00314	1.17
Particulate matter	0.000436	0.163
Sulphur dioxide	0.0279	10.5
Nitrogen oxides	0.0675	25.3

IX. Conclusion

The optimal PV/generator hybrid system for school (Baghar, Gorakhpur) is optimized using HOMER software

tool. Load demand is fulfilled by use of 5kW photovoltaic panels and 2 kW inverter, 2.5 kW capacity diesel generators and 10 batteries of 6V are the optimal solution for school based on load and net present cost. All the selected components are easily available in the market and system can be easily implemented at the school. Cost of electricity of system is Rs.31.21/kWh and 4259.6 kg/year emission of greenhouse gas is reduced.

X.References

[1] Munasinghe," Rural electrification in the third world".

[2] Zahnd A, "Benefits from a renewable energy village electrification system".

[3] Celik, "The System Performance of Autonomous Photovoltaic/Wind Hybrid Energy Systems."

[4] HOMERPro x64. (National Renewable Energy Laboratory, USA) ,http://www.nrel.gov/homer

[5] Hrayshat, "Techno- economic analysis of autonomous Hybrid photovoltaic-diesel battery system".

[6] Al-Hadhrami, S. R. "Study of a solar PV-diesel battery hybrid power system for a remotely located population near Rafha, Saudi Arabia,"

[7] Deepak Kumar Lal, "Optimization of PV/Wind/Micro-Hydro/Diesel Hybrid Power System in HOMER for the Study Area",

[8] Tamer Khatib,"Optimal Sizing of building integrated hybrid PV/diesel generator system for zero load rejection for Malaysia". Energy and Building, 43, 3430-3435

[9] M.S. Ismail, "Design of a PV/Diesel standalone Hybrid System for a community in Palestine".

[10] Benjamin O. Agajelu, O. G. "Life Cycle Cost Analysis of a Diesel/Photovoltaic Hybrid Power Generating System,"13, 19-30.

[11] Bhandari, R. a. "Electrification using solar photovoltaic systems in Nepal."

[12] Kamalapur, G. a."Rural electrification in India and feasibility of Photovoltaic Solar Home Systems".

[13] Daud, A.-K. a."Design of isolated hybrid systems minimizing costs and pollutant emissions". 44, 215-224.

[14] Twaha, S. M."Applying grid-connected photovoltaic system as alternative source of electricity to supplement hydro power instead of using diesel in Uganda". 37 (1), 185-194.

[15] Girma, Z. "Technical and Economic Assessment of Solar PV/diesel Hybrid Power System for Rural School Electrification in Ethiopia".

[16] Kandpal," techno-economic comparison of rural electrification based on solar home system and PV micro grid "

[17] Ranaweera, K. I. "TechnoEconomic Optimum Sizing of Hybrid Renewable Energy System in Sri Lanka.

[18] Khan, "Pre-feasibility study of stand-alone hybrid energy systems for applications in New-found land".

[19] Karakoulidis, "Techno-economic analysis of a stand-alone hybrid photovoltaic diesel-battery-fuel cell power system."

[20] Turkey. B, "Economic analysis of standalone and grid connected hybrid energy systems".

[21] Bilala, "Methodology to Sizing an Optimal PV/wind/diesel/battery System Minimizing the Levelized cost of Energy and the CO2 Emissions".

[22] Rajkumar R.K.., "Techno economical optimization of hybrid PV/wind/battery system using Neuro-Fuzzy."

[23] Kaldellis J.K. and Ninou I., "Energy balance analysis of combined photovoltaic diesel-powered telecommunication stations."

[24] NASA surface meteorology and solar energy: http://eosweb.larc.nasa.gov

[25] www.bijlibacho.com/solar-panel-cell-cost-price-list-in-india.html

[26] www.dieselgeneratorset.co.in/diesel-generator-sets.html

[27] www.bijlibacho.com/solar-inverter-price-in-india.html

[28] www.rollsbattery.com