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Design of Off-Grid Village With Bio-Solar Hybrid Energy

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***Abstract* - India is suffering from power crisis, mainly the remote areas where the transmission of electrical power is a major problem. Renewable energy based off-grid or decentralised electricity supply has traditionally considered as a single technology-based limited level of supply to meet the basic needs. The purpose of this paper is to propose the best hybrid technology combination of biogas and solar power for electricity generation to satisfy the electrical power needs in an off-grid remote village. The hybrid combination of bio-solar renewable energy generators at an off-grid location can be cost effective compare to grid extension and it is sustainable, techno-economically and eco-friendly. Research will be carried out to calculate the estimated load of the houses and the amount of electrical power is required during different times of the day to electrify the remote village by using bio-solar hybrid energy. In this paper case study is done for load and energy calculation of a village situated in remote area and simulations done by using HOMER software to analyse the results for its economic feasibility and reliability.**

Keywords- Biogas, PV array, Hybrid system and HOMER software.

1. INTRODUCTION

Every year the demand of electrical energy is growing rapidly and decreasing of conventional sources occurs throughout the year in the world. Now many villages in the world live in isolated area far from the main utility grid and it is impossible to meet by the conventional sources because of high cost of transport and distribution system. So new implementation is going on hybrid system with renewable sources as these sources are cost effective and eco-friendly [2].

Generally production of electrical energy is depends on fossil fuels which increases the emission of CO_2 which affects the environment. To reduce these effect, it is better to improvement the quality of renewable energy which is very eco-friendly to the environment. In rural area the environment is very suitable for implementation of renewable energy [3].

Extending power lines form centralized sources to rural areas is not economical and so decentralized power sources, such as the PV system is reliable alternative. One of the primary concerns in designing off- grid PV system involving PV array and storage battery capacity to supply the required energy at a specified energy load fraction.

There are many renewable energy can be implemented in hybrid systems like solar, wind, hydro, geothermal, biomass etc. But especially for rural and remote areas it is economical to use hybrid systems consisting of solar and biomass because the biomass supply should be available throughout the year in that areas [2]. In most of the remote areas the manure and crop wastes and other crop based residues are available at free of cost.

Standalone systems are intended to operate independent of electric utility. It is not being connected to main grid. Batteries are used in this system belongs to lead acid type. The main useful of this system are it requires lesser maintenance cost and as well as it is healthy as for environmental consideration. In near future the system is favouring to Distributed generation and micro grids [3].

2. HYBRID SYSTEM

Modern Hybrid systems usually incorporate renewable energy sources to provide electrical power as these sources provides backup with the help of battery bank in case of lack of primary source without interruptions. PV – Biomass power system, which is a combination of a photovoltaic array integrated with a biomass generator, is a better option for a remote area which is not connected to the grid and is a best solution to electrification of remote areas. This system consists of a PV array, a battery bank, a biomass generator and a DC/AC converter. In the design and sizing of the system, the system should be considered as an autonomous system. Such a constraint leads to an infinite number of possible system configurations.

Biomass System

Biogas is gaseous mixture of methane, carbon dioxide, hydrogen sulphides and several other gases, produced by anaerobic fermentation of organic material such as animal and human manure, leaves, twigs grasses, industrial waste etc. This energy release and allows biogas to be used as a fuel. It used in a gas engine to convert the energy in the gas into electricity and heat [1]. The biogas is produced by microorganisms in the absence of oxygen. This process is called anaerobic process.

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The main factor of choosing this type of hybrid system consist of biomass is that in remote area villages it is very easy and economically available in the form of dung of cow, buffalo, goat etc. During the cloudy day, the total electricity production can depend on the biomass. The most perspective was the building of biogas plant in a remote area and care has to be taken that, as there was located large dairy farm. It is recommended to include in feedstock, a part of manure, the different local biomass, e.g. maize, perennial grasses, waste biomass from food industry, biodegradable part of municipal wastes, aiming to increase economical viability for potential biogas projects and to provide stable and reliable biogas cogeneration plants [4].
Here in Homer Analysis we calculate only the price of generator. Raw materials cost is not included because we will collect it from our project nearby areas at free of cost. A minor transportation cost is needed which we evaluate as a maintenance and operating cost in generator [4].

PV-System
Photovoltaic is the direct conversion of light energy into electrical energy. As Solar radiation fall on the solar cell, the free electrons of solar cell capture that radiations andproduce electricity. Photovoltaics were initially used as a source of electricity for small and medium-sized applications [4]. Solar PV is rapidly becoming an inexpensive, low-carbon technology to harness renewable energy from the Sun [2].
Sizing a photovoltaic system is an important task in the system's design. In the sizing process one has to take into account three basic factors:

i. The solar radiation of the site and generally the Metrological data
ii. The daily power consumption (Wh) and types of the electric loads, and
iii. The storage system to contribute to the system's energy independence for a certain period of time.

If the PV generator is oversized it will have a big impact in the final cost and the price of the power produced and in the other hand if the PV-generator is undersized, problems might occur in meeting the power demand at any time. The amount of solar radiation at a site at any time, either it is expressed as solar intensity (W/m2) or solar radiation in MJ or Wh, is primarily required to provide answer to the amount of power produced by the PV generator. The amount of electrical energy produced by a PV-array depends primarily on the radiation at a given location and time.

3. SYSTEM DESIGN

The system was designed by calculating monthly demand of electrical energy required by a small remote area as well as power output of the bio-solar combinations. Following points were taken into account in system design [2].

- The power generated from PV and biomass generator combination has to meet the total load of the system.
- Short term electrical power storage using lead acid batteries is considered. The size of battery bank is worked out to substitute the PV array during cloudy and no-sun days.
- Life time of battery bank is considered to be 5 years. This point is important when estimating the capital costs.
- The storage battery bank will be able to supply power during a maximum of 5 days on no-sun days.
- The DC power from the PV array is converted to AC power by using system converter has life time of 15 years and efficiency of 90%.

i. Optimization Analysis of the Hybrid System
HOMER performs the optimization process in order to determine the best configuration of hybrid renewable energy System based on several combinations of equipment. Hence, multiple possible combinations of equipment could be obtained for the hybrid renewable energy system due to different size of PV array and biomass system, number of batteries and size of DC-AC converter. Each and every combination of the system configuration can be optimized by simulating it in the search space. The feasible one will be displayed at optimization result sorted based on the Total Net Present Cost (TNPC). The main feature of optimization is to know the optimized value and to meet the load and the entire load has to be supplied by the PV-biomass system for the entire year without depending on grid.

i. Modelling of PV and Biomass:

a) PV System:
In order to efficiently and economically utilize the renewable energy resources, one optimum match design sizing method is necessary. The sizing optimization method can help to guarantee the lowest investment with adequate and full use of the solar system, biomass system and battery bank, so that the hybrid system can work at optimum conditions in terms of investment and system power reliability requirement. Various optimization techniques such as the probabilistic approach, graphical construction method and iterative technique have been recommended by researchers [4].
Power output from PV array: For design of a PV system, we should know how much solar energy is received at the concern place. It is effected by sun position, could covering atmospheric affect, and the angle at which the collector is placed, called tilt angle 'β'. Normally this angle is equal to the latitude of the concern place. The related equation for estimation of the radiation is listed below [2]:
1. Isolation $i = Io \{ \cos\phi \cos\delta \cos\omega + \sin\phi \sin\delta \}$ kW/m2

2. $Io = Isc\ [1 + 0.033 \cos(360N/365)]$ where Isc solar constant. =1.37 kW/m2 3.HoA = energy falling on t

3. $H\,o = \int i dt \omega_{sr}$ = hour angle when sun rising

ω_{ss} = hour angle when sun setting
$= (24/\pi)\ I\ sc\ [1+ 0.033 \cos(360N/365)]\ \{\cos\phi \cos\delta \cos\omega + \sin\phi \sin\delta\}$ kWh/m 2 /day he concern place considering atmospheric effect = KT Ho kWh/m2/day
where KT dearness index

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4. H oA = energy falling on the concern place considering atmospheric effect = K T Ho kWh/m 2 /day where K T dearness index

5. K T = A1 + A 2 sin (t) + A 3 sin (2t) + A 4 sin (3t) +A 5 cos (t) +A 6 cos (2t) +A 7 cos (3t) t = (2π/365) (N-80) N= 1 for Jan 1 stWpeak = {1/ hpeak } [(Wh((load) * No. of no sun days / (ηb * no of discharging . Days)) + Whload(day) + Whload(night)/ ηb)]

Where: ηb = battery efficiency hpeak = no of hours for which peak insolation falls on the PV cell.[8] b

b) Biomass:

Manure output from livestock in a year will be calculated as follows:

Where,

M- Livestock (animals and crops residues) manure produced in remote area, t.

n- average number of livestock present year-round within ith group of livestock

Ni- Number of specified groups of livestock population in remote area,

mi- manure produced per one head in a year in the ith group of livestock, t,

Biogas production from manure potential was calculated as the sum of biogas volumes obtainable from manure produced by animals and crop residues in that area:

Where,

VB- biogas volume, potentially obtainable from manure biomass in parish (municipality, region) in a year, m^3,

KDMi- dry matter content in manure produced by ith group of animals

KOmi- organic matter content in dry matter of manure produced by ith group of animals VOmi- specific biogas output from manure organic matter for ith group of animals

Energy of biogas obtainable from manure biomass in municipality (region) was calculated as follows:

Where,

EB- energy potential obtainable from biogas produced from manure,

kWhebi- specific heat energy content of biogas obtained from manure produced by ith group of animals, kwh/m^3[2].

4. OPTIMIZATION SIMULATION

The optimization simulation of hybrid system is done by using HOMER software. This software is helps to find the best electricity generation system configuration which shows the appropriate technology, size and no. of equipment required. It also compares the cost and environmental impact. This model is helpful for both conventional and renewable energy system. Homer is able to evaluate economics and technical feasibility of the system. First, Homer simulates the working power system by calculating the hourly energy balance for a year. Hour by hour, Homer determines the electric demand of the site and the local electricity supplied by the system. Comparing these energy flows, Homer is able to estimate if the configuration is feasible that is to say if the system can satisfy the electricity requirements. Then, Homer optimizes the results. Among the possible configurations defined by the simulation, Homer retains the most cost-effective in a table ranked by Net Present Costs (NPC). Homer can realize a sensitivity analysis by modifying some inputs in a range defined by the user in order to compare different possible scenarios.

Arrangement of source and load

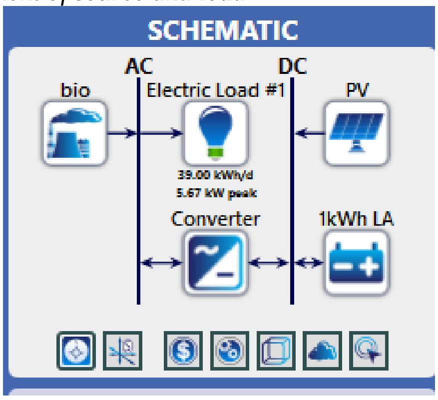

Fig. 1: Basic design of load and sources in homer

The main feature of simulation in Homer is selecting the suitable sizes of the sources to meet the daily load curve pattern of the system. As shown in "Fig. 1" the load is having an average load of 39.00kwh/day and the peak load is 5.67kw. Hence the size of the PV, biomass generator, battery and converter are matched with the load patterns.

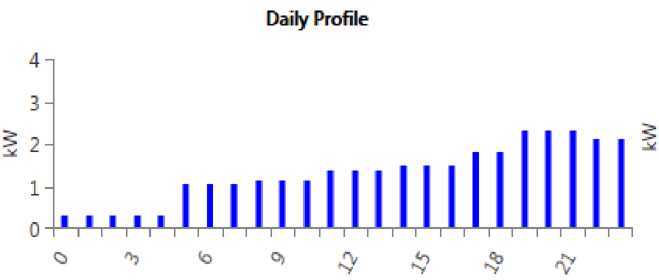

Fig. 2: Daily load profile

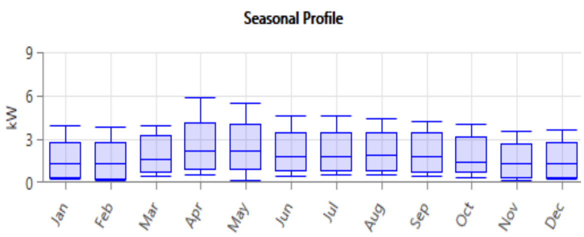

Fig. 3: Monthly load profile

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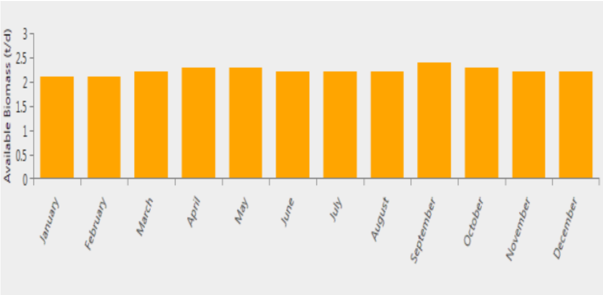

Fig. 4: Monthly average available biomass resource

The main feature of the Homer software is it will gives the availability of solar radiation once the area latitude and longitude has given. Once the solar power source is available for load pattern, then schedule of the solar power is available and at what time periods the solar PV will works also available.

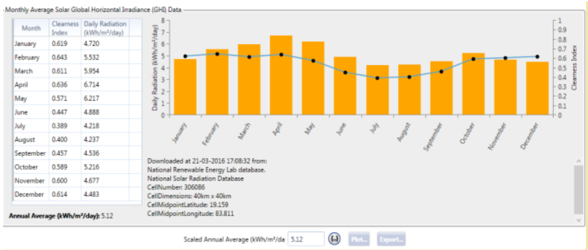

Fig.5: Monthly average solar resource

Production	kWh/yr	%
Generic flat plate PV	9,478	52.17
biomass generator	8,690	47.83
Total	18,168	100.00

Consumption	kWh/yr	%
AC Primary Load	14,235	100.00
DC Primary Load	0	0.00
Total	14,235	100.00

Fig. 6: Production and consumption of power

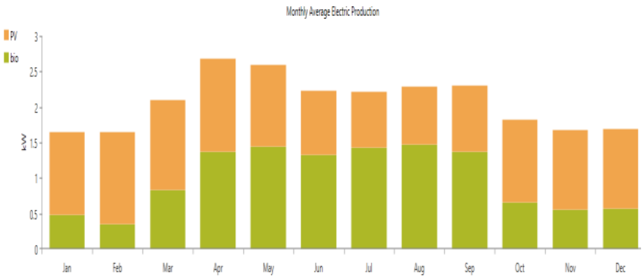

Fig. 7: Yearly share of PV-SOLAR system

This is the combined output power of both bio-generator and solar-pv.

By observing "Fig. 6 & 7" the load met by PV array has 9.478 kwh/year and biomass is 8.690 kwh/yr. In other words the percentage shared by PV array is 52.17% and by biomass is 47.83%. Care should be taken that the dependence on PV array should be more and biomass will be less. Because initially the PV array is high, the operation and maintenance cost of PV array for the life span of 25 years will be almost nil except the change of batteries for every 5 years. In case of biomass generator the initial cost of the generator is less, but every day procuring the 2.23 tons of biomass feed and the maintenance and operation of biomass for the 25 years will be more.

Quantity	Value	Units
Total fuel consumed	3,249.50	L
Avg fuel per day	8.90	L/day
Avg fuel per hour	0.37	L/hour

Fig. 8: Fuel consumption

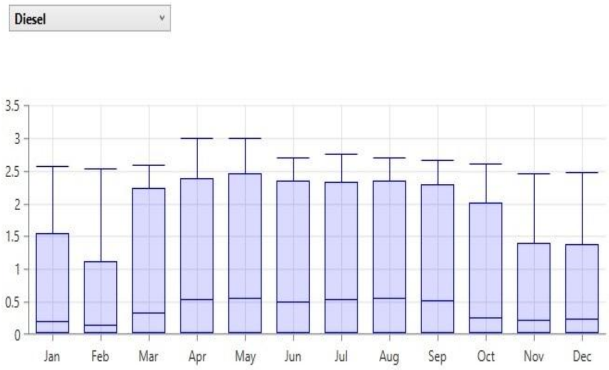

Fig. 9: Monthly fuel curve

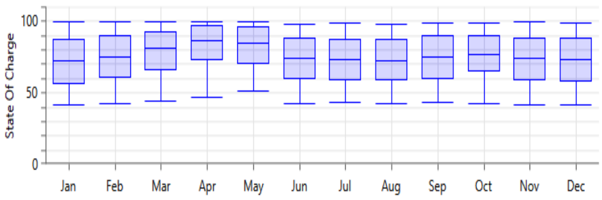

Fig. 10: Monthly charging of battery

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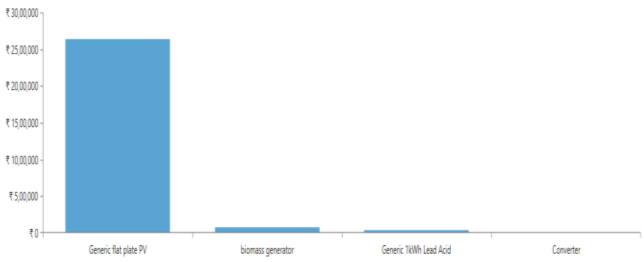
Quantity	Value	Units
Carbon Dioxide	8,557.10	kg/yr
Carbon Monoxide	21.12	kg/yr
Unburned Hydrocarbons	2.34	kg/yr
Particulate Matter	1.59	kg/yr
Sulfur Dioxide	17.18	kg/yr
Nitrogen Oxides	188.47	kg/yr

Fig. 11: Emission of gases



Component	Capital (₹)	Replacement (₹)	O&M (₹)	Fuel (₹)	Salvage (₹)	Total (₹)
Generic flat plate PV	₹26,40,000.00	₹0.00	₹3,068.00	₹0.00	₹0.00	₹26,43,068.00
biomass generator	₹20,000.00	₹15,184.00	₹6,797.30	₹41,540.00	₹-1,346.20	₹82,175.00
Generic 1kWh Lead Acid	₹16,800.00	₹24,130.00	₹0.00	₹0.00	₹-1,177.60	₹39,752.00
Converter	₹889.33	₹371.09	₹0.00	₹0.00	₹-69.07	₹1,191.30
System	₹26,77,689.00	₹39,685.00	₹9,865.30	₹41,540.00	₹-2,592.90	₹27,66,186.00

Fig. 12: explain total cost analysis and cash flow of entire system.

5. CONCLUSION

The results obtained by using Homer software can be very reliable and gives very efficient results for Hybrid systems. The main feature of this software is, it will integrate the local climatic conditions and hence planning of energy model is simpler. In this paper the analysis has been given for systematic procedure towards to plan a PV-Biomass based hybrid system and its Economic analysis including calculation of percentage savings, payback period analysis. It will give the best solution to remote areas which are not accessible to the grid. Initially these schemes may be costly but, the frequent usage of such schemes and wide acceptance of the technology can able to decrease the cost of such schemes.

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