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Design of Standalone Hybrid Biomass & PV System of an Off-Grid House in a Remote Area

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ABSTRACT
The use of renewable energy sources is becoming very necessary due to the limited reserves of fossil fuels and global environmental concerns for the production of electrical power generation and utilization. In remote areas, villages, it is easy to get more amount biomass. Hence by the use of hybrid systems consisting of Biomass and PV for production of electrical energy in these remote areas can be more economical. If the development of a computer-based approach for evaluating, the general performance of standalone hybrid PV- Biomass generating systems are analyzed ,then these results are useful for developing and installing hybrid systems in remote areas
This paper focuses the economical consideration of standalone hybrid systems having PV and Biomass for electrical production in remote areas. Also in this paper a simulation approach has been suggested for designing stand alone grid for remote areas. The average solar radiation and quantity of biomass required data are to predict the general performance of the generating system. The batteries can also be used in this system to store the extra energy which can further be used for backup. Also the extra power is used to supply to the grid. Here the simulation is carried out using HOMER software. The results and analysis can used to improve the development of the proposed model.
Keywords **–** Biomass, Hybrid system, Homer software, Micro grid, PV array

I. INTRODUCTION

Many villages in the world live in isolated areas far from the main utility grid. It is really impossible their meet by the conventional sources because of the high cost of transport and the distribution of energy to this remote areas [1]. Currently, the electric provisioning of these sectors is done by the hybrid systems of production of electricity whose diesel generator plays a significant role like auxiliary source [2]. These hybrid systems involve combination of different energy sources with wind, PV, mini hydro, Biomass, fuel cells etc.,

It was shown that the hybrid systems of energy can in a significant way reduce the total cost of energy produced, while providing a more reliable provisioning of electricity by the combination of Electrical energy plays crucial factor in development of economical and technological of present society. Every year the demand of electrical energy is grow rapidly throughout the world. In India it is very difficult and also uneconomical to transmit power over long distances through transmission lines for special remote villages. Also 70% of its population is live in rural areas. Generally the production of electrical energy generally depends on fossil fuels. As a result it increases CO2 emissions, which are not healthy for environment concern [2]. So as to reduce emissions of CO2 and also to meet the growing needs for generation of electricity we should adopt the renewable energy by using hybrid systems. Renewable energy based technology for production of electricity is suitable to remote and rural areas. So the use of standalone Hybrid systems using Renewable energy for production of electricity is more economical in remote areas[4]. 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 once the biomass supply should be available throughout the year. 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. Generally such type of systems supports to the distributed generation and connected to micro grids. In near future the system is favoring to Distributed generation and micro grids.

II. HYBRID SYSTEMS

A 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, where extension of national grid is not a cost effective option. The system which is analyzing consists of a PV array, a battery bank, a biomass generator, a charge controller 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.

A. PV System:

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 insolation 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

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, the PV-generator is undersized, problems might occur in meeting the power demand at any time. The sizing should be carefully planned, examining various possible PV system configurations and various models of components in order to get a cost effective and reliable system [3].

The amount of solar radiation at a site at any time, either it is expressed as solar intensity (W/m2) or solar insolation or 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 insolation at a given location and time. Data on solar insolation are usually given in the form of global radiation that is beam, direct and diffuse radiation over a horizontal surface.

B. Biomass power:

Biomass is the amount of living matter in a given habitat, expressed either as the weight of organisms per unit area. Biogas is a mixture of gases, generally carbon dioxide and methane. It is produced by microorganisms, especially in the absence of oxygen. This process is called anaerobic process. Biogas also can develop at the bottom of lakes where decaying organic matter builds up under wet and anaerobic conditions. And a biodiesel is made from vegetable oils and animal fats.

The main factor of choosing this type of hybrid system consist of biomass is that in remote area villages it is easily 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. Rest of the needed feedstock for this cogeneration plant is provided by plant biomass, e.g. cereals, perennial grasses, maize, other energy crops or biomass from unused agricultural areas. It is recommended to include in feedstock, a part of manure, the different local biomass, e.g. maize, perennial grasses and legumes, straw, reed, waste biomass from food industry, biodegradable part of municipal wastes, aiming to increase economical viability for potential biogas projects and to provide stable round year running of biogas cogeneration plants.

III. SYSTEM DESIGN

The system was designed by calculating monthly demand of electrical energy required by a small community in remote area as well as power output of the different solar PV-wind turbine generator combinations. Following points were taken into account in system design [2, 3]:

- The power generated from PV and biomass combination has to meet the total load of the system. Energy required for water heating of the community is provided by the solar water heater.
- 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 AC power from the inverter of the system is fed to the distribution network of the community.

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 equipments. Hence, multiple possible combinations of equipments 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[6].

ii. Modeling 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[7]. Various optimization techniques such as the probabilistic approach, graphical construction method and iterative technique have been recommended by researchers.

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:

1. Isolation
   $i = Io \{ \cos\phi \cos\delta \cos\omega + \sin\phi \sin\delta \}$ kW/m^2
2. $I_o = I_{sc} [1 + 0.033 \cos(360N/365)]$ where I_{sc} solar constant. =1.37 kW/m^2
3. H_{oA} = energy falling on t 3. $H_o = \int i\, dt$ ω_{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
   $= K_T H_o$ kWh/m^2/day where K_T dearness index
4. H_{oA} = energy falling on the concern place considering atmospheric effect
   $= K_T H_o$ kWh/m^2/day where K_T dearness index
5. $K_T = A1 + A_2 \sin(t) + A_3 \sin(2t) + A_4 \sin(3t) + A_5 \cos(t) + A_6 \cos(2t) + A_7 \cos(3t)$
   $t = (2\pi/365)(N-80)$ N= 1 for Jan 1st

$W_{peak} = \{1/ h_{peak}\} [(Wh((load) * \text{No. of no sun days} / (\eta_b * \text{no of discharging . Days})) + Wh_{load}(day) + Wh_{load}(night)/ \eta_b)]$

Where: η_b = battery efficiency

h_{peak} = no of hours for which peak insolation falls on the PV cell.[8]

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

$$M = \sum_{n=1}^{i} N_i m_i$$

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

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

m_i- 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:

$$V_B = \sum_{n=1}^{i} N_i . m_i . K_{DMi} . K_{OMi} . V_{Bi}$$

Where,

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

K_{DMi}- dry matter content in manure produced by ith group of animals

K_{Omi}- organic matter content in dry matter of manure produced by ith group of animals

V_{Omi}- 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:

$$E_B = \sum_{n=1}^{i} N_i . m_i . K_{DMi} . K_{OMi} . V_{Bi} . e_{bi}$$

Where,

E_B- energy potential obtainable from biogas produced from manure, kWh

e_{bi}- specific heat energy content of biogas obtained from manure produced by ith group of animals, kwh/m^3[3,10].

IV. SIMULATION WITH HOMER SOFTWARE

Homer is an abbreviation of "Hybrid Optimization Model for Electric Renewables." It is a micro power optimization model developed and regularly improved by the American National Renewable Energy Laboratory. This software helps to find the best electricity generation system configuration that is to say the appropriated technologies, the size and number of each component, also comparing costs and environmental impacts. It models both conventional and renewable energy technologies in particular solar photovoltaic and wind turbines which are the options envisaged for energy efficient technologies. 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 [11]

i. Arrangement of sources and load

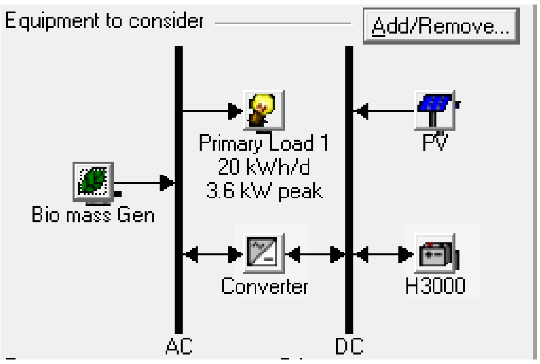

Fig.1: Basic setting of loads and sources in Homer

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 20kwh/day and the peak load is 3.6kw. Hence the size of the PV, biomass generator, battery and converter are matched with the load patterns.

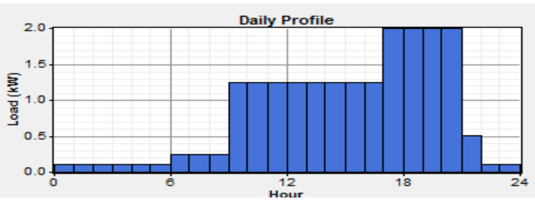

Fig. 2: Daily load profile

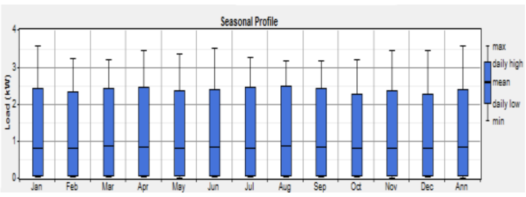

Fig. 3: Monthly load profile

The "fig.2 and 3" shows the daily and yearly load curve of the consumer. Once the load profile has uploaded in to the Homer software, the software simulates according the availability of the solar power. But it will depend on the availability of solar power in a given area.

The main feature of the Homer software is it will gives the availability of solar insolation once the area latitude and longitude has given as shown in the "fig.4". 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. The remaining time periods the biomass generator has to be operated.

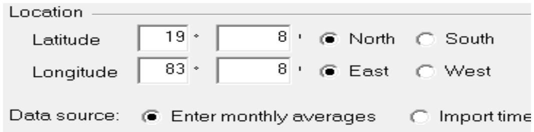

Fig. 4: Solar location data entry

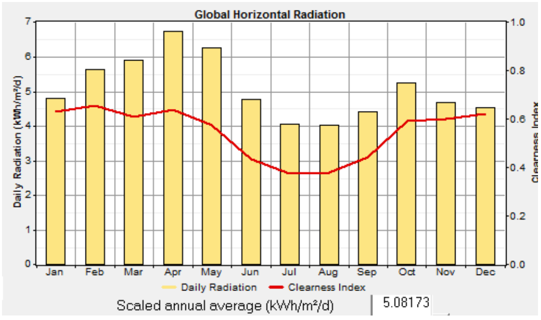

Fig. 5: Solar yearly radiation

Production	kWh/yr	%
PV array	6,292	62
Bio mass Gen	3,845	38
Total	10,136	100

Fig. 6: Percentage share of PV-Biomass

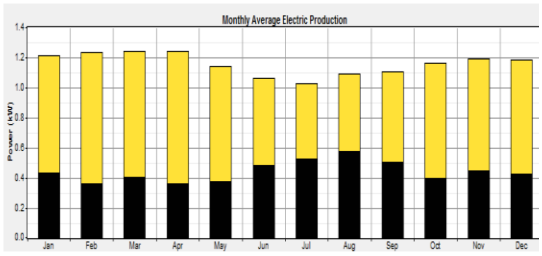

Fig.7: Yearly share of PV-Biomass

By observing "Fig.6 & 7" the load met by PV array has 6,292 kwh/year and biomass is 3,845 kwh/yr. In other words the percentage shared by PV array is 62 and by biomass is 38%. The care should be taken that the dependence on PV array should be more and biomass will be less. Because initially the PV array cost is high but, 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 0. 250 tons of biomass feed and the maintenance and operation of biomass for the 25 years will be more.

The initial cost of the PV and biomass is around 900,000 Rs/- and the total no. of units generated from the system is 10,136 kwh/year and the commercial rate of one unit is 7Rs/-. Hence the payback period is comes around 12 years. But, considering the subsidies of the government of about 50%, the payback period will reduces to 6 years. The prices of PV panels and other auxiliary system prices are also decreasing considerably.

V. CONCLUSION

The results obtained by using Homer software can be very realistic and gives very promising 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 complete 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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