Optimal Rural Microgrid Energy Management Using HOMER

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Abstract-The microgrid concept is a natural evolution of distributed resources that may be used to serve energy to customers in areas where conventional power system approaches cannot satisfy the reliability needs. Microgrids[2] may also provide support to conventional power systems that are too constrained to meet the power demands of customers. This paper presents a case study of a remote village dependent on agriculture, with no grid extension. The remote village consists of 400 people and 200 cattle including poultries, bovines, swine etc. The latitude and longitude of the study area are 30° 32' N and 76° 39' E respectively. The proposed model consists of Photovoltaic (PV) array, wind energy sub-system, micro hydro, biogas fueled generator and battery storage sub-system. The final goal is to maximize energy output from distributed energy resources (DERs) by Optimization using HOMER. Performance of each component of the model will be evaluated and finally sensitivity analysis will be performed to optimize the system at different conditions.

Keywords – DERs, HOMER, Optimization, Microgrid, PV

I. INTRODUCTION

In coming scenario the need of an hour is to improve the power system reliability and clean power in which microgrid is the promising concept. A micro-grid is a power system with distributed resources serving one or more customers that can operate as an independent electrical island with the bulk power system. Micro-grids[3] may range in size from a tiny residential application involving the islanding of a single house up to small-city-size islands with 100 MW of total load. The aim of this paper is to present optimization of DERs includes distribution generation (solar PV array, wind energy, hydro and biogas fueled generator) with battery backup. The approach is based on mathematical modeling of each component of DERs and then optimizes using HOMER in order to determine the economic feasibility of DERs to ensure reliable power supply to load demand and minimization of cost. The goal of the project was to provide a reliable, continuous, sustainable, and good-quality electricity service to users, as provided in bigger cities[5]. As a consequence, several technical challenges arose and were overcome successfully as will be related in this paper, contributing to increase of confidence in renewable systems to isolated applications[12].

II. SYSTEM MODEL

2.1 Research method –

The purposed model consist of consist of solar photovoltaic modules, wind energy, hydro and biogas generators with battery as storage system and converters are used. The purposed system is shown in fig 1.

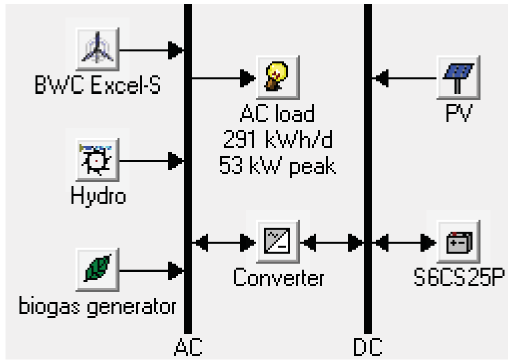


Fig 1:- DERs model in HOMER for cost optimization

In this purposed area consist of 450 people with 90 houses. Daily electrical load profile is acquirement based on basic demands of utilities such as lighting, cooling, communication and other household appliances etc. for each household.The total electrical load consumption is 291 kWh/day of remote village. The daily load profile is shown in fig 2.

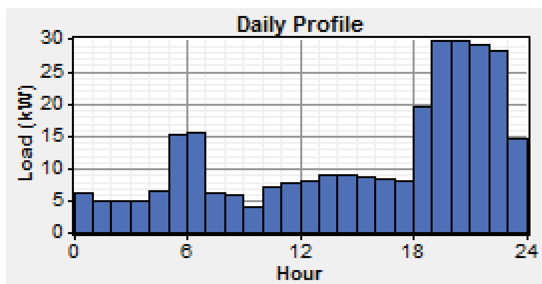


Fig 2:- Daily electrical load profile of study area

2.2 Solar PV modules

Solar resource indicates the amount of global solar radiation that strikes earth's surface. Solar radiation for this study area was obtained from the NASA Surface Meteorology and Solar Energy website. An average solar radiation of 5.22kWh/m2/day and a clearness index of 0.608 were identified for the study area. The PV array modeled in HOMER gives DC output in direct proportion to incident solar radiation. The installation cost of PV array is taken $2000/kW [6] and replacement cost is $1800/kW. Operation and maintenance (O&M) cost is practically zero and its lifetime is 25 years. A derating factor of 80% is applied to each panel to account for the degrading factors caused by temperature, soiling, tilt, shading etc. The Global horizontal radiations are shown in fig 3.

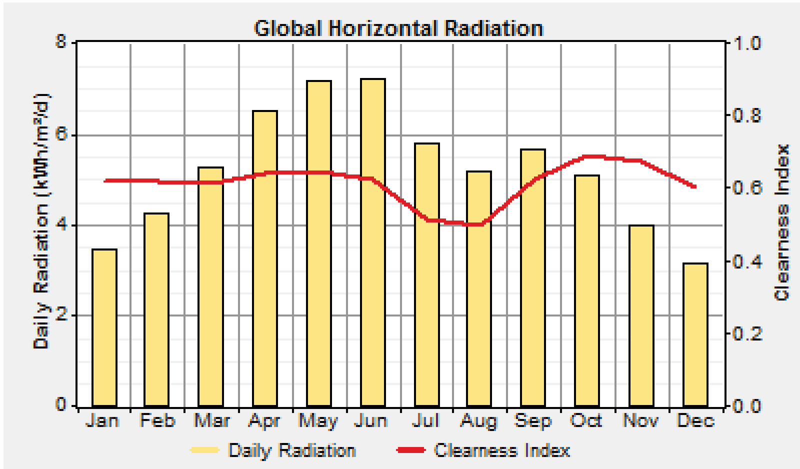


Fig 3:- Global horizontal radiation of study area

2.3 Wind turbine

Wind resources are determined using the NASA Surface Meteorology and Solar Energy database considering the wind direction at 10 meters above the surface of the earth. The database provides average wind speed is 4.19 m/s. Technical information of wind turbine [9] is presented below in Table and fig 3 represents monthly average wind speed.

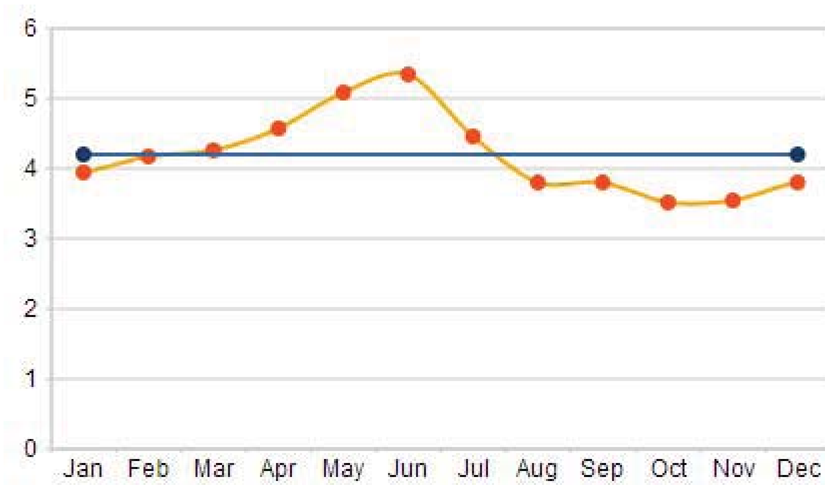


Fig 4:- Monthly average wind speed

2.4 Micro hydro turbine

In the study area, the stream has a monthly average flow of 47.1 L/s. With design flow of 50L/s (0.050 m^3/s), 30m head and 80% efficiency, it is determined that a run-of-river type micro hydro plant [7] of 11.8 kW rated capacity can be installed. The capital cost for the installation of micro hydro is taken as $23,000 with replacement cost of $19,000 and operation and maintenance (O&M) cost of $400 per year [11]. The electrical power generated by micro hydropower generator in kW is:

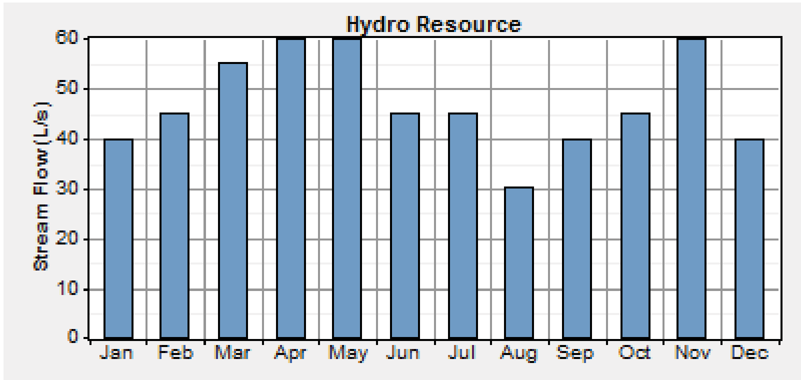


Fig 5:- Monthly average stream flow

2.5 Biogas generator

As mentioned earlier, biomass comprises of wood chips and wastes from wood industry, agricultural and forest residues, animal wastes, kitchen wastes and energy crops if available. Biomass undergoes anaerobic fermentation to produce biogas in community scale or household scale biogas digesters. Biogas is used as fuel to generate power from engine-generator set. The average biomass available in study area is 3.95 tonnes per day and monthly available average biomass resource is shown in Figure IV. 4. The capital cost of biogas powered generator is $1,000/kW with replacement cost of $850/kW and O&M cost of $0.01/hour [8]. The hourly energy generated by biogas generator is given

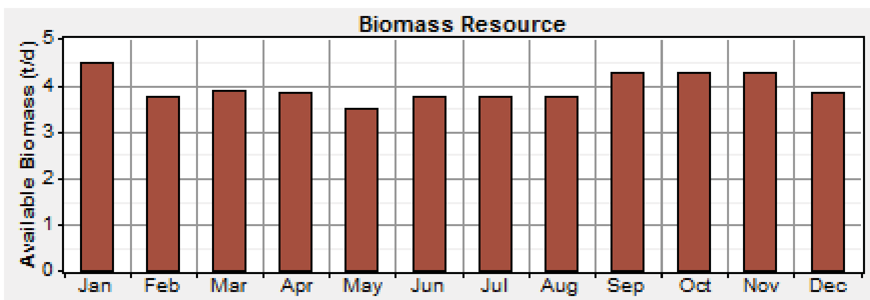


Fig 6:- Monthly average available biomass resource

2.6 Battery

Homer uses DC battery to store the energy and retain the energy when peak load appears. It is assumed that battery property of battery remain constant throughout its lifetime and are not affected by external factors. Surrette 6CS25P is a deep cycle, high capacity, lead acid battery and is most suitable for renewable energy application [8].

Battery Type	Surrette 6CS25P
Nominal Voltage	6V
Nominal Capacity	1,156Ah (6.94kWh)
Lifetime Throughput	9,654kWh
Capital Cost	$1,250
Replacement Cost	$1,100
O&M Cost	$15/yr

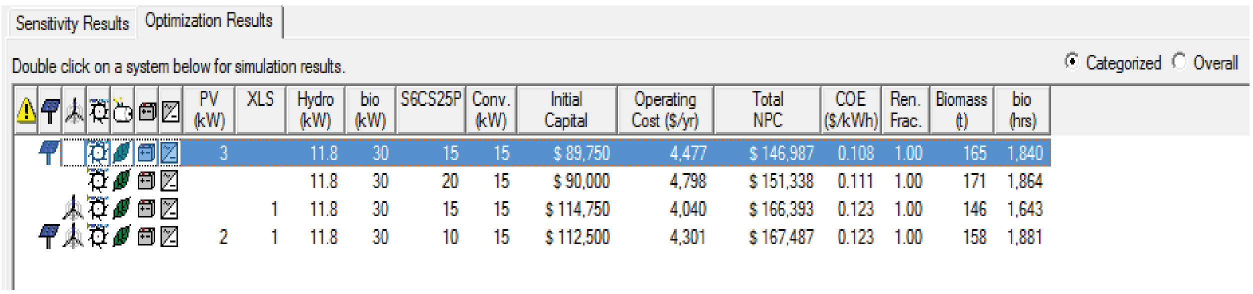
Table 6:- Technical details

2.7 Converter

A converter is a device that converts DC power to sinusoidal AC power in inversion process and from AC to DC power in rectification process. The bidirectional converter costs $800/kW, has replacement cost of $750/kW and O&M cost of $15/yr for a lifetime of 30 years. The inverter and rectifier efficiencies are assumed to be 85% and 90% respectively [45].

III. EXPERIMENT AND RESULT

The optimization results of DERs using HOMER are shown in figure 5. Solar photovoltaic system, hydro and biogas plant with battery, converter have the lowest total net present cost at $ 1,46,987 and cost of electricity of $ 0.108 per KWh.



Sensitivity Results | Optimization Results

Double click on a system below for simulation results. ◉ Categorized ○ Overall

PV (kW)	XLS	Hydro (kW)	bio (kW)	S6CS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Biomass (t)	bio (hrs)
3		11.8	30	15	15	$ 89,750	4,477	$ 146,987	0.108	1.00	165	1,840
		11.8	30	20	15	$ 90,000	4,798	$ 151,338	0.111	1.00	171	1,864
	1	11.8	30	15	15	$ 114,750	4,040	$ 166,393	0.123	1.00	146	1,643
2	1	11.8	30	10	15	$ 112,500	4,301	$ 167,487	0.123	1.00	158	1,881

Fig 7:- Optimal solution of DERs by HOMER

For this combination if we goes towards the electricity produced by that system then it is observed that PV array produce 5,182 Kwh/Yr about 19.7 % , hydro generator produces 82,572 KWh/Yr about 80.1 % and biogas produces 37,659 KWh/Yr about 21.3 % so the 10.6 % excess electricity is remaining with maximum renewable penetration of 1.621 % shown in Fig. 3.

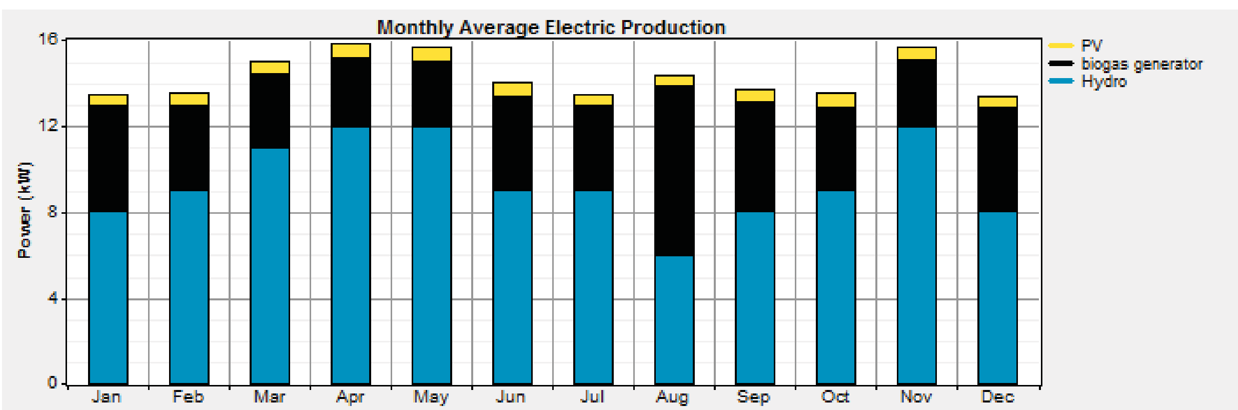


Fig 8:- Electricity production by PV, biogas and hydro generator

Another second solution given by HOMER is hydro and biogas plant with battery has total net present cost at $90.000 and cost of electricity of $ 0.111 per KWh. The electricity produced by this combination is 122,026 KWh/Yr out of this total 68% meet by hydro plant and 32% by biogas plant. From this it is clear that combination of solar wind system is not a feasible option concern with electricity production.

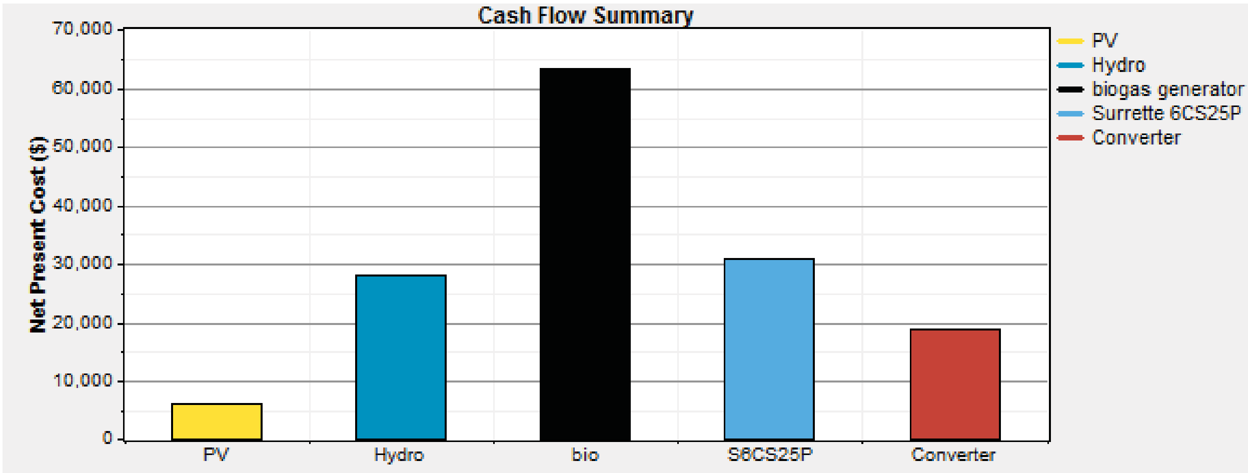


Fig 9:- Cost summary of different components

The annualized cost of the solar PV components contributes 469$/Yr, hydro plant contributes 1779 $/Yr,biogas plant contributes 2,347 $/Yr, battery cost 1.467 $/Yr, inverter cost 939 $/Yr and total system capital cost 7,021 $/Yr. The cost of generator plays an important part in determining the total net present cost and cost of electricity.

IV.CONCLUSION

The result from simulation of DERs by HOMER shows that solar PV modules , hydro, biogas generator with battery and inverter is the most economical solution to design integrated system with minimum total net present cost and cost of electricity. Optimization study of DERs for a rural community shows that the system can be implemented in cost effective manner. Though the different DERs are technically suitable and available in market, but not necessarily be financially viable. Economical viability should be in top priority over the technical feasibility exclusively for rural electrification in rural part of country where people cannot pay well.

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