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# Techno-Economic Feasibility Analysis of a Hybrid Solar Photo Voltaic/WT Connected Micro Grid fora Rural Area

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***Abstract:*** *This paper focuses on the economical feasibility of hybrid power system for rural area application in India .It is modeled by considering metrological data for a rural area of Madhya Pradesh Chitrakoot District at MGCGV ( 25° 09'22.20''N81°07'.99''E) . Thus the proposed standalone hybrid power system includes PV panels, Wind Turbine, Power Converter & Battery for storage. Analysis was carried out by connecting a load with daily energy consumption of effective 11.27Kwh/day for max demand of 2.39KW. The metrological data of the site was extracted from National Aeronautics and Space Administration (NASA) and National Renewable Energy Lab (NREL).The simulated results shows economical combination and sizing of components which leads us to the sensitivity analysis to get a better understanding of which model is feasible from both efficiency and economy point of view for the proposed region.*

***Keywords:*** *PV, Wind Turbine, Diesel, Battery, Economical Analysis, HOMER Pro. Generic freewheel battery*

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## I. Introduction

As energy demand around the world increases, the need for renewable energy sources that will not harm the environment has started to increase. Some projections indicate that the global energy demand will almost triple by 2050.Renewable energy sources currently supply somewhere between 15% to 20% of the total world energy demand.PV and Wind Energy System (WES) are the most promising as future energy technology.The use of this energy is going to reduce CO2 emission by 25%.

With their advantage of being abundant in nature and nearly non pollutant renewable energy sources have attracted worldwide attention. Wind power is one of the most promising clean energy sources since it can easily be captured by wind generators with high power capacity. Photovoltaic (PV) power is another promising clean energy source since it is global and can be harnessed without using rotational generators. In fact ,the wind power and PV Power are complementary to some extent since strong winds occur during the night time and cloudy days whereas sunny days are often calm with weak winds .The economic aspects of these renewable energy technologies are adequately promising at present to include the development of their market [1-3]. Hence Wind –PV Hybrid generation system can offer higher reliability to maintain continuous power output than any other individual power generation system[4].

Several design scenarios have been proposed to design Integrated Renewable Energy Systems, [5-11] where a combination of wind, solar and in some cases other renewable resources have been used.

The aim of this paper is to design a hybrid power system model with metrological data inputs, also to describe feasible technology, component costs based on the availability of resources. The data considered as inputs is used to simulate different system configurations, or combinations of components, and generates results which are viewed as a list of feasible configurations sorted by net present cost[12]. This paper proposes a simulated model of a hybrid power system composed economic combination of PV and WT, Converter and battery storage. [14,15]. The simulated results using HOMER gives the comparative economic analysis with each configuration and evaluates the best configuration. This is understood through the results presented in this paper. Thus HOMER is advantageous in performing energy balance configuration for each hour to choose whether configuration is feasible or not. For the same feasible combination the total cost of operation is estimated over the life time of the project at a particular area before installation [16].

This study was carried with the help of Hybrid Optimization Model for electrical Renewable (HOMER) ,which is most widely ,freely available and user friendly software. The software is found suitable for carrying out prefeasibility, optimization and sensitivity analysis in several possible system configurations.

In the analysis ,a detailed assessment of load ,site layout and available resources for the selected building at MGCGV was conducted. This was carried out outside Homer environment and data is fed into the software. In the HOMER analysis the hybrid RET system is designed ,along with by a techno-economic analysis. It compares a large range of equipment's with different constraints and sensitivities to technical properties of the system and life –cycle cost (LCC) of the system. The LCCis the comparison of the initial capital cost ,cost of installation followed by operation costs over the systems life span. HOMER performs simulations to satisfy the given demand using alternative technology options and resource availability .Based on the simulation results the best suited configuration was selected . The rest of the paper is as follows. Section II focuses on the system model .Methodology has been described in Section III.Simulation model is given in section IV and optimization results are evaluated in Section V. Finally, conclusions were drawn and provided in Section VI.

## II. System Description

For this paper, Hybrid power system model has been designed using HOMER to calculate and determine the cost. HOMER simulation software requires some input data evaluate the optimization results for the different combinations which are described in the next section [17].

### *A. Load Profile*

In this paper the load profile considered average energy demand by the proposed area and it is considered to be 11.27k Wh/day the peak demand which determines the size of the system, where 2.39kW is considered as the peak load consumption. The scaled annual average (kWh/d) is assumed to be 11.27 kWh/ day .

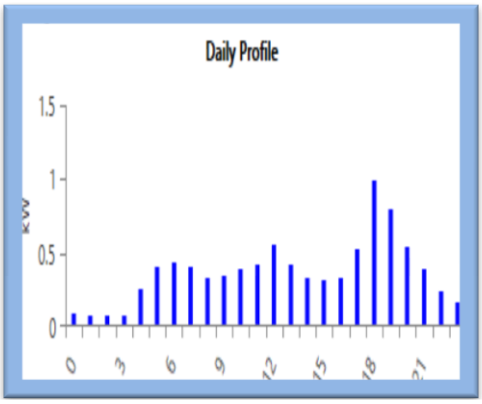


**Figure 1.** Load profile (daily).

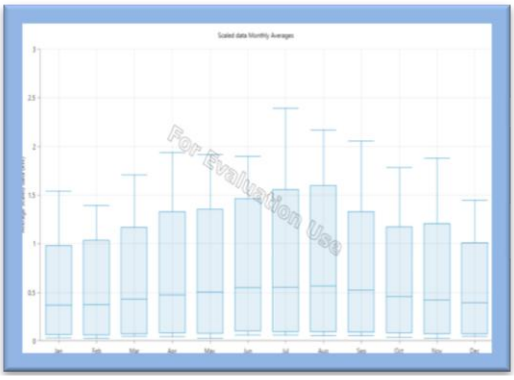


**Figure 2.**Load for a complete year (monthly average)

### *B. Wind Speed and Solar Radiation*

The data of wind speed and solar radiation was obtained from NASA surface metrology and solar energy data base. Wind speed data is obtained at a height of 50m above the surface of sea level for the location of Chitrakoot Madhya Pradesh [18] as shown in Figure 3.The figure shows that the wind speed ranges from 4.26 to 4.37m/s. The highest wind speed recorded was in June .Monthly average solar radiation data is shown in Figure 4. As used in HOMER software, the latitude and longitude of Chitrakoot District are25° 09'22.20''N81° 07'.99''E,respectively .The annual average solar radiation is estimated to be 4.94kWh/m2/day[18].

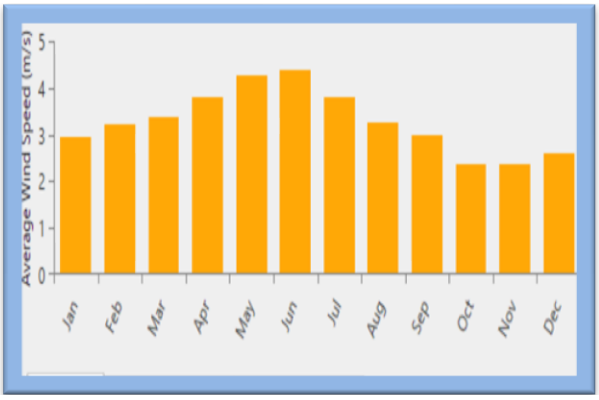


**Figure3**.Wind Speed (monthly average)

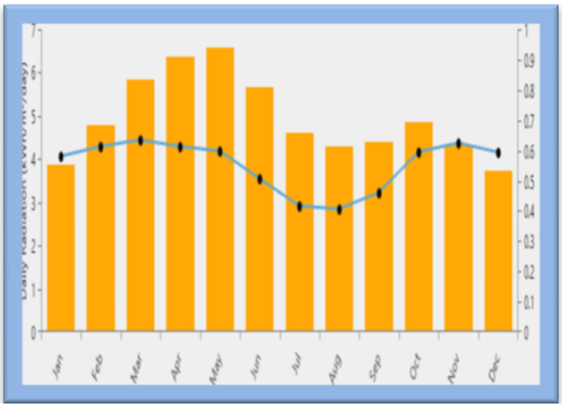

**Figure4.** Solar radiation and clearness Index(monthly average)

## III. Methodology

### *A. HOMER Software*

National Renewable Energy Laboratory (NREL) of the United States(USA) developed HOMER software [18].It is basically used for design and analysis of hybrid system. In this paper ,electrical load ,wind speed and solar radiation data ,component details and costs are provided as input information to HOMER.

### *B. Cost Analysis Procedure by HOMER [18,19,20]*

**1)*Net present cost* (NPC):**NPC is the installation cost and the operating cost of the system throughout its lifetime which is calculated as follows[20]:

NPC=TAC/CRF(i, Rprj)

Where, TAC, CRF, i and Rprj are the total annualized cost($),capital recovery factor ,interest rate in percentage ,and project
life time in year ,respectively.

**2)*Total annualized cost*:** It is the sum of annualized costs of every equipment of the power system including capital, operation and maintenance cost. It also includes replacement and fuel cost [20].

**3)*Capital recovery factor***: It is a ratio which is used to calculate the present value of a series of equal annual cash flow[20].

$$\text{CRF}=\frac{i\times(1+i)^{n}}{(1+i)^{n-1}}$$

Where ,n and i represents the number of years and the annual real interest rate, respectively.

**4)*Annual real interest rate***: It is a function of the annual nominal rate given as:

$$i=\frac{i^{'}-F}{1+F}$$

**5)*Cost of Energy*(COE)**: It is the average cost /KWh of useful electrical energy produced by the system.The COE is calculated as follows[20];

$$\text{COE}=\frac{\text{TAV}}{\text{LprimAC}\ +\text{LprimDC}}$$

Where ,LprimAC and Lprim DC are the AC primary load and the DC primary load ,respectively.

## IV. Simulation Model

The components where chosen from HOMER for the simulation to be performed .Figure 5 Shows the hybrid power system design connected using HOMER which contains a PV array, Wind Generator, Converter, load and battery .
To optimize the system performance in diverse situations. HOMER simulates the above arrangements at the same area and same load based on different costs such as the estimated installation cost ,operation and maintenance cost ,replacement cost ,interest and cost of energy.
The key components of the grid connected hybrid system are wind turbine, PV array, battery bank ,and a power converter .For economic analysis the following values are used:

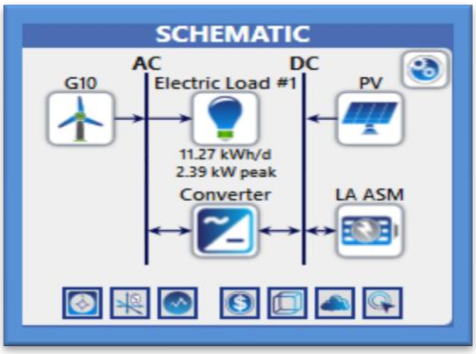


**Figure.5**.The arrangement of hybrid power system

*a.* ***Solar PV Panels*****:** The capital cost of 1KW is considered to be Rs. 50,000. Replacement, operation and maintenance cost are assumed as Rs. 40000 and 10.Rs/yr respectively. Further it is assumed that sizes of PV array (1KW, 4KW, 8KW & 10KW) to find optimal size through simulation in HOMER. Life time of a PV array is considered as 25 years with a derating factor of 80%[22]

*b.* ***Wind Turbine*****:** The wind turbine included in simulation model is manufactured by Ennera Energy and Mobility S.L with rated capacity of 10KW and an Alternating Current (AC) output of 220V. This is connected to AC bus to serve the connected load. The capital cost of 1KW unit is considered as Rs.25000. Replacement, operation and maintenance is considered as 20000Rs/yr and 120Rs/yr respectively. The optimum value is obtained through HOMER. The life time of wind turbine is considered to be 20 years. As the wind varies with altitude, hub height can also be taken as major factor which influences generating power, the hub height, 12.5m is given as the sensitivity value[23].

*c.* ***Battery*****:**To improve the efficiency of system by reducing capacity shortage factor, energy storage is required. Lead acid (LA) batteries of 1KWH LA is considered for economic analysis of the proposed model. The capital cost of one battery is assumed as Rs.1000. Replacement, operation and maintenance cost are assumed as 900Rs/yr and 10Rs/yr respectively. HOMER select optimum configuration of number of batteries for the hybrid system[23].

*d.* ***Converter*****:**The flow of Energy between AC and DC buses should be maintained by a power converter. Hence, for 1KW converter, the capital cost is to be Rs. 1000. Replacement, operation and maintenance cost are assumed as 900Rs/yr and 10Rs/yr respectively. Life time of converter is to be 15years.

Considering the availability of renewable energy sources in the proposed area, wind and solar energy are used to design the hybrid power system. A battery energy storage is used to support the system in its off grid mode.

## V. Optimization Results

In Figure 7 the optimized result for the hybrid power model is shown. For the connected system as shown in fig.7 ,the minimum COE obtained from the simulated result is Rs.6.32 .In this scenario ,the percentage of renewable energy contribution is 100%.
n the proposed model, an optimum number of renewable energy sources is activated and supplies electricity to the load. The NPC for system is Rs 3,35,890.
From Fig.9 it can be seen that the total yearly production of the proposed hybrid model is7376kw/yr and consumption by the load is 4110 kWh/yr. The remaining energy so generated can be sold to the grid. The monthly average electricity production from different units using the proposed model is showninFigure.6

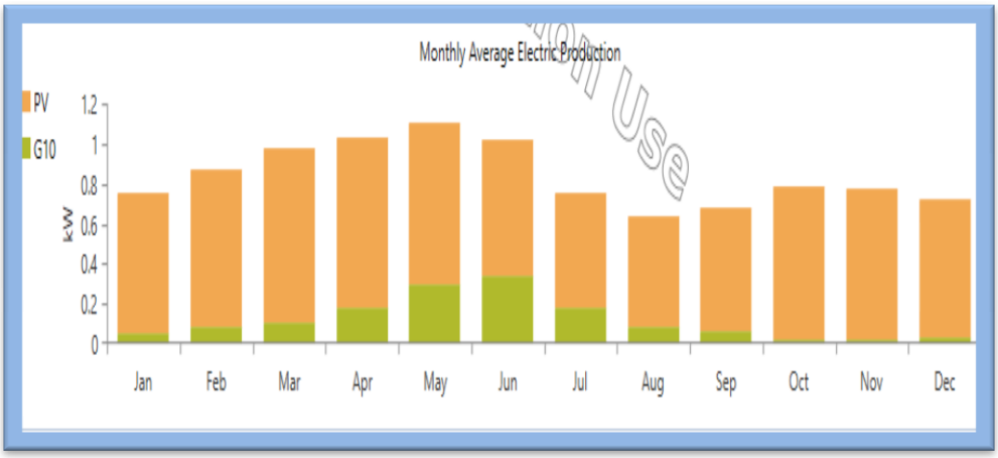


**Figure.6**.Monthly average electricity production using the proposed model

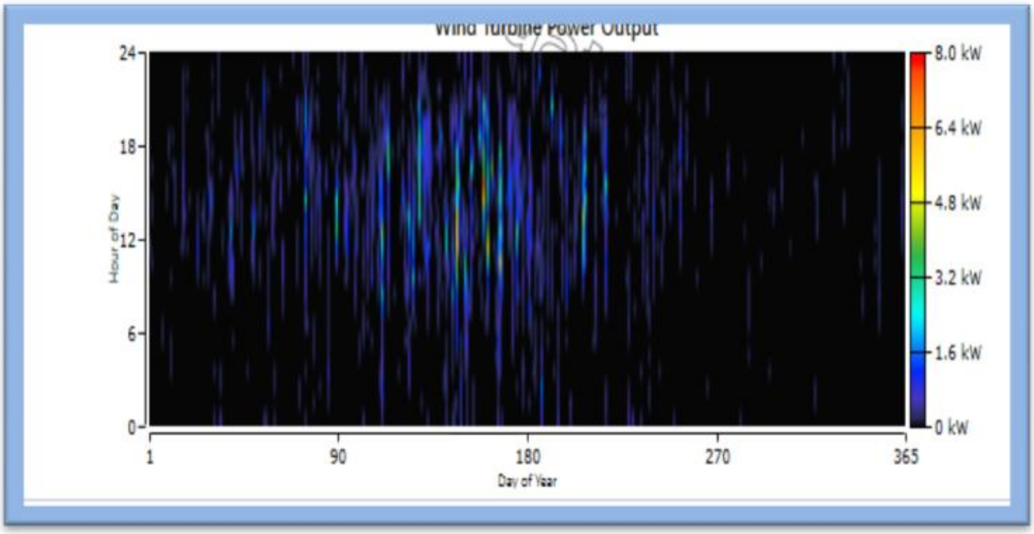


**Figure.7**.Simulation Result of the Wind Turbine for a year

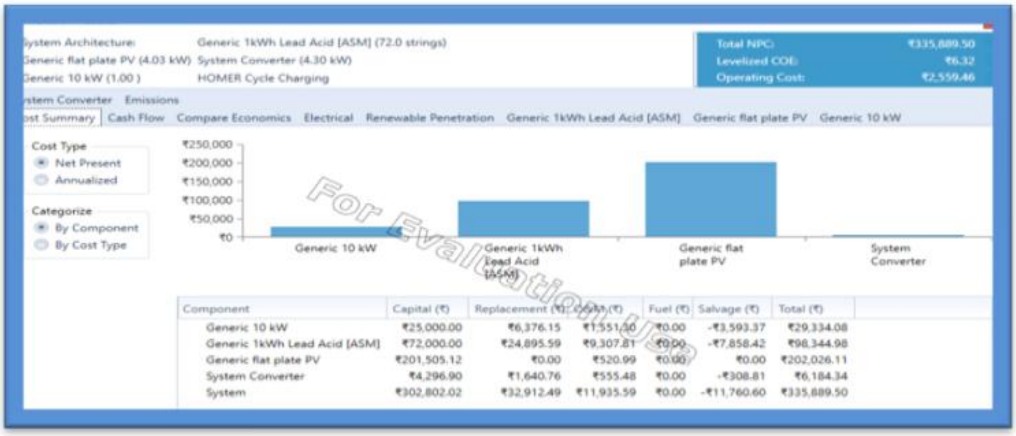


**Figure.8.**Snapshot of the production and consumption scenario

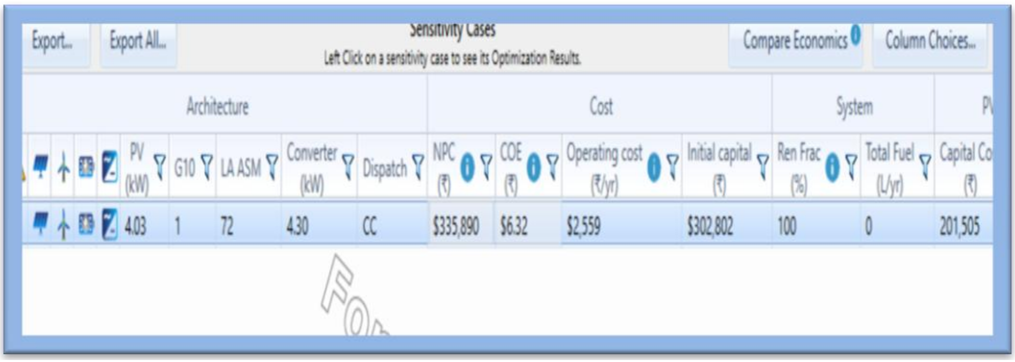


**Figure.9.** Screenshot of simulation for finding optimal design

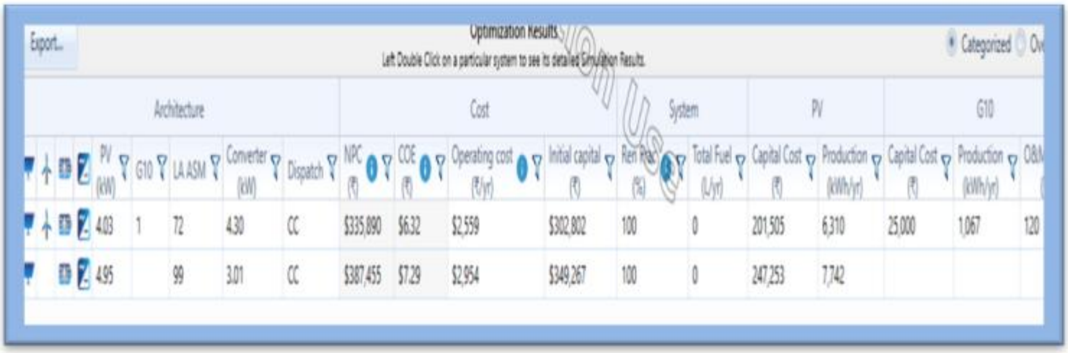


**Figure.10.** Screenshot of optimization result

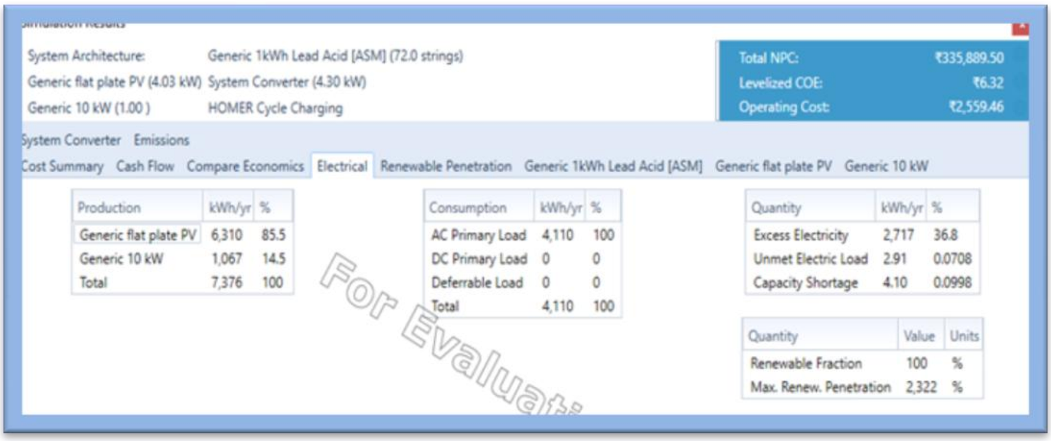


**Figure11.**Cost Summary of the Model

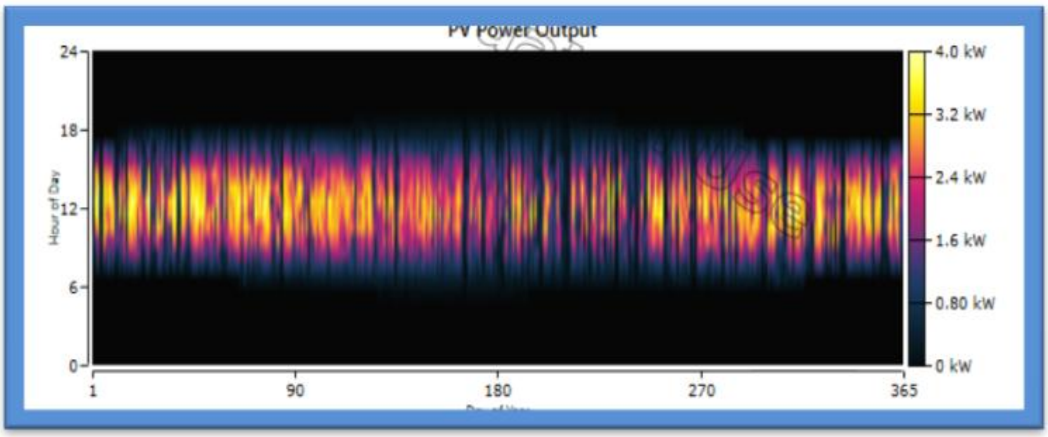


**Figure12 .**PV simulation results for a year data

## VI. Conclusion

A case study was done in the chitrakootDistrict of Madhya Pradesh at MGCGV.This study is carried out by taking into consideration the latitude and longitude of the study area.The model was generated by using HOMER software.The optimization result shows that the grid connected hybrid(PV /Wind) system is more efficient and economic compared to the traditional hybrid system (PV/Generator/Wind /Battery) for the same load. After performing the above analysis, we arrived at the following conclusions:

(1) The obtained results after simulation is the best combination of the system with all sensitivity parameters i.e., PV-4.03KW, Wind Generator-10KW, with 481KWH and 4.30KW converter with COE of Rs6.32. The net present cost of system is Rs.335890 with a renewable fraction of 100%.

2) Fig-6 shows that the energy generated by the PV modules is higher when compared to the wind.

3) Fig-7 shows that the energy production by the wind Turbine is done for the Whole day.

4) Fig-11 shows that, during the installation of plant, the large part of the initial cost is associated with the PV modules, then with the Wind Turbine and then small parts are associated with other components. But there is no maintenance cost associated with the PV system. This shows that, energy production by Solar PV is cost effective. This energy production is maximum in the month of May and minimum in the month of October.

5) From Fig-12 we can see that the energy production by the PV modules occur from morning 6 am to evening 6 pm, when the sun is present and the highest KW is produced in the peak /noon Hrs i.e. from 12 pm to 2 pm.

6) Although the Net Present Cost is high but the running and maintenance cost is low of the Grid connected system. The Monthly average electricity production of the system is as follows:

(i)Photovoltaic production-85.5%.

(ii)Wind Turbine-14.5% .

The total Net Present Cost (NPC) ,Capital Cost and Cost Of Energy (COE) for such a system is Rs335889.50,Rs.201505,6.32RskWh, respectively.

7) Moreover, in case of remote areas that present small incomes ( common parameters for most rural areas ),the extension of utility grids for its increased demand is not feasible and the total dependence on imported fossil fuels is economically unaffordable, fuel transport costs become too expensive. So this approach of a grid connected hybrid model can prove to be the most viable solution for the most of the rural areas in India.

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