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Optimal Hybrid Energy System for Rural Electrification in India using HOMER Software

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Abstract - *Renewable energy/alternative energy based hybrid energy systems have been considered as an efficient mechanism to generate electrical power. For rural electrification where grid extension is uneconomical or not feasible a decentralized or off-grid renewable energy based hybrid energy system is an economic and appropriate option. The basic idea of hybridizing the energy sources is that the base load is to be supplied by principal energy source and the peak load supplied by other irregular sources. The purpose of this study is to suggest the optimal hybrid energy system for generation of electricity from a combination of energy sources to fulfill the energy demands of the village in India. The design of hybrid energy system based on SPV system, diesel generator and grid are considered in this study. The study area is the Jatpura village in Aligarh district of Uttar Pradesh, India. The study is based on simulation and optimization of renewable energy system using Hybrid Optimization Model for Electric Renewable (HOMER). The hybrid model has been designed to provide optimized system configuration based on hybrid energy component costs, technical specifications and energy demand. The proposed hybrid energy system is environmental friendly which mitigates the CO2 emission and other greenhouse gas emissions.*

***Key Words*: Rural electrification, Optimization, HOMER, Hybrid energy system, SPV System**

1. INTRODUCTION

Energy is one of the foremost factors for the economic growth of the rural areas of any country. A majority of population of India is living in rural areas without electric utility grid and this is the main hindrance to overall development. The rural electrification plays vital role for the development of the rural areas for obtaining economic growth and improvement of livelihood of the villages. More than 77 million households still use kerosene for lighting in India [Census 2011]. The electrified villages have poor quality, low availability and irregularity of power supply. The situation prevailed leads us to search other options to meet the day to day needs of energy demand. The Government of India has introduced several programmes such as Remote Village Electrification Programme (RVEP), Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) etc. [1].

In addition to above programmes, Government of India proposed to launch Jawaharlal Nehru National Solar Mission under the National Action Plan on Climate Change with plans to generate 20,000 MW of solar power by 2022, 1,00,000 MW by 2030 and of 2,00,000 MW by 2050 [2].

Inspite of government of India efforts and initiatives still the fossil fuel based energy including coal and petroleum are considered as primary source of energy. During the year 2016-17 (up to 30.06.2016), the total installed capacity was 304.50 GW with generation mix of thermal including coal gas and diesel (70%), Hydro (14%), Renewable (14%) and Nuclear (2%) [3]. The major contributors for power production in India are fossil fuel based resources (coal, natural gas and oil). The Consumption of these conventional energy resources has the impact on the increase of carbon emissions. However, the Government of Indian is very serious to reduce the carbon emissions and percentage production of electrical energy from fossil energy and increase the proportion of the electrical energy from renewable energy sources. The Ministry of New and Renewable Energy, Government of India encourages the number of activities to produce the electricity from renewable energy sources. The development in the technology of the renewable energy results in the reduction of the cost and increases eco-friendly environmental scope that made it increasingly available to supply the load in the intermittent period.

Hybrid energy system is an excellent solution to supply the load continuously and reliably in remote rural areas where the grid extension is difficult and expensive or grid supply is unavailable most of the time. Hybrid energy system includes a combination of one or more renewable energy sources such as solar photovoltaic, wind energy, micro-hydro etc. and may be the conventional diesel generator set for backup [4, 5, 6]. Hybrid energy system is proposed after detailed survey of the site corresponding to availability of kind of source and its quantity and the load profile of the site area. The widely available energy source is the solar energy for the site under study. This paper presents a design of SPV-diesel and grid-based hybrid energy system for the site under study.

2. STUDY AREA AND SYSTEM CONFIGURATION

The study was conducted in Jatpura village situated in Jawan Sikanderpur Block of Aligarh district in the state of Uttar Pradesh, India. It is located 12 Km towards North from district headquarter of Aligarh and 143 Km from New Delhi [7]. The village comprises of 70 households and total demand for electricity is about 202 kWh/day. This load comes from street lighting, school, small commercial market, domestic uses and tubewell for crop irrigation.

There are many ways to incorporate different renewable energy /alternative energy sources to build a hybrid energy system. The methods can be generally classified as dc-coupled, ac-coupled, and hybrid-coupled. The system architecture employed in the hybrid energy system is AC coupled where the different alternative energy/renewable energy sources are connected to the AC Bus. Primary loads are also connected to the AC Bus through power electronic interfacing circuits (if needed) as shown in figure 1. Utility grid is also connected to the AC bus. Utility grid supplying power to the load as well as provide power to the energy storage system. The energy storage system provides energy to the AC Bus via power electronic converters when grid power is absent [8].

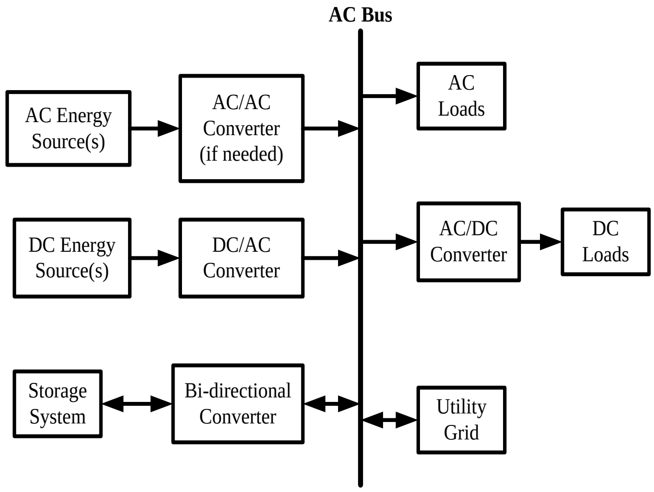

Fig. 1: Schematic of ac-coupled hybrid energy system

In this paper, Hybrid Optimization Model for Electric Renewable (HOMER version 3.10.3) has been used as simulation tool for sizing and optimization of hybrid energy system. It has a number of energy component models and calculates appropriate technology alternatives based on cost and availability of resources. Analysis with HOMER needs resource data, economic constraints and control methods etc.

2.1. Load Pattern

The electrical loads of the rural area include domestic, agricultural, community and rural industries. The community load contains schools and public office buildings. The rural industries include milk storage and small-scale milk processing plants [9, 10].

The daily load profile is shown in figure 2. The total load demand comes out approximately 202kWh/day and peak load of 16.67kW with a day-to-day random variability of 10%.

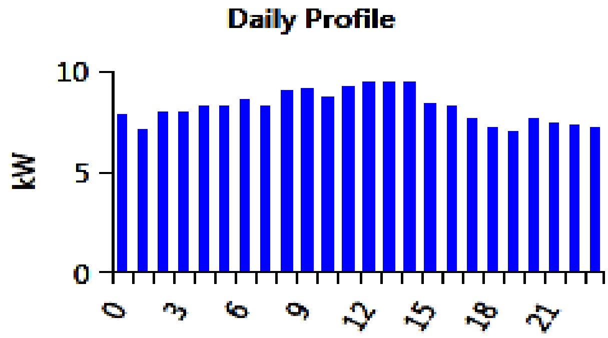

Fig. 2: Load profile of a day

3. HYBRID ENERGY COMPONENTS

3.1 Solar Energy Resources and SPV System

The Solar resource data used for Jatpura village at a location of latitude 28.0133 and longitude 78.1099 was taken from NASA surface meteorology and solar energy data via HOMER software [11]. The annual average solar radiation was scaled to be 5.16 kWh/m^2/day and the average clearness index was found to be 0.548. The solar radiation is available throughout the year, therefore a considerable amount of PV power output can be obtained as shown in figure 3. In summer solar power is higher than winter season. In rainy season clearness index and solar power availability is lower than summer and winter season. The capital cost and replacement cost for a 1 kW SPV system is taken as $3000 and $3000 respectively. Since little maintenance is required for PV system, only $10/kW/year is taken as operation and maintenance cost. The costs per kW considered include installation, logistics and dealer mark-ups. The SPV is connected to a DC output with a lifetime of 25 years. The de-rating factor considered is 80% for each panel to the varying effects of temperature and dust on the panels. The panels modelled in this study have no tracking system [12].

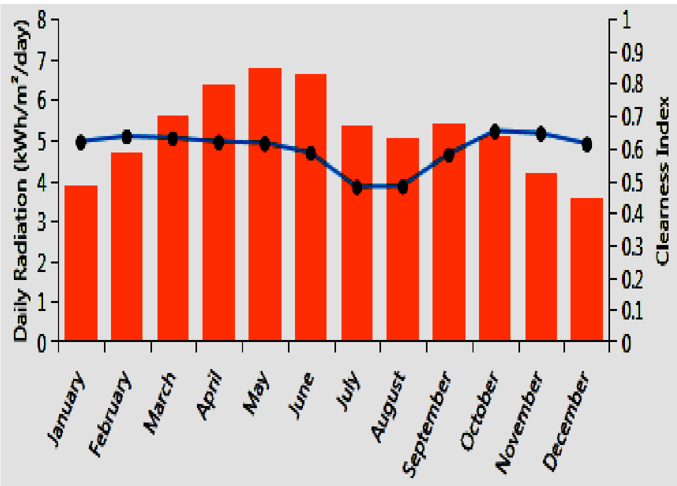

Fig. 3: Solar energy profile at the study area

3.2. Battery Bank

A battery bank is used as a backup system and it also maintains constant voltage during peak load. The battery chosen for this study is Generic 1kWh Lead Acid. It is a 12 V battery with a nominal capacity of 83.4 Ah. It has a lifetime (10 years) throughput of 800 kWh. The capital cost and replacement cost are US$300 and US$300 respectively. The operation and maintenance cost for 1 kWh battery is consider as US$10/year. The costs and specifications are taken as default values from homer energy [13].

3.3 Converter

A power electronic converter is necessary to maintain flow of power between the ac and dc components. For a 1 kW converter system the capital cost and replacement cost are taken as $300 and $300 respectively. Lifetime of this component is considered to be 15 years with an inverter efficiency of 95% and rectifier efficiency of 90%. The costs and specifications are taken as default values from homer energy [13].

3.4 Diesel Generator

A diesel generator set is used to meet the peak demand when there is no output from the SPV in off-grid hybrid energy system and for backup in grid-connected hybrid energy system. The capital cost and replacement cost of a 1 kW DG set are taken as $500 and $500 respectively. The operation and maintenance cost is taken as $0.03/h/kW. The generator is connected to an AC output with a lifetime of 15,000 operating hours. The minimum load ratio is taken to be 25% of the total capacity. The costs and specifications are taken as default values from homer energy [13]. The conversion rate of 1US$ is taken as INR 64.46 in this paper [14].

4. ANALYSIS

In this paper, HOMER is used to design off-grid and grid-connected hybrid systems serving electric loads using different renewable and alternative energy sources along with power converter component. The various input parameters is required for the modelling of the system such as load and energy demand, energy components for the generation of electricity and different energy resources available in the village. The lifetime of project is considered to be 25 years with an annual discount rate of 8% and expected inflation rate of 2 % [13, 15]. Based on these parameters and constraints optimal hybrid energy system can be designed which is suitable for electrification of the village through this simulation tool.

5. RESULTS AND DISCUSSION

In the proposed hybrid energy system only purchasing electricity from the grid is consider and assuming no option for selling electricity back to the grid. The optimal design of hybrid system components for this case study is a 14.6 kW PV system, 19.0 kW DG set, 56 Generic 1kWh lead-acid batteries, 16.0 kW converter with a dispatch strategy of cycle charging. The total net present cost and capital cost of this hybrid system are $151,801.90 and $74,997.78 respectively. The cost of electricity (COE) for this grid-connected hybrid energy system is US$ 0.1903. The design of grid-connected hybrid energy generation system is shown in figure 4 and their size for optimal design is shown in table 1.

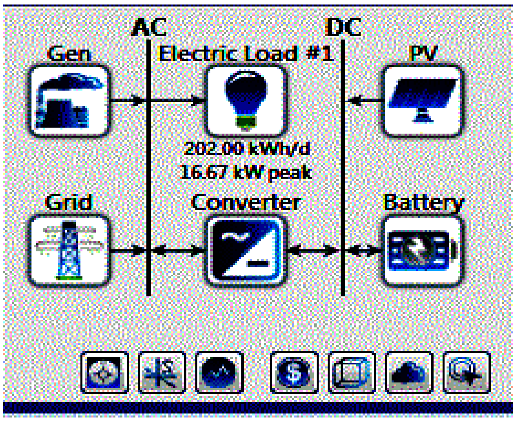

Fig. 4: Design of grid-connected hybrid energy system

For the same load of 202 kWh/day and peak load of 16.67kW, the cost of electricity (COE) for off-grid hybrid energy system is high that is $ 0.4886.

Table 1: optimal system architecture and cost of hybrid system for the case study

Cost Summary		System Architecture	
Total net present cost	$151,801.90	System Component	Size (kW)
Levelized COE	$0.1903	SPV	14.60
Operating cost	$7,098.76	Battery	56 (no.)
		Grid	100.00
		Diesel Generator	19.00
		Converter	16.00

From table 2 it reveals that the power purchase from grid is dominated the PV modules throughout the year. The PV modules produces 24,632 kWh/year with capacity factor of 24.6 % and DG set produces electricity about 279 kWh/year with capacity factor of 75.4% [16]. Furthermore, system is meeting the power consumption of 73,730 kWh/year with excess of power generation, which can be used for some useful purpose or can be used for additional battery charging.

Table 2: Annual electricity generation and consumption by the hybrid system

Production	kWh/year	%	Consumption	kWh/year	%
SPV	24,632	32.1	AC Primary Load	73,730	100
Diesel Generator	279	0.363	DC Primary Load	0	0
Grid Purchases	51,927	67.6	Total	73,730	100
Total	76,837	100			

5.1 Environmental Effects

The proposed Solar-diesel-grid hybrid system decreases gas emission by a substantial quantity due to reduced fuel consumption. In this hybrid system, carbon dioxide emission rate is 33,048 kg/yr and sulfur dioxide emission rate is 143 kg/yr.

6. CONCLUSION

This study has been conducted to achieve a technically feasible and economically viable grid-connected hybrid energy system to meet the electricity demand of a village. This hybrid system is an integration of solar PV-diesel and grid. Simulation results clearly show that the cost of energy for the grid-connected hybrid system is cheap as compared to an off-grid hybrid system for same load profiles. Hence cost of energy in grid-connected and off-grid system is US$ 0.1903/kWh and US$ 0.4886/kWh respectively. This study has been conducted for analysing the load of a village in India to develop the concept of grid-connected hybrid energy systems, but the structure and analysis is general in nature. Moreover, this hybrid system reduces the emission of harmful gases and help to mitigate the environmental pollution.

REFERENCES

[1] R. Rajbongshi, D. Borgohain and S. Mahapatra, "Optimization of PV-biomass-diesel and grid base hybrid energy systems for rural electrification by using HOMER", In Energy, Volume 126, 2017, pp. 461-474, https://doi.org/10.1016/j.energy.2017.03.056.

[2] http://www.mnre.gov.in/file-manager/UserFiles/mission_document_JNNSM.pdf

[3] Central Electricity Authority, "All India Installed Capacity of Power Stations," Minist. Power, Gov. of India, pp. 1–7, 2016.

[4] S. Ashok," Optimized model for community-based Hybrid Energy systems", Renewable Energy", Vol. 32, No. 7, pp. 1155-1164, 2007

[5] M.A. Elhadidy, S.M. Shaahid, "Role of hybrid (wind + diesel) power systems in meeting commercial loads", Renewable Energy, Vol. 29, No. 12, pp. 109–18, 2004.

[6] R.K. Pragya Nema and R. Saroj, "Integrated Design approach for standalone PV-solar and wind hybrid energy system: For Rural electrifications, International conference on advance energy systems (ICAER-2007) held at IIT Bombay, 12th-14th Dec.2007 pp.354-359

[7] http://wikiedit.org/India/Jatpura/39950/

[8] M. H. Nehrir et al., "A Review of Hybrid Renewable/Alternative Energy Systems for Electric Power Generation: Configurations, Control, and Applications," in IEEE Transactions on Sustainable Energy, vol. 2, no. 4, pp. 392-403, Oct. 2011.

[9] M.J. Khan and M.T. Iqbal, "Pre-feasibility study of stand-alone hybrid energy systems for applications in Newfoundland", Renewable Energy, Vol. 30, Issue 6, May 2005, Pages 835-854

[10] P. Droege, "Urban energy transition: from fossil fuels to renewable power", Elsevier, 2008

[11] NASA Latitude/Longitude Finder; https://mynasadata.larc.nasa.gov/latitudelongitude-finder/

[12] Usman, M., et al., Techno-economic analysis of hybrid solar-diesel-grid connected power generation system. J. Electr. Syst. Inform. Technol. (2017), http://dx.doi.org/10.1016/j.jesit.2017.06.002

[13] Homer Energy, http://www.homerenergy.com/software.html, [Accessed November 30, 2017]

[14] http://www.xe.com/currencyconverter/

[15] Rohit Sen, el al., Off-grid electricity generation with renewable energy technologies in India: An application of HOMER, In Renewable Energy, Volume 62, 2014, Pages 388-398, ISSN 0960-1481,https://doi.org/10.1016/j.renene.2013.07.028.

[16] Shahzad MK, Zahid A, ur Rashid T, Rehan MA, Ali M, Ahmad M, Techno-economic feasibility analysis of a solar-biomass off grid system for the electrification of remote rural areas in Pakistan using HOMER software, Renewable Energy (2017), doi: 10.1016/j.renene.2017.01.033.