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Design of Off-Grid Home with SOLAR-WIND-BIOMASS Energy

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ABSTRACT
Due to the limited reserves of fossil fuels and global environmental concerns for the production of electrical power generation and utilization, it is very necessary to use renewable energy sources. By use of hybrid systems we can implement renewable energy sources which are very economical for remote villages, homes etc. In particular, rapid advances in wind-turbine generator ,biomass generator and photovoltaic technologies have brought opportunities for the utilization of wind and solar resources for electric power generation world-wide .So by the use of hybrid systems consisting of Biomass ,PV and also wind 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-wind generating systems are analyzed ,then these results are useful for developing and installing hybrid systems in remote areas This paper focuses the economical consideration and simulation approach for a standalone hybrid systems having PV, wind and Biomass for electrical production in remote areas. In this paper we are taken the average solar radiation, quantity of biomass, average wind speed for the remote area for prediction of general performance of the generating system. Simulation studies were carried out using HOMER software Simulation results will be given for performance evaluation of a stand-alone hybrid wind-PV generating unit for a residential house which is to be located in a remote area . The system is a off grid one. Finally, the results obtained and methods are suggested to enhance the performance of the proposed model

***Keywords* -** Biomass, Hybrid system, Homer software, Micro grid, PV array, Wind generator

I. INTRODUCTION

Energy plays a crucial factor in technological and economic development of present society. It has always been the key to man's greatest dream of a better world. But now also 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]. For this only now new implementation is going on hybrid systems consisting of renewable energy sources .These hybrid systems involve combination of different energy sources with wind, PV, mini hydro, Biomass, fuel cells etc.

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]. To reduce the emissions of CO_2 and green house gas effects & improvement of quality of life renewable energy is very much useful for environment as well as to develop the economy of a country .While many of the renewable energy projects are of large scale, renewable technologies are also suited to rural and remote areas, where there is often crucial in human development. To develop the electrification in rural areas or remote area house, it is very expensive to extend the power lines form centralized sources to rural areas.

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, wind and biomass.

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. [3]

II. HYBRID SYSTEMS

A PV –wind- Biomass power system, which is a combination of a photovoltaic array integrated with a wind generator and 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, wind generator, a battery bank, a biomass generator, a charge controller and a DC/AC converter. It is a autonomous system.

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 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

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 [3]

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.

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.

C. Wind energy:

Wind energy sources have the potential to significantly reduce fuel costs, greenhouse gas emissions, and natural habitat disturbances associated with conventional energy generation. Wind turbine generators (WTGs) are an ideal choice in developing countries where the most urgent need is to supply basic electricity in rural or isolated areas without any power infrastructure. Wind energy has become competitive with conventional forms of energy. Power system deregulation has opened opportunities for many private energy producers. Wind energy is a potential choice for smaller energy producers due to relatively short installation times, easy operating procedures, and different available incentives for investment in wind energy [7].

III. 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 different solar PV-wind turbine generator combinations. Following points were taken into account in system design [2, 3]:

- The power generated from PV, wind generator and biomass 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 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 and wind generator 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.

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) * No. of no sun days / (η_b * no of discharging . Days)) + Wh_{load}(day) + Wh_{load}(night)/ η_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].

c) Wind Speed :

A good expression that is often recommended to model the behavior of the wind speed is Weibull PDF (Probability Density Function), as shown next

$$f = (v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} exp\left[-\left(\frac{v}{c}\right)^{k}\right] \qquad - (1).$$

Where '*k*' is shape index that is adjusted to match the wind speed profile of a site which is under study. While *c* is the scale index that is calculated based on the annual mean wind speed that is not constant from one year to another. This means that these two factors are calculated based on data that exhibit great mount of uncertainty. This fact indicates a significant level of error associated with this method since the shape of the We bull PDF is highly sensitive to the variation of these two indexes. Yet, the methodology proposed to estimate the annual wind speed profile is based on two steps utilizing three years of historical data. The first step is to divide the data into clusters. While in the second step, a constrained Grey predictor will be utilized to estimate the wind speed profile.

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]

Arrangement of sources and load

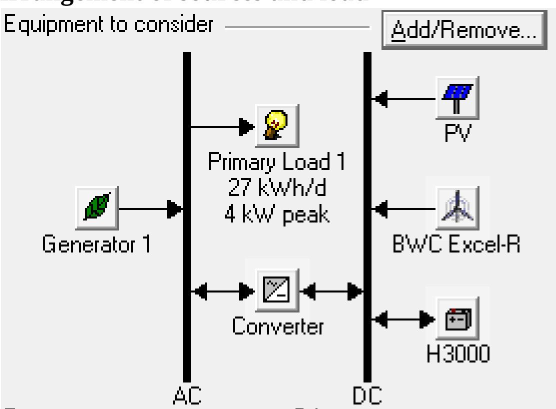

Fig.1: Basic setting of loads and sources in Homer

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 26.6kwh/day and the peak load is 3.98kw. Hence the size of the PV, wind generator, biomass generator, battery and converter are matched with the load patterns.

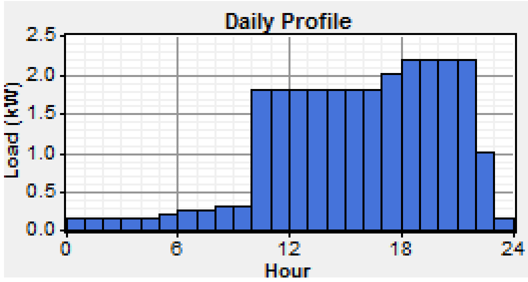

Fig. 2: Daily load profile

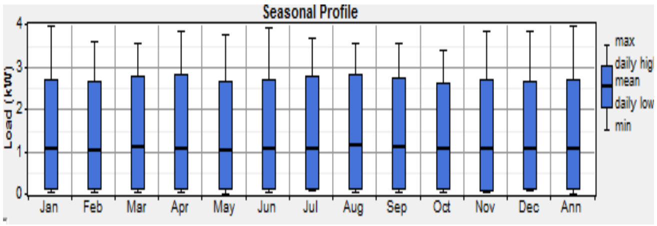

Fig. 3: Monthly load profile

The "fig.2 and 3" shows the daily and yearly load curve of the consumer.

The main feature of the Homer software is it will gives the availability of solar radiation 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.

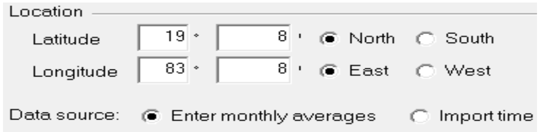

Fig. 4: Solar location data entry

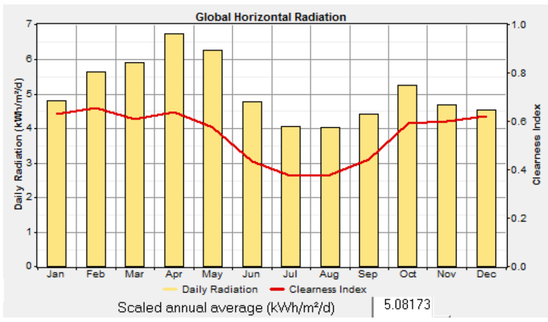

Fig. 5: Solar yearly radiation

Similarly wind speed resources is shown in the fig 6

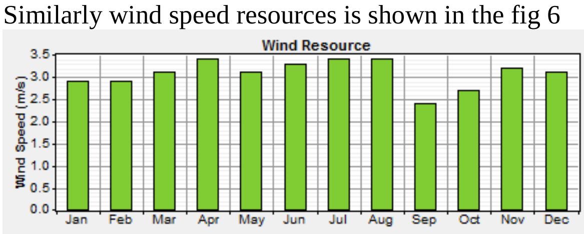

Fig. 6: Wind speed resources

Production	kWh/yr	%
PV array	6,294	46
Wind turbine	2,872	21
Generator 1	4,661	34
Total	13,827	100

Fig. 7: Percentage share of PV-wind gen-Biomass

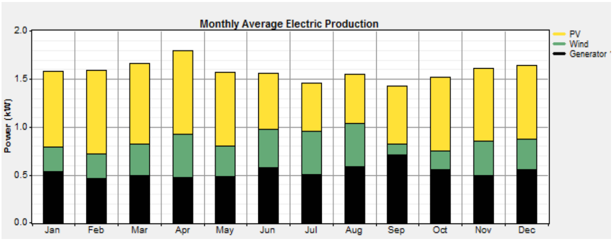

Fig. 8: Yearly share of PV-Wind –Biomass

By observing “Fig.7 & 8” the load met by PV array has 6,292 kwh/year , wind turbine has 2,872 kwh/yr and biomass is 4,661 kwh/yr. In other words the percentage shared by PV array is 46%, wind turbine has 21% and by biomass is 34% care should be taken that the dependence on PV array and wind turbine should be more and biomass will be less. Because initially the PV array and wind turbine 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.

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	8,000	8,000	25	0	-6,000	10,025
BWC Excel-R	20,000	20,000	125	0	-6,667	33,458
Generator 1	3,500	7,000	22,275	0	-105	32,670
Hoppecke 24 OPzS 300	300	1,500	0	0	-221	1,579
Converter	1,500	1,000	0	0	-333	2,167
Other	0	0	1	0	0	1
System	33,300	37,500	22,426	0	-13,326	79,900

Fig. 9: Cost analysis of total hybrid system

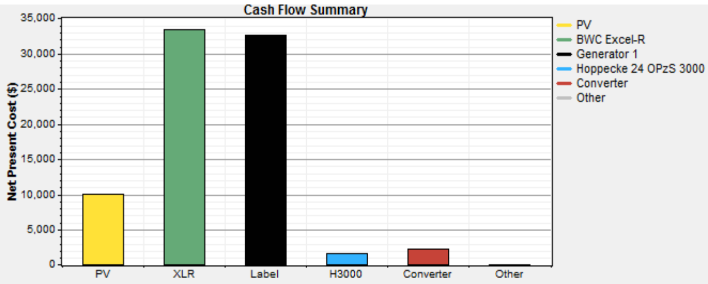

Fig. 10: Cash flow summary of total system

Fig : 9 & 10 explain total cost analysis and cash flow of entire system

Again due to cloud or rainy day we may unable to get solar radiation, so at that time we can use wind , biomass to produce electricity. Here fig 11 & 12 show the production of electricity doe to only wind and biomass.

Production	kWh/yr	%
Wind turbine	2,872	25
Generator 1	8,532	75
Total	11,405	100

Fig. 11: Percentage share of wind – biomass

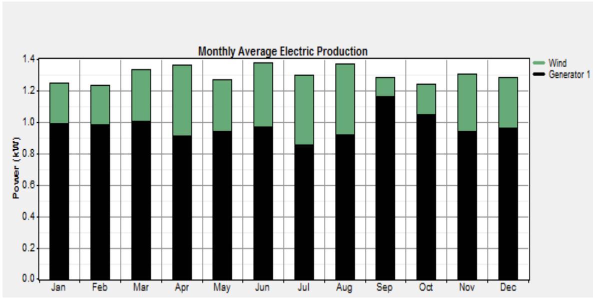

Fig. 12 : Yearly share of PV-Wind –Biomass

For this hybrid systems initial cost is high but operting cost is low. After use of minimum 12 years all the expenditure for this project is recovered.

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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