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Hybrid Solar PV And Biomass System For Rural Electrification

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Abstract: One of the primary needs for socio-economic development in any nation is the provision of reliable electricity supply systems. A large proportion of the world's population lives in remote rural areas. This paper discusses the renewable hybrid power generation system which is suitable for Maulana Ganj village situated in Uttar Pradesh. All the load details of the village is collected and accordingly amount of power to be generated is calculated. The technical, economic and C02 mitigation potential of solar PV-bio hybrid system is evaluated.
Key words: Rural electrification, Biomass plant, Solar PV plant, Economic considerations, Carbon credits, load details.

Introduction:

Energy is vital for the progress of a nation and it has to be conserved in a most efficient manner. Energy should be produced in a most environment-friendly manner from all varieties of fuels as well as should be conserved efficiently. The use of Renewable Energy technology has been steadily increasing so as to meet demand. However, there are some drawbacks associated with renewable energy systems such as poor reliability and lean nature.

Over 200 million people, live in rural areas far away from the grid[10]. The installation and distribution costs are considerably higher for remote areas. Moreover, there is greater transmission line losses and poor supply reliability. Like several other developing countries, India is characterized by severe energy deficit. In most of the remote and non-electrified sites, extension of utility grid lines experiences a number of problems such as high capital investment, high lead time, low load factor, poor voltage regulation and frequent power supply interruptions. There is growing interest in harnessing renewable energy sources since they are available in abundance, pollution free and inexhaustible. Presently, standalone solar photovoltaic systems and biomass systems have been promoted around the globe on a comparatively larger scale[11].

This study deals with assessing the technical and economic feasibility of solar- biomass hybrid system for Maulana Gunj village, U.P, India.

Methodology:

(i) Study Location

Maulanaganj is a village in Uttar Pradesh, a number of parameters was used for the selection of the village.

- Unelectrified
- Different degree of economic development
- Population size not exceed 1500
- Income disparity between different group not too high
- Good public co-operation

A survey was done to find information on energy consumption, data was collected from all 196 houses in Maulanaganj the total animal dung collectable was also calculated.

Village Profile

Village	**Maulanaganj**
Block	Paniyara
District	Gorakhpur
Population	1196
Average family size	6
Number of household	196
Livestock population	274

Maulanaganj is endowed with more land (0.28 ha/capita). The animal density is 0.7/capita as far as cooking fuel is concerned small quantity of kerosene is used with biomass.

(ii)

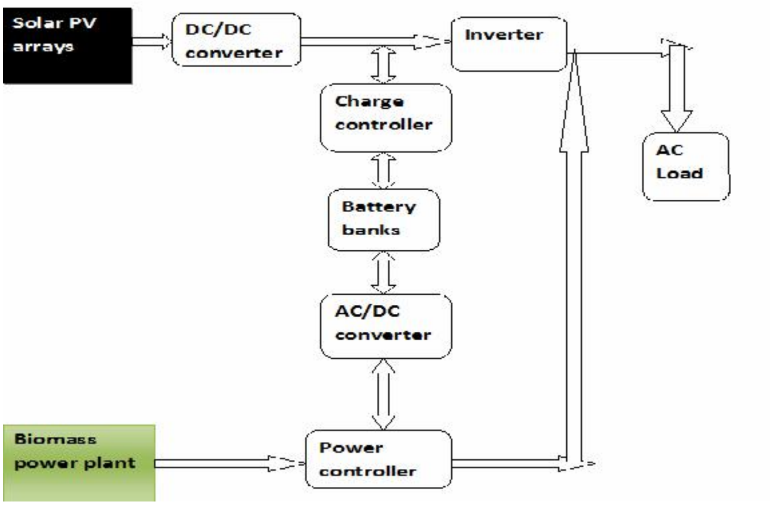

Fig: 1 Block diagram of hybrid energy system

Design:

(i) Solar PV

Sun is the primary source of energy. It is renewable, inexhaustible and environmental friendly. India is blessed with large amount of sunshine all the year with an average sun power of 490W/m2/day. Solar charged battery systems provide power supply for complete 24hours a day. PV cell are solar cells that convert sun energy directly into D.C electricity. Semiconductor materials are used to make this solar cell in PV module. The electricity generated from PV cell can be used to power a load or can be stored in a battery. PV systems generally can be much cheaper especially to remote areas.

Fig 2: Solar PV plant

The major components are PV modules, dc to dc converter, battery and inverter. The capacity of these components can be determined by estimating the load to be supplied. The size of the battery bank required will depend on the storage required, the maximum discharge rate, and the minimum temperature at which the batteries will be used[3]. For choosing a battery size, all these factors should be considered. Lead-acid batteries are the most common in P.V systems.

PV cells are used to generate electrical energy by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaics include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years.

When light shines on a PV cell, it may be reflected, absorbed, or pass right through. But only the absorbed light generates electricity. The energy of the absorbed light is transferred to electrons in the atoms of the PV cell semiconductor material. With their newfound energy, these electrons escape from their normal positions in the atoms and become part of the electrical flow, or current, in an electrical circuit. A special electrical property of the PV cell—what is called a "built-in electric field"—provides the force, or voltage, needed to drive the current through an external load, such as a light bulb.

Storage battery: A **rechargeable battery**, **storage battery**, or **accumulator** is a type of electrical battery. It comprises one or more electrochemical cells, and is a type of energy accumulator. It is known as a **secondary cell** because its electrochemical reactions are electrically reversible. Rechargeable batteries come in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of chemicals are commonly used, including: lead–acid, nickel cadmium (NiCd), nickel metal hydride (NiMH), lithium ion (Li-ion), and lithium ion polymer (Li-ion polymer).
Rechargeable batteries have lower total cost of use and environmental impact than disposable batteries. Some rechargeable battery types are available in the same sizes as disposable types.

Charge controller, otherwise called as charge regulator, is the core of every solar system, and is required to monitor and control the flow of power into and out of the battery. It also regulates the power flow from solar panel to the battery to ensure that the battery is not overcharged. The charge controller must also ensure that the connected loads don’t over-discharge the battery, thereby damaging it.

A **solar inverter** is used to convert the DC output of a solar panel into a utility frequency alternating current that can be fed into a grid . Battery backup inverters are special inverters which are designed to draw energy from a battery, manage the battery charge via an onboard charger, and export excess energy to the utility grid. Solar inverters are used for other purposes like maximum power point tracking and anti-islanding protection.

Electric load:

Design Analysis:

The storage capacity, S_c, of the battery can be obtained by (4 x Total energy to be stored per day)/ (Battery voltage x battery current).
Number of panels required, N_P = Rating of solar PV plant / Rating of solar pv panel
The charging controller can be designed using the following formula:

Controller current, $I_{C,}$ Total power to be stored per day / V_B
The number of batteries required can be obtained by, N_B , Total power to be stored / (V_Bx I_B)
where, V_B, I_B are the voltage and current rating of each battery.

(ii) Biomass:

a) Rice husk

b) wheat husk

c) Wood chips

d) Saw dust

Fig 3: Biomass Crops

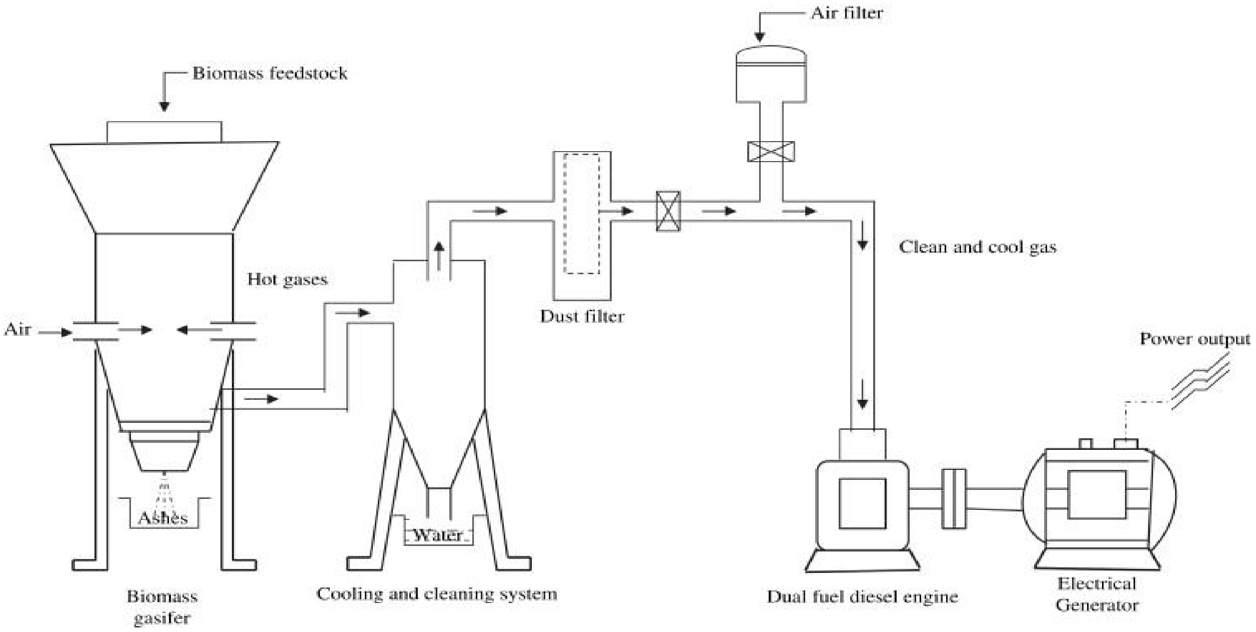

Fig 4: Biomass Gasifier plant

Biomass is the most interesting and emerging option to supply future energy demands. Although not all biomass can be used to generate electricity, only small fraction of it can be utilized to produce substantial amount of energy. However, the energy efficiency of this technology is limited and the operating and investment costs are high, resulting in low financial returns[3]. Biomass power plants have capacities typically ranging between 2-50 MWe. The larger plants benefit from comparatively higher energy efficiencies (usually up to 22-23 %) but have to face the challenge of meeting a demand for large amounts of biomass, a resource characterized for its increasing scarcity, high cost and seasonality[6]. Biomass particles size ranges varies from 5 cm to few mm. The feedstock should preferably be free due to the heat needed to vaporize the water within the particle, however maximum moisture content up to 30% to 50% were mentioned as suitable[6].

Analysis:

Load Estimation:

Table1: Domestic load of the village

S.No.	Gadget	Number	Rating(W)	Total rating(W)	Duration(hrs)	Load(KWh)
1.	Compact fluorescent lamps	200	15	3000	8	24
2.	Fans	200	60	12000	8	96
3.	Water pumps	7	1500	10500	4	42

Due to domestic loads units consumed per day is 162 units

Table2: Community load of the village

S.No.	Gadget	Number	Rating	Total rating	Duration	Load(KWh)
1.	T.V	1	300	300	8	2.4
2.	Computer	1	600	600	4	2.4
3.	Tube fluorescent lamp	4	55	220	8	1.76
4.	C.D player	1	100	100	8	0.8
5.	Fans	4	60	240	8	1.92

Energy Consumption of Village:

For community hall design the load consumed per day is 9.28For street lighting we are using 30 T.F.Ls and these are operating 8 hrs per day, so these consume 13.2KWh per day. So the total units consumed per day are 185 units.

Design Results:

(i) Design of PV Panel:

Total load = 15KWe
Period of operation or duration = 7 Hours
Then, Total Watt-Hour = 15×7= 105KWhr
The period of the solar panel exposed to the sun = 7 Hours (Averagely between 9am and 4pm)
Therefore solar array wattage = 15 KW
Hence solar panel of 15,000W will be needed for this design.
If solar panel of 150W is to be use the number of panels to arrange in parallel to achieve 15,000 Watt will be:
No. of panel= $1500W/150W$=100
This shows 100 of 150 Watt solar panel will be required for this design

(a) Charging Controllers:

For this design of 15KW solar power supply P=IV
Where,
I is the expected charging current and
V is the voltage of the battery and = 12 V
P is the power supply rating= 15KW

Normally 8 hours per day is the sunshine available hours, from solar PV array maximum units can generate is 15 X 7= 105 KWh, if solar PV array can generate 70% of its rated capacity then it can generate 73.5 KWh per day, in day time directly we are giving to the consumers from solar power plant, so minimum 24KWh directly we can distribute without storing it, remaining 50KWh is we have to store in the battery banks.

Hence I = P/V= 50000/12=4166*Amps.*

Since the value 5KA charging controller is needed to charge the battery banks.

(b) Battery capacity:

Watt-hour capacity = 50 kWh

To make the chosen battery to last long it is assumed that only a quarter (¼) of the battery capacity will be made used of so that it will not be over discharged therefore hence the required batter capacity will be ---50,000 X 4 = 2,00 kWh

Now the choice of battery hour depends on A-H rating of the storage battery. For example, for 500Ah, 12V battery the number of batteries that will be needed is 2,00,000/(12 X 500)=34 batteries. Hence, for this design and to avoid too much weight and occupying unnecessary space, 34 batteries will be needed.

(c) Inverter:

Since the total load is 50KWh it is advisable to size the required inverter to be 10KW as designed for solar panel ratings. Hence 10KVA pure sign wave inverter is recommended in other to prolong the lifespan of the inverter.

(ii) Biomass power plant:

(a) Biomass resource availability:

In maulanaganj the biomass availability is 0.36 kg/cap/day

Population of the village is 1196

The total biomass availability in the village is around 420 kg, from this we can generate the sufficient power, to satisfying the load requirement of MaulanaGanj village.

(b) Plant rating:

Here we are installing the power plant is 10 KWe and we are connecting to the synchronous generator, so it will gives the rated voltage and frequency and gasifier can give the gas 12 hrs/day from this we can generate 120 units minimum per day, biomass plant is working at peak loads and solar is working at day time and solar power we are storing through batteries and one controller also we are placed so that it will control the power flow to the consumer load.

Economic Consideration:

Biogas power plant:

Table 3: Summary of biomass gasifier plant

Plant capacity	10 kW
Cost of installation	Rs. 5,00,000 ($ 11,450)
Maintenance cost	Rs.10,000 ($ 229)
No of consumers	196
Operation hours	12 hrs
Fuel efficiency	1.5 kg of crop residue/kWh
Cost of fuel	Rs. 0.30/kg ($6.7/t)
Operating period	20 years

Table 4: Operation cost per unit electricity:

Description	With grid system	With gasifier system
Electricity	Rs.4.5/kWh	Rs.0.45/kWh
Labour cost	Rs.0.45/kWh	Rs.0.66/kWh
Maintenance cost	Rs.0.07/kWh	Rs.0.28/kWh
Total	Rs.5.02/kWh	Rs.1.39/kWh

Table 5: Summary of Solar PV power plant

Plant capacity	15 kW
Cost of installation	Rs.26,25,000 ($60,112)
Maintenance cost	26,250 ($ 601.125)
No of consumers	196
Operation hours	7 hrs
Operating period	15 years

Hybrid system cost:

Biomass:

Total installation cost of biomass = Rs 5,00,000

maintenance cost of the biomass plant = 2 % of the installation cost

total cost(installation and maintenance) of the plant = 5,00,000 + (0.02 X 5,00,000)

=Rs.5,10,000

Operating years = 20 years

Per day we can generate = 120 units

So, per unit cost = 5,10,000/(20 X 120 X 365) = Rs 0.582.

Total cost per unit generation = Installation and maintenance costs + operation cost

= 0.582 + 1.39 = Rs 1.972.

Solar:

Total installation cost = 175 X 15,000 = 26,25000. (per watt installation cost is Rs.175)

Maintenance cost of the solar PV plant = 1 % of the installation cost

= 26,25,000 + (0.01 X 26,25,000)

= Rs.26,51,250

Operating years = 15 years.

Per day we can generate = 73.5 units.

Per unit cost = 26,51,250/(15 X 365 X 73.5) = Rs 6.588.

Hybrid:

Per unit cost from hybrid system = (2400 X 1.972 + 1102.5 X 6.588)/(2400 + 1102.5)

= Rs 3.425.

Through hybrid energy system, per unit generation and distribution cost is not beyond Rs 4.

But through main grid connection per unit tariff is minimum Rs5.50.

So, through hybrid energy system, the cost of generation is also less as compared with the conventional energy.

Carbon Reduction Potential:

Co_2 emission from biomass per unit generation = 6 g/kwh

Co_2 emission from solar pv plant per unit generation = 68 g/kwh

Per day we can generate power from biomass = 120 X 365 = 43,800 kWh

Per year we can generate the power from solar pv plant = 73.5 X 365 = 26,827.5 kwh

Carbon emission from solar pv plant per year = 26827.5 X 0.067 = 1824.25 kg

= 1.825 tonnes/year

= 1.825 carbon credits

Carbon emission from biomass plant per year = 43,800 X 0.006 = 262.8 kg

= 0.2628 tonnes/year

= 0.2628 carbon credits

From total hybrid system, the carbon emitted per year = 1.825 + 0.2628 = 2.0878 tonnes/year

If the same energy is generated through conventional (coal), then carbon emitted per year

= 1.5*(43,800+26827.5)

= 105.94 tonnes/year.

So by installing renewable hybrid system, the carbon emission reduction = 105.94 – 2.0878

= 103.85 tonnes/year

= 103.85 carbon credits.

Total money earned through carbon credits = 103.85* 30 = 3115.50 $ (USD)

= Rs 1,36,048 per year.

A 15kw standalone solar photovoltaic system has been considered to evaluate the unit cost of energy generation. Assuming the sunshine hours of 6 hrs per day and 365 days of operation. Capital cost of solar pv is Rs 26,51,250 and the total cost of bio energy system is 5,10,000. Therefore, the total cost of installed capacity is Rs 31,61,250 which is shown in Table 3 and Table 5. The unit cost of the solar- biomass hybrid energy system is calculated above and it was found to be Rs 3.425.Here we are installing the power plant is 10 kWe and we are connecting to the synchronous generator with the rated voltage and frequency. Gasifier can produce the gas 6-7 hrs/day, from this we can generate 120 units minimum per day. Biomass plant is working at peak loads. Similarly solar plant can generate power at day time for 7 hrs(from 9 a.m to 4 p.m)and at night time, batteries will discharge the stored electricity. and one controller also we are placed so that it will control the power flow to the consumer load. So during clear sunny day the net power generated from solar plant is 73.5 kWhr. Charge controller is placed in between solar panels and batteries to control the power flow.

Conclusion:

Some of the remote villages are far away from the main grid so they are still unelectrified. Due to the distance problem, losses increases and transmission line installation cost goes high. This paper discusses the renewable hybrid system with solar pv and biomass which helps in overcoming all these problems. In this paper the load requirement of MaulanaGanj village is calculated and in order to satisfy this load the energy requirement is predicted. It can be concluded that solar and biomass hybrid system is a viable green technology source for rural electrification.

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