Available online at www.elixirpublishers.com (Elixir International Journal)

Renewable Energy

Elixir Renewable Energy 102 (2017) 44242-44245

ISSN: 2229-712X

Optimization of off-grid SPV – Diesel Hybrid Energy System for Different Electrical Loads at Jaipur in Rajasthan, India

S.K.Saraswat and K.V.S.Rao

Department of Renewable Energy, Rajasthan Technical University, Kota, India.

ARTICLE INFO

Article history:

Received: 23 December 2016;

Accepted: 5 January 2017;

Published: 10 January 2017;

Keywords

Hybrid Energy,
Optimization,
Annual Average Electric Load,
LCOE.

ABSTRACT

An off-grid hybrid energy system consisting of SPV - diesel generator – converter – battery is considered with zero percent loss of load for different electrical loads at a particular location of Jaipur, Rajasthan. Electrical loads of 1 kW, 2 kW, 3 kW, 5 kW, 8 kW, 10 kW, 20 kW and 50 kW are considered to analyze the system economically, electrically and emission point of view and optimized using HOMER software. LCOE decreases with increase in load up to 5 kW and it is almost constant between 5 kW to 20 kW and increases sharply beyond 20 kW electrical load

Introduction

A hybrid Energy System (HES) is a combination of multiple sources of energy such as renewable energy and diesel generator and may also include energy storage as battery bank. For off grid power generation, hybrid energy system is a clean and more reliable source of energy. It gives continuous power supply and reduce greenhouse gases emission [1].

In this study, a combination of solar PV – diesel generator with energy storage device (batteries) are used. Hybrid Energy System (HES) is analyzed using Hybrid Optimization Model for Electric Renewables software (HOMER version 3.4.3) developed by National Renewable Energy Laboratory, USA. HES is analyzed economically, electrically and emission point of view for different electrical loads such as 1 kW, 2 kW, 3 kW, 5 kW, 8 kW, 10 kW, 20 kW and 50 kW.

Literature Survey

Shaahid and Elhadidy [2] designed a Hybrid Energy System (HES) for kingdom of Saudi Arabia. They optimized the system with three different energy models namely (a) diesel only (b) solar PV and diesel generator (c) solar PV, diesel generator and batteries. The optimum result was given by a combination of 4 kW solar PV, 10 kW diesel generator and 1 hour battery storage with 22 % renewable fraction and 3% excess energy. They obtained least Levelized Cost of Energy (LCOE) of $ 0.172/kWh. Harsha et al. [3] proposed a standalone power generation system for coastal area near Visakhapatnam. They designed HES for 585 kWh/day annual average electrical load. LCOE and Net Present Cost (NPC) of optimized system were 0.218 $/kWh and $ 725, 853 respectively. Agustin and Lopez [4] reviewed the simulation and design tools for the HES. They collected literature on the design, control, optimization and simulation of the HES. They found that most frequent HES consists solar PV, wind turbines, diesel generator and batteries. Baghdadi et al. [5] investigated the performance of hybrid solar PV/wind turbine/diesel generator/battery system for climate of southern Algeria. They developed mathematical model to ensure efficient energy management on the basis of various operational strategies. HES reduced 70% of fuel consumption as compared to diesel only system. Ghasemi et al. [6] analyzed techno – economic feasibility of standalone hybrid solar PV/diesel generator system for electrification of remote villages of northeastern part of Iran. They designed system for 200 kWh/day annual average electrical load. LCOE for diesel only and HES were obtained as 0.304 $/kWh and 0.430 $/kWh respectively.

Cost Aspect and Components Details

The system is designed for different electrical loads with zero percentage loss of load for a particular location of Jaipur, Rajasthan (India). Solar radiation intensity and clearness index are 5.43 kWh/m^2/day and 0.61 respectively taken form NREL using latitude and longitude of location as shown in Figure 1.

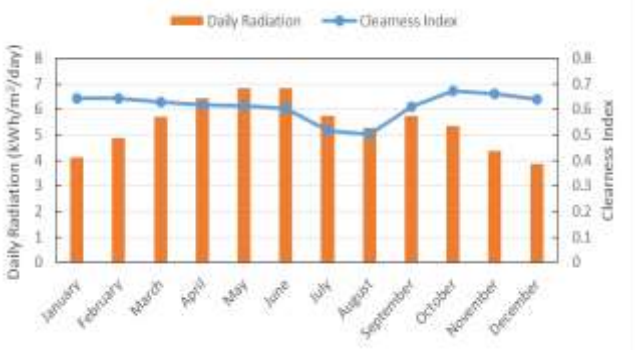


Figure 1. Daily solar radiation and clearness index for Jaipur location.

Solar Photovoltaic System

In this study, solar PV is used as a renewable energy source. Capital cost of solar PV panel is taken as Rs. 60,000 /kW and operation & maintenance cost is taken as Rs. 600 per kilowatt per annum. Life of solar PV system is taken as 25 years.

Tele: +91-8946809397

E-mail address: santosh.saraswat738@gmail.com

Diesel Generator System

In this study, a diesel generator is used for continuous power supply in the absence of solar energy. Capital cost and replacement cost are taken as Rs. 22,600 and Rs. 20,400 per kW respectively. Operation & maintenance cost is taken as Rs. 0.50 /kWh [7]. Life of diesel generator is taken as 15,000 hours. Fuel price is considered as Rs. 50 per Litre.

Battery Bank System

In this study, battery bank is used for backup energy in the absence of both solar PV and diesel generator. Both capital and replacement cost of one battery is taken as Rs. 30,000. Operation & maintenance cost is taken as Rs. 600 per annum per battery. The discover energy battery (12VRE – 3000TF-L) is taken into consideration which is having 245 Ah capacity and 12V voltage. Lifetime throughput of battery is taken as 3,550 kWh.

Converter System

Converter is used to convert the AC current to DC current and vice – versa. Both capital and replacement cost are considered Rs. 18,000 per kilowatt. Operation & maintenance cost is taken Rs. 180 per kilowatt per annum [8].

Results and Discussion

Hybrid energy system is studied with different loads and analyzed. Comparison of various parameters is as shown in Table 1. Battery bank voltage is taken 12V, 24 V and 48 V for the load range of 0 – 1 kW, 2 – 5 kW and more than 5 kW respectively.

Economic Analysis

System analyzed at different electrical loads, indicates that the minimum levelized cost of energy is obtained at 5 kW electrical load. LCOE decreases with increase in load up to 5 kW and it is almost constant between 5 kW to 20 kW electrical load and increases sharply beyond 20 kW electrical load. From the results it is found that minimum LCOE is obtained as 12.677 Rs./kWh at 5 kW electrical load as shown in Figure 2.

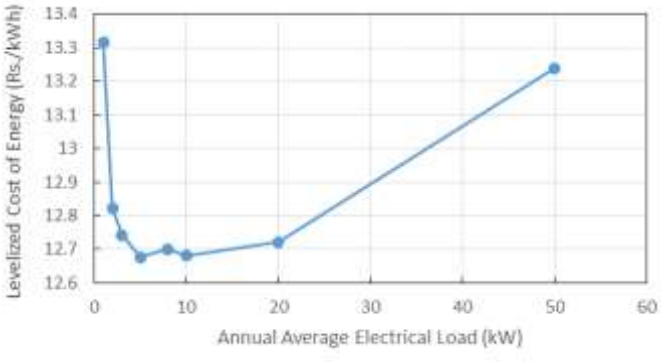


Figure 2. Variation in LCOE with different annual average electrical loads.

Annualized cost of HES is linearly incresing with increase in different annual average electrical loads as shown in Figure 3.

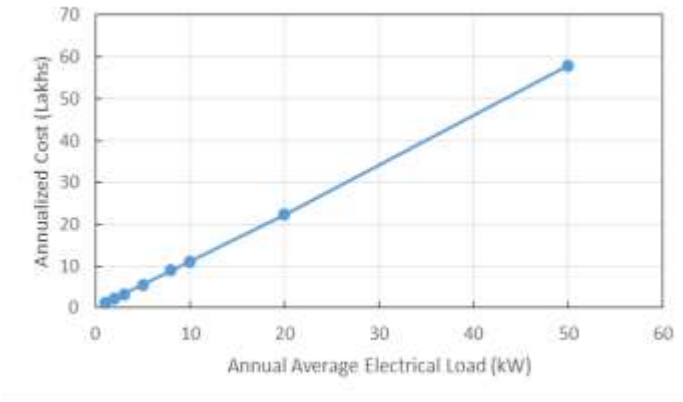


Figure 3. Variation in Annualized cost with different annual average electrical loads.

Electrical Analysis

Maximum renewable fraction of 96.76 % at a load of 50 kW and minimum renewable fraction of 88.62 % at a load of 10 kW are obtained. There is not much variation in the renewable fraction. It is varying in the range of 89 – 96 %. Renewable fraction at loads of 1 kW, 2 kW, 3 kW, 5 kW, 8 kW, 10 kW, 20 kW and 50 kW are 89.34 %, 90.29 %, 90.22 %, 89.49 %, 89.60 %, 88.62 %, 91.91 % and 96.76 % respectively. Figure 4 shows variation in LCOE and renewable fraction for different loads.

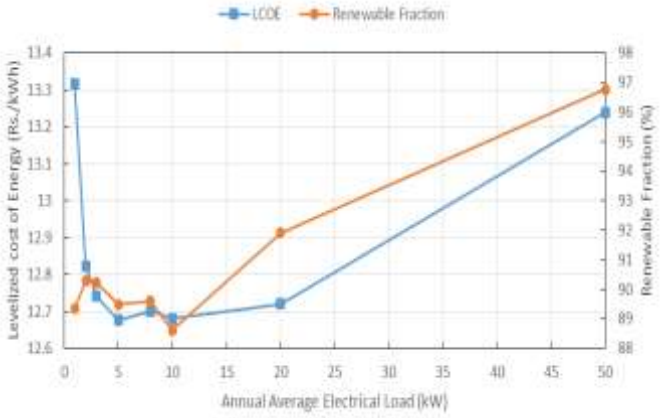
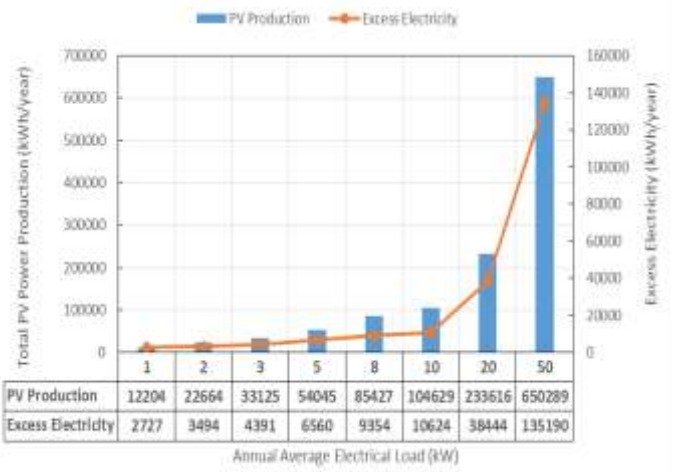


Figure 4. Variation in LCOE and renewable fraction for different annual average electrical loads

Maximum excess electricity 135190 kWh/year is produced by 50 kW electrical load hybrid system because it is having highest solar PV system capacity. Excess electricity is from the electricity generated by the solar PV system as shown in Figure 5.

Table 1. Various Parameters of HES for Different Annual Average Electrical Loads.

No.	Description	Annual Average Electrical Load (kW)							
		1	**2**	**3**	**5**	**8**	**10**	**20**	**50**
1.	Solar PV (kW)	7	13	19	31	49	60	134	373
2.	Diesel generator (kW)	2	3	4	6	9	11	22	55
3.	Converter (kW)	2	3	4	6	9	11	22	55
4.	Number of batteries	8	18	28	46	76	92	192	656
5.	LCOE (Rs./kWh)	13.3	12.8	12.7	12.6	12.7	12.6	12.7	13.2
6.	Annualized Cost (Lakhs)	1.16	2.24	3.34	5.55	8.90	11.10	22.27	57.94
7.	Total PV production (MWh/yr)	12.2	22.6	33.1	54.0	85.4	104.6	233.6	650.2
8.	Excess electricity (MWh/yr)	2.7	3.4	4.3	6.5	9.3	10.6	38.4	135
9.	Renewable fraction (%)	89	90	90	89	89	88	91	96
10	Operational hours of DG	1295	1110	1115	1213	1181	1320	895	354
11	Fuel Consumption (Litre/year)	360	620	922	1637	2595	3549	4998	4987
12	CO_2 Emission (tons/yr)	.949	1.63	2.4	4.3	6.8	9.3	13.1	13.1



	1	2	3	5	8	10	20	50
PV Production	12204	22664	33125	54045	85427	104629	233616	650289
Excess Electricity	2727	3494	4391	6560	9354	10624	38444	135190

Figure 5. Total PV Power production and Excess electricity for different annual average electrical loads.

Emission Analysis

HES of 20 kW load consumes 4998 Litre of fuel yearly which is the highest. 20 kW system consumes more fuel than 50 kW system because operational hours of diesel generator is higher in the 20 kW load system. CO_2 emission for 1 kW, 2 kW, 3 kW, 5 kW, 8 kW, 10 kW, 20 kW and 50 kW load are 949 kg/year, 1632 kg/year, 2428 kg/year, 4310 kg/year, 6834 kg/year, 9345 kg/year, 13161 kg/year and 13132 kg/year respectively. A 50 kW load HES system is having 354 minimum operational hours of diesel generator and a 10 kW diesel generator is having 1320 highest operational hours of diesel generator.

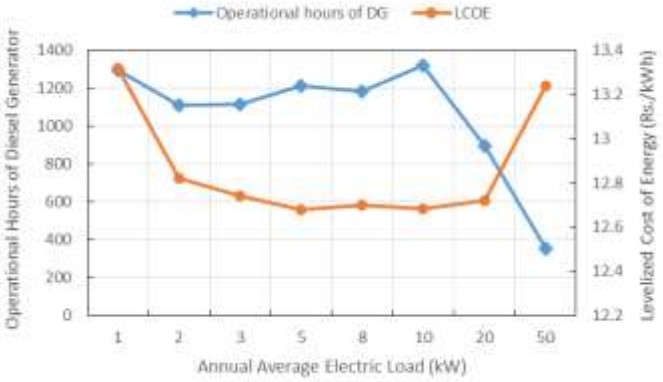


Figure 6. Operational hours of DG and LCOE for different annual average electrical loads.

Conclusions

Hybrid energy system is designed and analyzed using HOMER software for different annual average electrical loads at a particular location of Jaipur, Rajasthan.

- Minimum LCOE 12. 677 Rs./kWh is obtained at 5 kW load. LCOE for loads of 1 kW, 2 kW, 3 kW, 5 kW, 8 kW, 10 kW, 20 kW and 50 kW are 13.317 Rs./kWh, 12.823 Rs./kWh, 12.742 Rs./kWh, 12.677 Rs./kWh, 12.701 Rs./kWh, 12.681 Rs./kWh, 12.721 Rs./kWh and 13.239 Rs./kWh respectively.
- Excess electricity for 1 kW, 2 kW, 3 kW, 5 kW, 8 kW, 10 kW, 20 kW and 50 kW electrical loads are 2727 kWh/year, 3494 kWh/year, 4391 kWh/year, 6560 kWh/year, 9354 kWh/year, 10624 kWh/year, 38444 kWh/year and 135190 kWh/year respectively.
- Maximum and minimum renewable fraction is obtained at 50 kW and 10 kW respectively.
- CO_2 emissions for 1 kW, 2 kW, 3 kW, 5 kW, 8 kW, 10 kW, 20 kW and 50 kW electrical loads are 949 kg/year, 1632 kg/year, 2428 kg/year, 4310 kg/year, 6834 kg/year, 9345 kg/year, 13161 kg/year and 13132 kg/year respectively.
- LCOE decreases with increase in load up to 5 kW and it is almost constant between 5 kW to 20 kW electrical load and increases sharply beyond 20 kW electrical load for a particular location of Jaipur, Rajasthan.

References

[1]. K. Sopian and M. Y. Othman, "Performance of a photovoltaic diesel hybrid system in Malaysia," ISESCO Science and Technology Vision, vol. 1, pp. 37-39, May 2005.

[2]. S. M. Shaahid and M. A. Elhadidy, "Economic analysis of hybrid photovoltaic – diesel – battery power systems for residential loads in hot regions — A step to clean future," Renewable and Sustainable Energy Reviews, vol. 12, pp. 488–503, 2008.

[3]. Sai Sri Harsa, Shaik Sharif and Ravi Sharma, "Techno-Economic and Environmental Impacts of Hybrid generation to supply a load in Visakhapatnam, 6th IEEE Power India International Conference, India, p. 446, 2014

[4]. J. L. Bernal-Agustin, R. Dufo-lopez, "Simulation and optimization of stand-alone hybrid renewable energy systems," Renewable and Sustainable Energy Reviews, vol. 13, pp. 2111–2118, 2009.

[5]. F. Baghdadi, K. Mohammedi, S. Diaf, and O. Behar, "Feasibility study and energy conversion analysis of stand-alone hybrid renewable energy system," Energy Conversion and Management, vol. 105, pp. 471–479, 2015.

[6]. A. Ghasemi, A. Asrari, M. Zarif, and S. Abdelwahed, "Techno-economic analysis of stand-alone hybrid photovoltaic – diesel – battery systems for rural electrification in eastern part of Iran — A step toward sustainable rural development," Renewable and Sustainable Energy Reviews, vol. 28, pp. 456–462, 2013.

[7]. Rangan Banerjee, "Comparison of options for distributed generation in India," Energy policy, vol. 34 pp. 101–111, 2006.

[8]. P. Arun, R. Banerjee, and S. Bandyopadhyay, "Optimum sizing of battery-integrated diesel generator for remote electrification through design-space approach," Energy, vol. 33, pp. 1155–1168, 2008.