International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-7, Issue-6S, March 2019

Micro-Grid Based Electrification For Remote Villages

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Abstract— Our Country is on its path of development and this requires a major concentration on catering the energy demands of the nation. This can be achieved by tapping more from the renewable resources available within our vicinity rather than the conventional coal and petroleum resources. With abundant renewable sources available, they can be used to provide power locally to rural areas primarily based on their electricity demands.

This paper discusses the study of use of a microgrid to meet the energy demand for a remote village named Mudikandan which falls in Sivaganga district in the state of Tamil Nadu in India. A micro-grid is an integrated energy system that consists of loads and distributed energy resources which can either function independently or in parallel with the main grid. Through this paper we propose a micro-grid based electrification solution for the village. The proposed micro-grid based solution will integrate renewable energy sources such as solar and wind to provide stable electricity supply for residential load. For that purpose, we employ a microgrid simulation and optimization software by Homer Energy called as HOMER Pro. The results using both wind and solar energy has been analysed and compared after the simulation.

Keywords—Solar, Wind ,Microgrid, Homer

I. INTRODUCTION

As India grows from a developing country to a developed country, its energy needs also increases. The total installed capacity according to Ministry of Power, Govt. of India [1] as on 30th September 2015 is 278,734 MW of which 28.3% is accounted by renewable energy sources. According to the Central Electricity Authority [2] the capacity shortage for the 2015-2016 fiscal year is around 2.1-2.6%. In northern and southern India, this could go up to as high as 11%. As issues such as global warming and depletion of non-renewable energy resources such as coal and petroleum gain more and more importance at a global level, the need to expand the use of renewable energy sources increases. For a country like India it assumes even greater importance as its energy needs grow as it aims to move from an agriculture based economy to becoming a manufacturing hub. India has enormous potential to utilize renewable energy resources such as solar, wind, hydel, tidal, etc. Figure 1 shows the wind power density map of India. Figure 2 shows the distribution of Direct Solar Horizontal Irradiance in India.

Renewable energy technologies are ideally suited to distributed applications, and they have substantial potential to provide a reliable and secure energy supply as an alternative to grid extension or as a supplement to gridprovided power. Over 400 million people in India, including 47.5% of those living in India's rural areas, still had no access to electricity. Because of the remoteness of much of India's un-electrified population, renewable energy can offer an economically viable means of providing connections to these groups.

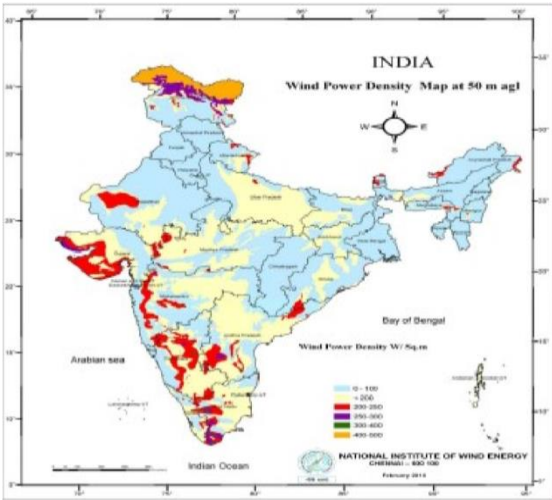

Fig. 1 The wind power density map of India

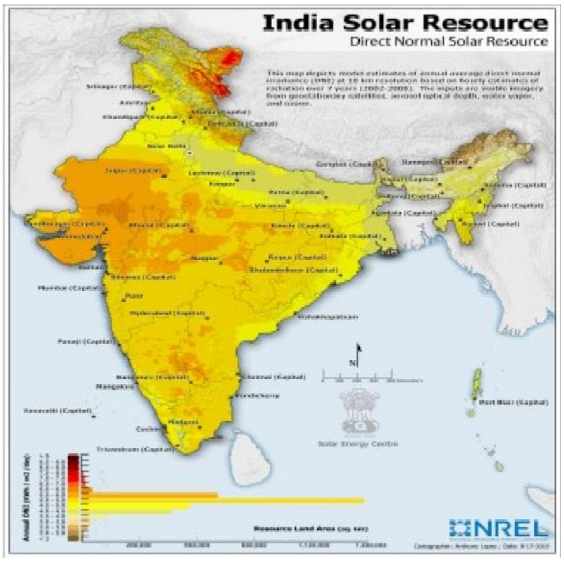

Fig. 2 The distribution of Direct Solar Horizontal Irradiance in india

Revised Version Manuscript Received on March 08, 2019.

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However, renewable energy technologies face a number of issues related to their integration to the main grids. These include integration costs, variability in supply from renewable sources, frequency response, energy storage capacity, solar and wind forecasting and so on.

Therefore it will be much more feasible to use a microgrid for the purpose of utilizing the renew-able sources. A micro-grid is an integrated energy system that consists of loads and distributed energy resources which can either function independently or in parallel with the main grid. Through this paper we propose a micro-grid based electrification solution for a remote village named Mudikandan which falls in Sivaganga district in the state of Tamil Nadu in India.

II. SITE DETAILS

A) Geographical Details

According to the National Census [3] conducted in 2011, Mudikandan is a medium size village located in Sivaganga tehsil of Sivaganga district, Tamil Nadu with total 259 families residing. The Mudikandan village has population of 1019 of which 526 are males while 493 are females as per Population Census 2011. It has a 259 households and out of a total of 1019 residents 344 are working. Figure 3 shows the geographical location of the village.

Fig. 3. Geographical location of the village

B) Climate

The climate in this part of Tamil Nadu shows slight variations throughout the year. Due to its proximity to the sea, the humidity and the temperature remains fairly high throughout the year. The village gets most of its rainfall due to North-East monsoon in the months of October-December.

C) Load Details

For the purpose of this paper, we have considered the following appliances to be installed at every household in the village.

1. Ceiling Fan 1: 50 Watts
2. Television 1: 110 Watts
3. FTL 2: 14 Watts each
4. Socket 1: For charging mobile phones

An average Indian household in a remote village will consist of these appliances. On the basis of the demographic details and the climate we have considered the following load as shown in figure 4.

The average load is 9.73 KW and peak load is 28.99 KW thus giving a load factor of 0.34.

III. SIMULATION USING HOMER

HOMER Pro [4] is a microgrid simulation and optimization software by Homer Energy. HOMER simulates the operation of a hybrid microgrid for an entire year, in time steps from one minute to one hour. It examines all possible combinations of system types in a single run, and then sorts the systems according to the optimization variable of choice.

In this paper, we have explored the use of solar PV panels, wind turbines and diesel generators to cater for the electricity needs of the residents of the village as per the load curve shown in Section 2

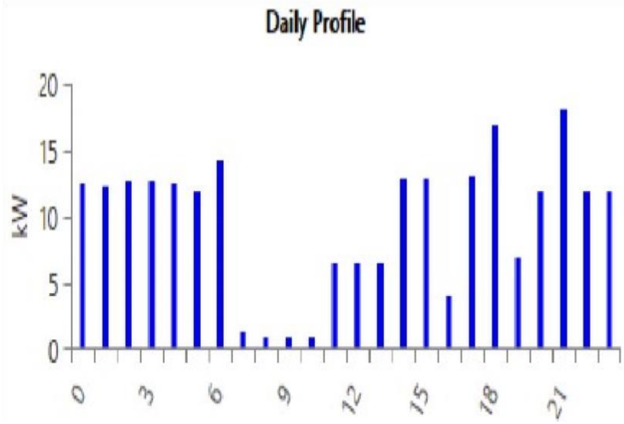

Fig. 4. Daily profile of load consumption

A. Renewable Energy Potential Assessment

Micro grids help in exploiting locally available RE sources, which are also the fundamental units of the smart grid architecture. However, available energy potential of the region and seasonal variability assessment is the primary step to map the viable regions for power harvesting. [5] We explored the availability of renewable energy sources in the village. We obtained the Solar Global Horizontal Irradiance data for the village through the database of National Renewable Energy Lab database [6] using HOMER. This is depicted in Figure 5.

Similarly, we obtained the Wind Resource Data from the same source as depicted in Figure 6.

The Solar GHI data shows that Solar PV panels can alone cater to the electricity needs of the residents. Wind can be used as an add-on source, how-ever its constructional costs may make the system economically infeasible. This was also confirmed by the simulation results as shown in Section 4.

Fig. 5. Solar Global Horizontal Irradiance data for the village

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Fig. 6. Wind Resource Data for the village

B. Equipment Details

We simulated the power system using 2 schemes as depicted in Figures 7 and 8.

As shown in Figure 7, we use solar PV cells, wind turbines, inverter system, energy storage batteries and diesel generator set to supply the required power. On the other hand, as shown in Figure 8 we do not use wind turbines in the power system.

The equipment details are as follows:

Converter System:

- Efficiency: 85 % Lifetime: 15 years
- Capital Cost: 17,50,000 INR (for 35 KW system)
- Simulation Sizes: 40 KW, 80 KW, 160 KW

Battery:

- Type: 1 KWh Li-Ion
- Nominal Voltage: 12 V
- Nominal Capacity: 200Ah
- Lifetime: 15 years
- Capital Cost: 12,000 INR
- Simulation Quantity: 0, 300, 350, 400, 450

Diesel Generator:

- Capacity: 100 KW
- Lifetime:15000 hours
- Capital Cost: 5,00,000 INR (for 50 KW system)
- Simulation Size: 0 KW, 100 KW

Solar PV

- Panel Type: Flat Plate
- Lifetime: 25 years
- Capital Cost: 35,000 INR (for 1 KW panel)
- Simulation Size: 70 KW, 77 KW, 80 KW,
- 90 KW

Wind Turbine:

- Rated Capacity: 5 KW Hub
- Height: 17 meters
- Lifetime: 20 years
- Capital Cost: 1,50,000 INR per turbine
- Simulation Quantity: 0,5,8,10

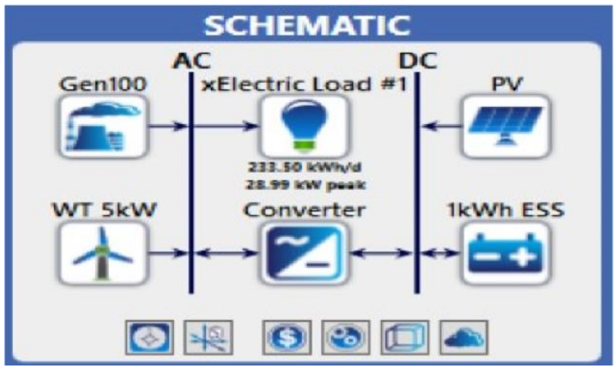

Fig. 7. Power System Simulation -1

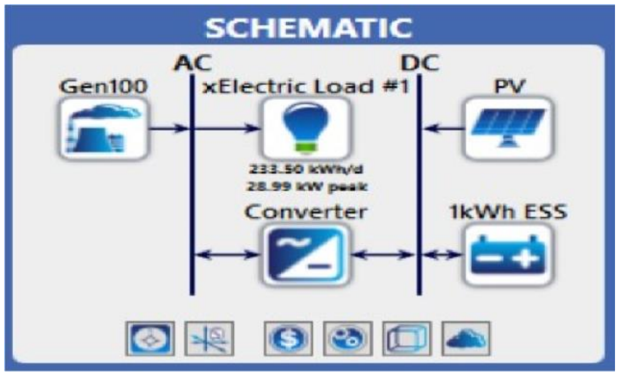

Fig. 8. Power System Simulation - 2

IV. SIMULATION RESULTS

For the scheme that uses wind turbines, the following was the most optimum result:

Table I Results- Including Use Of Wind Turbine

Equipment and Factors	Optimized Quantity
PV (KW)	90
Wind Turbine (5 KW)	5
DG (100 KW)	0
1KWh ESS	340
Converter (KW)	35
Cost of Energy (INR)	10.94
Initial Capital (INR)	9.73 million
Renewable Fraction	100%

The results showed that the battery storage sys-tem can provide required power for 67 hours in the absence of wind and sunlight. An excess electricity of 50,085 KWh/year is generated by this system.

Figure 9 shows the cost summary of the system. Figure 10 shows the electrical data summary of the system.

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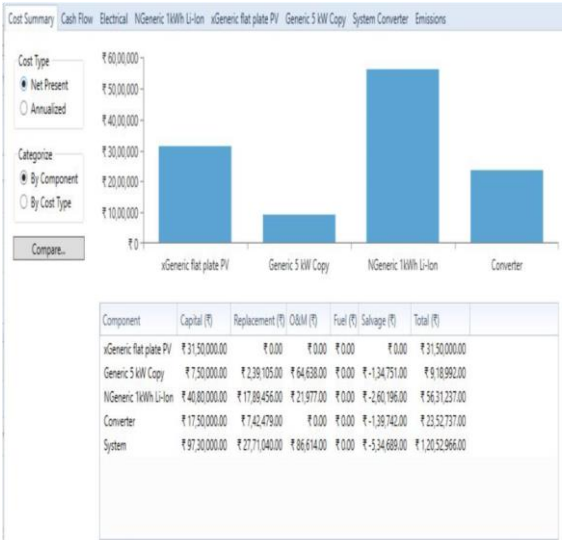

Fig. 9. The cost summary of the system (with wind turbine)

Fig. 10. The electrical data summary of the system (with wind turbine)

For the scheme that does not use wind turbines, the following was the most optimum result:

Table II Results- Without Use of Wind Turbine

Equipment and Factors	Optimized Quantity
PV (KW)	77
Wind Turbine (5 KW)	0
DG (100 KW)	0
1KWh ESS	400
Converter (KW)	35
Cost of Energy (INR)	10.78
Initial Capital (INR)	9.25 million
Renewable Fraction	100%

Here, the initial capital cost comes down because the wind turbine are not used and thus the cost of energy per unit comes down slightly. More number of battery storage systems are used here due to 100 % dependency on solar PV to supply required energy. An excess electricity of 23,118 KWh/year is generated by this system.

Figure 11 shows the cost summary of the system. Figure 12 shows the electrical data summary of the system.

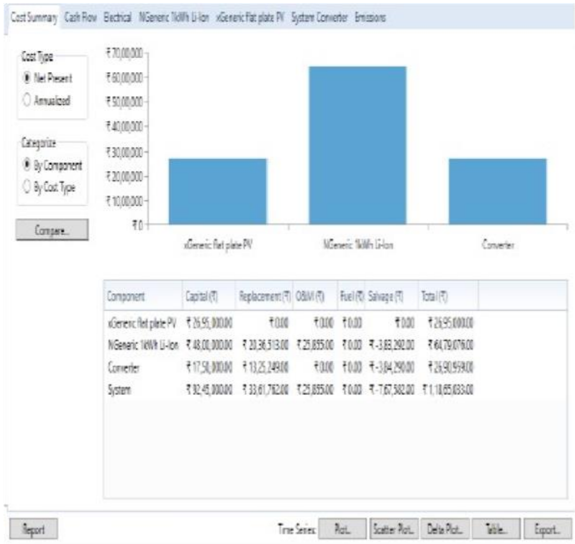

Fig. 11. The cost summary of the system (without wind turbine)

V. CONCLUSION

In both schemes it has been found that diesel generator sets are not required to cater to the residential load at Mudikandan village. Renewable energy sources can independently supply the load efficiently for the project lifetime of 25 years. A significant amount of excessive electricity is generated which can be transmitted to the main grid or it can be utilized for supplying electricity to nearby villages. Though the cost of energy is significantly high, but it compensated by the reduction in emissions produced as well as the generation of excess electricity produced. Also, the village of Mudikandan is surrounded by small tributaries and lakes. Thus the possibility of a micro-hydel generation system can be explored as well.

Overall, the results demonstrate that a micro-grid based solution utilizing renewable energy sources only can be effective in electrification of remote areas. It solves the problems of electrification of a village, counters the challenge of grid integration issues by using a micro-grid based approach, and makes use of a 100 % renewable form of power.

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Fig. 12. The electrical data summary of the system (without wind turbine)

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