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Hybrid Energy Option for a Local Community in Punjab- A Case Study on Sustainable Energy

Atul Kumar[1], Pabitra Kumar Nayak[2], Dharminder Kumar[3]
RIMT University, India

Abstract: In today's world the amount of energy used describes the standard of living of any country. Because energy is the utmost requirement for doing any productive work. But unfortunately still there are many such small communities' lies in our country where the energy is out of reach. The paper tries to electrify one such small community by the integration of Biomass and PV modules. The paper investigates the availability of load and resources to find out the optimal value of such power plant which can provide clean, green and cost competitive power to such communities.
Keywords: Biomass , PV, hybrid system, sustainable energy

I. INTRODUCTION

Biomass power plant are the power plants which produces energy from the waste. Where the biomass is converted to flammable gas by the chemical process and then this gas is converted to thermal energy and this thermal energy is used to produce electricity by the help of coupled unit of turbine and generator. Biomass is the plant material derived from the reaction between CO_2 in the air, water and sunlight, via photosynthesis, to produce carbohydrates that form the building blocks of biomass. Typically photosynthesis converts less than 1% of the available sunlight to stored, chemical energy. The solar energy driving photosynthesis is stored in the chemical bonds of the structural components of biomass. If biomass is processed efficiently, either chemically or biologically, by extracting the energy stored in the chemical bonds and the subsequent 'energy' product combined with oxygen, the carbon is oxidised to produce CO_2 and water. The process is cyclical, as the CO_2 is then available to produce new biomass [1].

Solar PV systems are usually intermittent, unpredictable and weather dependent. Therefore, a continuous and reliable power supply is hardly possible without energy storage. By employing an energy storage system (ESS), the surplus energy can be stored when power generation exceeds demand and then be released to cover the periods when net load exists, providing a robust back-up to intermittent renewable energy [2]. The ESS is thus a critical component and powerful partner to ensure sustainable supply of renewable energy [3], and the European Commission finds it will play a key role in enabling the world to develop a low-carbon power supply system [4]. The cost competitiveness of solar PV is likely to get even more obvious, particularly when compared with the continuous rising of conventional fuel prices and rapid decline of PV module prices and recent policies of governments. To eliminate the source to store the solar PV is integrated with biomass energy.

In this study, biomass is introduced for the standalone solar systems. The solar energy production is high in daytime, so that the entire load is taken care by solar PV alone. During times when there is no or less insolation, PV is working with biomass to serve the load. This hybrid technology provides a novel solution for the challenging task because during summer the biomass availability is less and vice versa and the biomass can also be saved for used later or during low insolation period . During both the seasons the hybrid model can work effectively, to remove dependency on grid, cost competitive and high quality energy.

A. Working Model

The proposed system involved in this study is equipped with a power generator (PV array and biomass gassifier), with an end-user (load) and a control station. The system is considered to be operated in stand-alone mode. The study is aims to find out the optimal size of PV and Biomass gassifier to produce energy to cater the local needs.

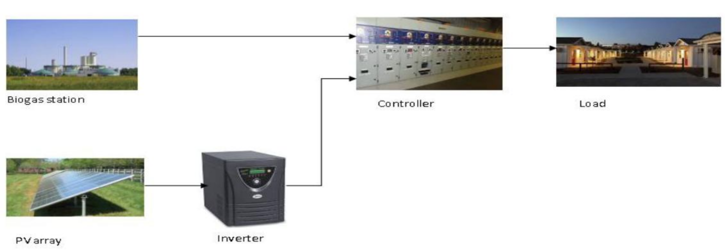

Fig. 1 Integrated PV-Biomass system

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The system is so designed that the power can be produced by both the systems simultaneously whenever required. During day time the load can alone be served by the PV array in case of sunny day and excess energy will be feed to the dump load for protecting the system. And in cloudy day and night, whenever the PV cant meet the load demand, then the biomass will work either simultaneously or standalone mode to serve the load.

B. *Load Profile*

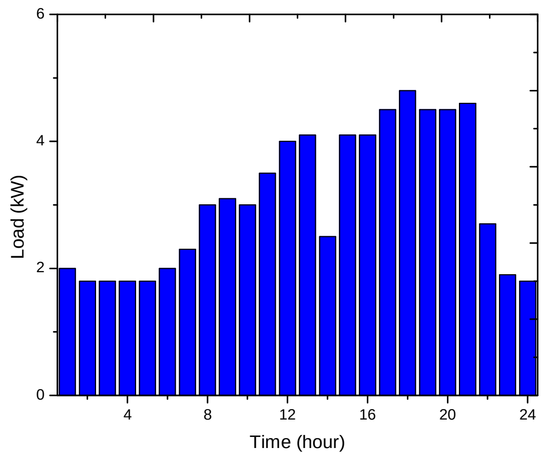

Fig 2 hourly load

The proposed system is designed to serve a daily load of 73 kWh/day with a peak load of 8.2 kW. However, the actual load demand on the site is not measured. Besides, the power demand will rise due to the increasing number of residents in near future.

C. *Resources*

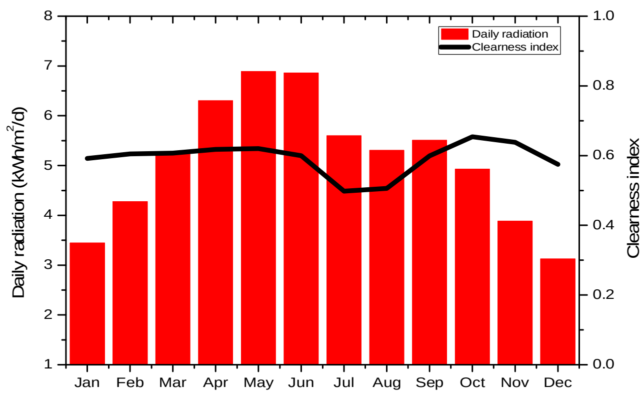

Fig. 3 Monthly variation in solar radiation and clearness index

For the proposed scheme solar energy plays an important role. With the advancement in technology the power production from the PV array is increasing. The power production from the PV array is dependent on the weather condition at which it is being installed. Typical variation of solar radiation in India is found to be 4-7 kWh/m^2/day. The study is conducted at 30.33 degree latitude and 76.38 degree longitude. And for the proposed site monthly average daily solar radiation found to be 5.118 kWh/m^2/day with clearness index of 0.508, the installed capacity of the PV array is 10 kW$_P$. The figure shows the live biomass availability for different months of a year . it is been observed that it is highest during December having around 1.3 tonnes/day and lowest accounts for 0.6 tonnes/day in May. Its shows complementary nature of each other sources as during may biomass is low but solar potential is more and vice versa for case of December.

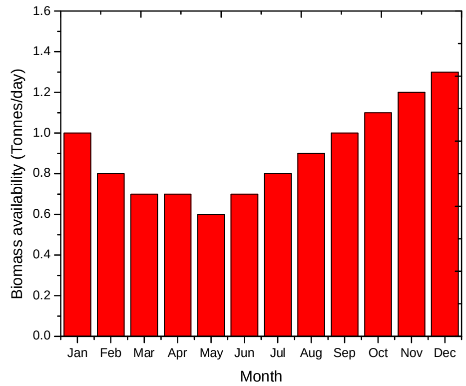

Fig.4 Biomass availability

D. Monthly Energy Density

The below figure represents monthly variation in solar radiation and biomass available throughout the year. The yearly average of solar radiation and biomass are 5.11 kWh/m^2/day and 0.901 t/day respectively. It can be seen that when the biomass collection/production rate is less the solar radiation is good so that maximum portion of load can be feed by PV arrays. And during low irradiance month the biomass collection from the community is sufficient to meet the load. This shows complementary nature of PV and biomass hybrid system.

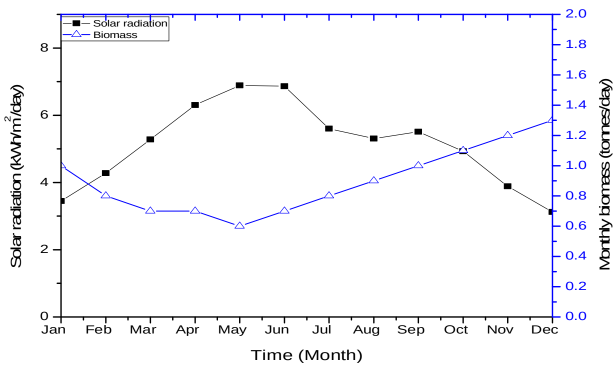

Fig. 5 Monthly energy density

E. Daily Mean Renewable Energy Production and Load Demand

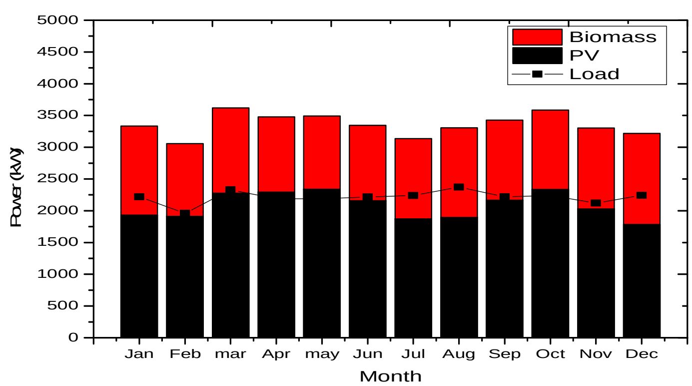

Fig. 6 Daily mean renewable energy production and load demand

The daily average biomass and PV power generation for each month of the year are presented in the below fig. It can be noted that hydro power production dominates the power supply, contributing almost 61% of the total production during the simulated year. The PV output is high in months of March, April and May. This is a favorable characteristics since maximum portion of electricity demand could meet by the proposed system.

F. Hourly Simulation Result

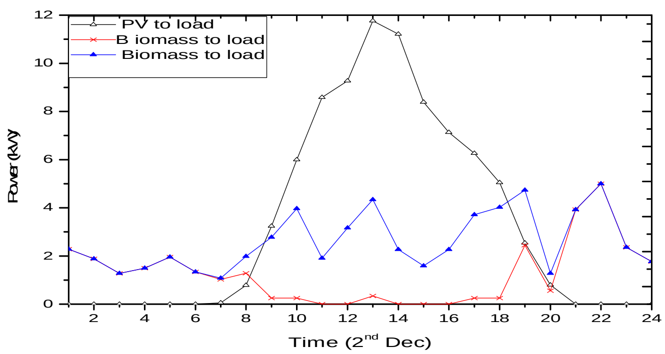

Fig.7 Hourly energy simulation

A plot of the hourly simulation results for 2nd Dec, as an example is given in above fig. it can be seen that no dumped energy occurred during that night as only biogas plant is working and its adjusting with the load demand. During day time both the systems can work. It is evident from the figure that the two systems can meet maximum portion of the load.

G. Economic Analysis

	PV (kW)	biogs (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Biomass (t)	biogs (hrs)
	10	3	4	$ 822,086	63,135	$ 1,629,168	5.187	0.53	0.12	8,226	7,838
	10	3	5	$ 892,086	281,896	$ 4,495,661	14.313	0.54	0.12	8,345	7,613
	9	3	5	$ 871,086	291,192	$ 4,593,496	14.658	0.51	0.13	8,564	7,806
	9	3	6	$ 941,086	319,462	$ 5,024,884	16.035	0.51	0.13	8,570	7,780
	9	3	7	$ 1,011,086	320,326	$ 5,105,922	16.294	0.51	0.13	8,557	7,780
	9	3	8	$ 1,081,086	328,633	$ 5,282,116	16.856	0.51	0.13	8,557	7,780
	9	3	9	$ 1,151,086	337,120	$ 5,460,617	17.425	0.51	0.13	8,557	7,780

Fig 8 Optimization result of pv-biomass system

The fig. shows the overall optimization result of the hybrid system which is generated in the HOMER software. Each row in the table represents a viable system configuration. The first 3 column shows icon , next three column indicate number or size of each component, the next eight column shows key simulation results, such as capital cost of the system, operating cost, Net present cost, levelized cost of COE, renewable fraction and capacity shortage. The optimal configuration is the one having lowest NPC which comprises of 10 kW PV, 3 kW hydro turbine, 4 kW converter. The COE is found to be INR 5.187/kWh and53% renewable fraction and capacity shortage of 12%.

II. CONCLUSION

In this study the integration of biomass in PV system is examined. The results are showing successful integration of the scheme. It concludes that with the integration, the power output of the system increases, the two schemes integrated in the study are also complementary in nature, the capacity shortage is 12% which also increases reliability of the scheme, the levilised cost of energy is decreased from 8.50 INR/kWh to 5.187 INR/kWh, proposed scheme is also having negligible emission and hence ecofriendly.

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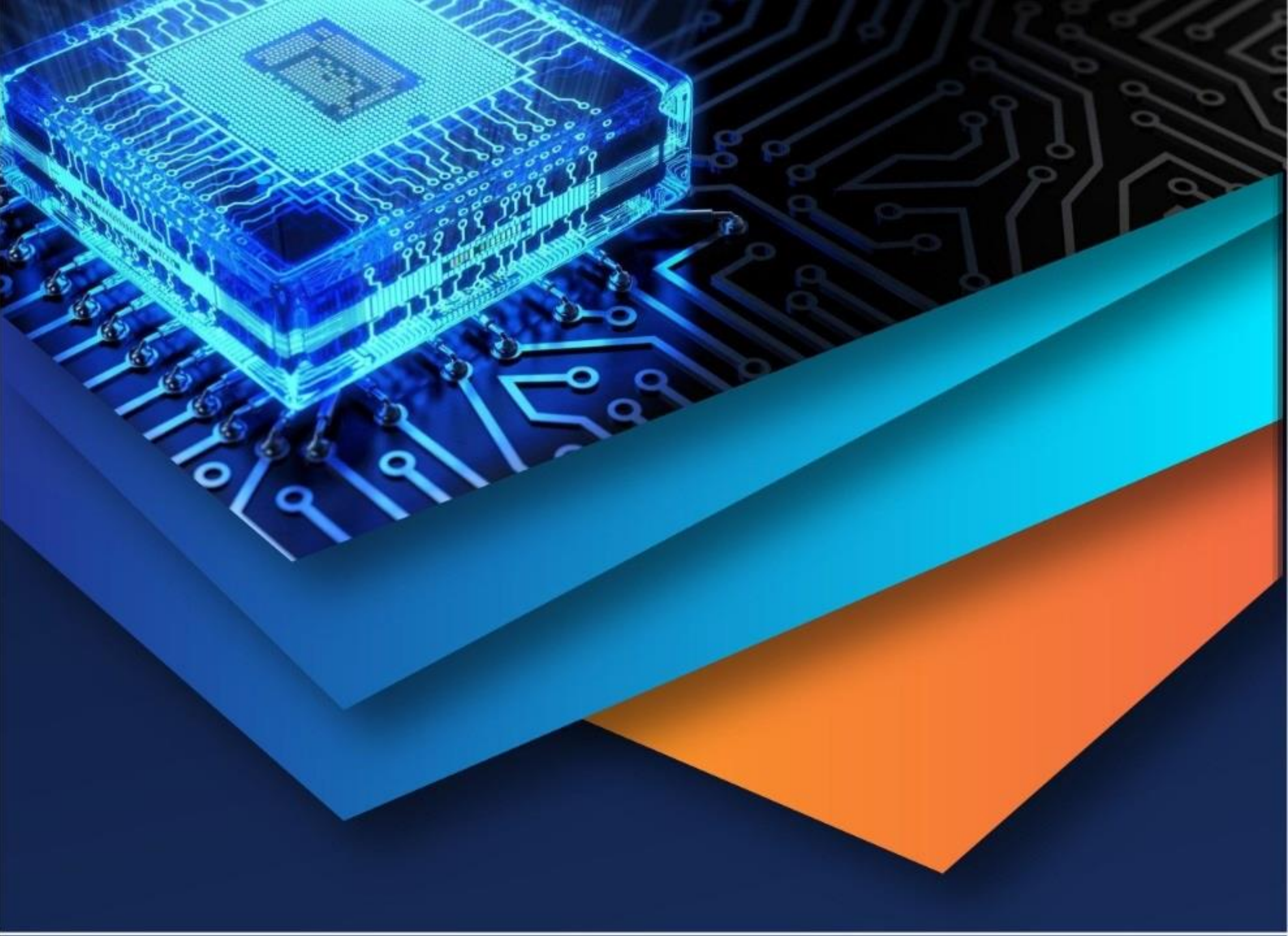

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