International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Design of Smart Grid in Rural Areas Using Homer

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Abstract: ***Smart Grid is a network created through information technology, communication technology and electrical power system. It is simply a "smarter" power grid which ensures a two-way communication between user and the power supplier. It mainly takes into consideration the renewable energy resources for its operation. This concept is used in this paper tosupply energy in rural areas ofIndia, where still over 4500 villages are not electrified. The paper proposes a smart microgrid design in one such Indian village called "Dheeya" of Rajasthan state,using solar PV panels, wind turbines and batteries and HOMER software is used for simulation and optimizationof the hybrid power plant including the costaspects for various loads throughout one complete year.***

Keywords: Homer, Smart Grids, India, Rural Areas, Renewable resources, Energy Access

1. Introduction

Strikingly different from developed countries, where the energy infrastructure is so efficient, developing countries like India and China still lack a solid infrastructure. Observing the ever increasing population of India, the demand for energy is expected to increase significantly. This growing energy demand will result in installing many new power stations, which run on fossil fuels and burden on the fossil fuels will increase to meet the energy requirements. [1].

Besides this, India has 67% rural population and till today 4732 villages are not electrified. [2-3]India has centralized energy infrastructure where bulk power is generated at a centralized station and transmitted to larger distances and eventually distributed among the consumers. Urban areas are covered under the Indian power grid but some of the rural areas are deprived of electric energy. The traditional and present Indian grid is not able to supply power to these areas because of some factors, one of them being the geographical factor. This causes the rural people of India to use biomass cooking stoves and kerosene lighting or use firewood or dung stove as primary cooking device which is causing health issues and forest depletion because of inefficient biomass consumption. [4] The common solution to all the above problems is to electrify those rural areas by using local renewable energy resources available to that area. Local renewable and conventional energy sources can operate together in a smart grid. A smart grid has a characteristic of two-way flow of electric energy and it can monitor and control the devices from a remote utility location. [5] Moreover, the smart grid uses the renewable energy resources so the burden on fossil fuels decreases and will also help in decreasing the pollution level.Renewable energy resources include solar, wind, hydro, batteries etc. and India has seen a tremendous growth in wind and solar energy production with a wind power capacity of 24.7 GW and solar power capacity of 4.68 GW. [6] Hybrid plants are those plants which produce electric energy from one or more renewable energy resources and they are very suitable in tropical countries like India hence there is a need to enlighten our work in this field.

Solar and wind can be considered as main source of renewable energy but due to their variable nature they can't supply the load continuously [7], also as the load demands are always changing, there is a need of an additional battery storage for providing continuous power supply to the load. But the battery energy costs very high therefore there is a need to find a solution to this problem. So the main aim of this paper is to present a hybrid model (PV/Wind/Battery) which can meet the demand of an Indian rural village and also to analyze the economic feasibility of the model. [8] The same is achieved by a software called HOMER.

2. Introduction to Homer

The Hybrid Optimization Model for Electric Renewables (HOMER) is used for designing standalone electric power systems that employ some combination of wind turbines, photovoltaic panels or diesel generators to produce electricity. HOMER is an application software by National Renewable Energy laboratory in US. It is used for designing and analysis of smart grid systems by calculating different combinations of possible designs depending on inputs and then simulating the power system network. [9].

Simulation, optimization and sensitivity analysis are main operations of HOMER. Each hour of the year modelling of the power system network is done in the simulation process to determine the technical feasibility. Then, many different system configurations are simulated which meet the required demands and also follow the technical constraints in the optimization process. Finally in sensitivity analysis, multiple number of these optimizations are performed according to variable nature of the inputs. In the simulation process, it calculates four types of costs:

- NPC (Net Present Cost)
- COE (Cost of Energy)
- O&M (Operations and Maintenance Cost)
- Initial Capital Cost

The life cycle cost of a system is represented by total net present cost (NPC) of the system. Cost of initial construction, maintenance, fuel, penalties from pollutants and all other costs are included in NPC.

The average cost/kWh of useful electrical energy is cost of energy (COE).[10-11-12].

3. System Description

HOMER simulation requires some input data to perform the optimization results for various combinations which are given as:

A. System Load Profile

The area considered is one of the Indian village which is still unelectrified. "Dheeya" village of Rajasthan state in India is taken into consideration and the "residential" load profile is selected. HOMER loads the profile and shows the hourly load variations of the region for one complete year. In this paper, the average energy consumption from the load profile selected is 11.27 kWh/d. The daily average load profile can be seen in figure 1. 2.39 kW is the peak load consumption of the area considered with scaled annual average assumed as 11.27 kWh/d. Figure 1 shows the load variations for 24 hours of the day.

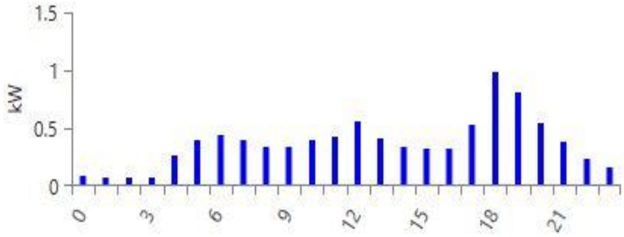

Figure 1: Daily Load profile (hourly)

B. Wind speed and Solar Radiation

NASA surface meteorology and solar energy database is the source of data of wind speed and solar radiation in the area considered. Wind speed is obtained at 50m above the surface of earth is shown in figure 2, ranging from 5.67 to 3.52 m/s, May being the highest wind speed month.

Figure 3 shows the monthly average solar radiation data and the annual solar radiation is assumed to be 5.16 kWh/m^2/day. The latitude and longitude of the area considered is 24.6^o N, 73.11^o E, respectively.

Figure 2: Monthly average wind speed

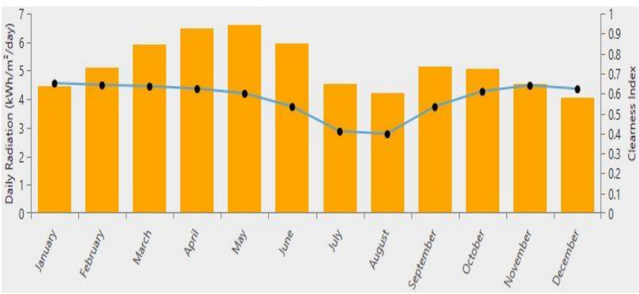

Figure 3: Monthly average solar radiation data and clearness index

4. Simulation Model

HOMER components are chosen to perform simulation. Figure 4 shows the hybrid power system design using wind generator, PV array, converter, battery and load. For economic analysis the following values have been used:

a) Wind Turbine

Generic 3 kW turbine manufactured by Generic have been used with a hub height of 17m and lifetime of 20 years. The capital and operation and maintenance costs are $32000 and $300 respectively.

b) Photovoltaic Array

Generic 1 kW flat plate PV, manufactured by Generic have been used with a lifetime of 25 years and initial capital cost of $3000 and replacement and operation and maintenance cost being zero.

c) Power Converter

1 kW System Converter, manufactured by Generic with efficiency of 95% and lifetime of 20 years with capital and replacement cost of $300 and operation and maintenance cost being zero.

d) Storage Bank

Kinetic Battery Model with 55 kWh nominal capacity and lifetime capacity of 240,000 kWh. The storage bank can be used to store the excess electric energy after meeting the load demands for various other uses. It supports the system as it is not connected to main centralized grid.

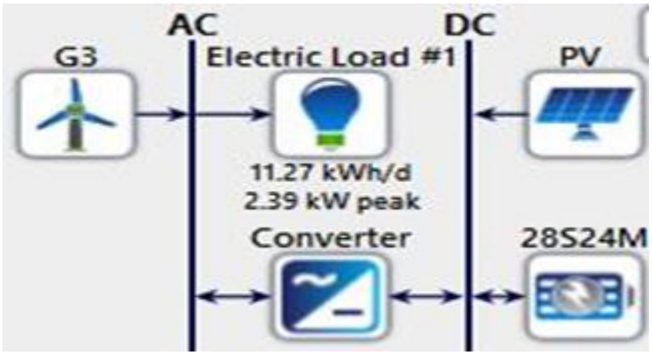

Figure 4: Hybrid Power System Arrangement

Production	kWh/yr	%
Generic flat plate PV	5,998	81.11
Generic 3 kW	1,397	18.89
Total	7,394	100.00

Consumption	kWh/yr	%
AC Primary Load	4,113	100.00
DC Primary Load	0	0.00
Total	4,113	100.00

Figure 5: Screenshot of production and consumption scenario

Figure 6: Monthly electric energy production from PV and Wind units

5. Optimization Results

From the results, the total yearly production of the hybrid model is 7394 kWh/yr and the load demand is 4113 kWh/yr and can be seen in figure 5. The rest of the energy can be stored or can be sold to the centralized grid to get money to use in the development of the village.

The optimization results for the hybrid power model are shown in figure 6. The minimum COE obtained is $0.550 and the renewable energy contribution is 100% and optimum number of renewable energy resources are used and supplies electric energy to the load. The NPC comes out to be $29,209.

Figure 7 depicts the monthly average electric energy production from different units used in this model.

6. Conclusion

A hybrid microgrid is modelled for Indian village Dheeya, which is unelectrified today, by using HOMER and the optimization results show that by using renewable energy units of flat plate PV panel of 1kW capacity, a wind turbine of 3kW capacity, 55kWh nominal capacity battery and a 1kW system converter, the village can be electrified with a total electric production of 7394 kWh/yr whereas the load demand is 4113kWh/yr and the rest of energy can be stored or sold to central grid. The monthly electric energy production from PV and wind units show that 100% of the produced electric energy is obtained from renewable sources of energy hence, it helps in somewhat reducing the burden on fossil fuels to meet the energy demands.

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