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An Economic Rural Electrification Study Using Combined Hybrid Solar and Biomass-Biogas System

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Abstract

One of the prime requirements for socio-economic improvement in any nation is the condition of consistent electricity provide systems. A huge quantity of the world's residents lives in isolated rural areas. This paper discusses the renewable hybrid power creation system which is proper for Khalardda village placed in Odisha. Every part of the load facts of the village is composed and as a result quantity of power to be created is designed. The technical, economic potential of solar PV-biomass-biogas hybrid system is considered.

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Keywords: Biogas plant; Biomass plant; Economic considerations; Rural electrification; Solar PV plant.

1. Introduction

Energy is essential for the improvement of a nation and it has to be sealed in a mainly capable mode. Energy should be formed in a mainly environment-friendly method from all different of fuels as well as should be saving poorly. The utilize of Renewable Energy technology has been gradually mounting so as to convene require. Though, there are several drawbacks related with renewable energy systems for example poor reliability and tilt nature. India is distinguished by strict energy shortage. In a large amount of the remote and non-electrified sites, expansion of service grid lines practices several problems for example large capital investment, large lead time, small load factor, low voltage regulation and regular power supply disturbances. There is rising concern in connecting renewable energy sources because they are presented in abundance, pollution free and inexhaustible.

2. Methodology

2.1 Study Location

Khalardda is a village in Odisha, several factors were applied for the choice of the village. They are low voltage problems, dissimilar degree of economic expansion, income gap between unlike group not too large, excellent public co-operation, 90% of people depends on farming. A study was done to discover information on energy consumption, data was composed from all 286 houses in Khalardda. The total animal dung and biomass amount were also considered.

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2.2 TABLE.1 Village Profile

Village	Khalardda
Block	Barang
District	Cuttack
Population	2364
Average family size	8
Number of household	286

Khalardda is gifted with more land (0.28 ha/capita). The animal density is 0.7/capita to the extent that cooking fuel is disturbed tiny quantity of kerosene is applied with biomass.

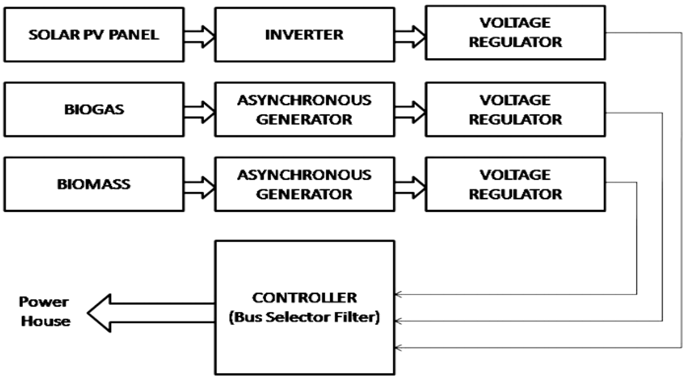

Fig.1. Block diagram of hybrid energy system

3. Design Solar PV Plant

Sun is the most important source of energy and it is inexhaustible, renewable and environmental friendly. India is sanctified with huge amount of sunshine throughout the year and an average sun power of 490W/m2/day. Solar exciting battery systems deliver power supply for complete 24 hours a day. PV cell are solar cells that transfer sun energy directly into D.C electricity. Semiconductor materials are applied to create this solar cell in PV module. The electricity produced from PV cell can be applied to power a load or can be accumulated in a battery. PV systems generally can be greatly low price particularly to remote areas.

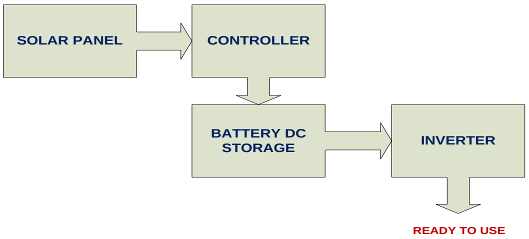

Fig.2. Solar PV plant

3.1 PV cells

PV cells are applied to produce electrical energy by changing the solar radiation directly into current electricity applying semiconductors that reveal the photovoltaic effect. Photovoltaic power generation uses solar panels collected of a number of solar cells including a photovoltaic material. Materials currently applied for photo voltaic contain polycrystalline silicon, mono crystalline silicon, cadmium telluride, amorphous silicon and copper indium gallium selenide/sulfide. Due to require for renewable energy sources, the developing of solar cells and photovoltaic arrays has complex significantly in current years.

3.2 Storage Battery

Battery is of several types like rechargeable battery, storage battery or an accumulator type of electrical battery. It includes one or more electrochemical cells and is a kind of energy accumulator which is known as a secondary cell because its electrochemical reactions are electrically reversible. Rechargeable batteries approach in several unusual shapes and sizes, ranging from button cells to megawatt systems attached to stabilize an electrical distribution network. Some unusual arrangements of chemicals are frequently applied, counting: lead–acid, nickel cadmium(NiCd), nickel metal hydride(NiMH), lithium ion(Li-ion), and lithium ion polymer(Li-ion polymer).

3.3 Charge Controller

Charge controller, or else called as charge regulator is the center of each solar system, and is essential to observe and manage the flow of power into and out of the battery. It also controls the power flow from solar panel to the battery to make sure that the battery is not overcharged. The charge controller should also make sure that the attached loads don't over-discharge the battery, thus damaging it.

3.4 Solar Inverter

A solar inverter is applied to renovate the DC output of a solar panel into a service frequency alternating current that can be supplied into a grid. Battery backup inverters are particular inverters which are considered to represent energy from a battery, control the battery charge via an involved charger, and send abroad surplus energy to the service grid. Solar inverters are applied for other purposes similar to maximum power point tracking and anti-islanding protection.

4. Design of Biogas Plant

Different types of gasifier e.g. fixed bed updraft and downdraft gasifier, fluidized bed gasifier and bubbling bed gasifier are present in the existing market. All the composed cow dung is fed into an anaerobic digester. The digester is found to hold 21 days of farm waste. Bacteria transfer the waste into various products, one of which is methane gas. Gas created by the bacteria expands the pressure in the concrete vessel, and a pipe transfers the biogas to a personalized natural gas engine. The biogas fuels the engine, which in turn spins an electric generator to produce electricity. Waste heat from the engine is applied to remain the digester warm and offsets fuel buy on the farm. One cow's waste can create sufficient electricity to light two 100-watt light bulbs for 24 hours a day. The energy is fed to the electrical system for distribution purpose.

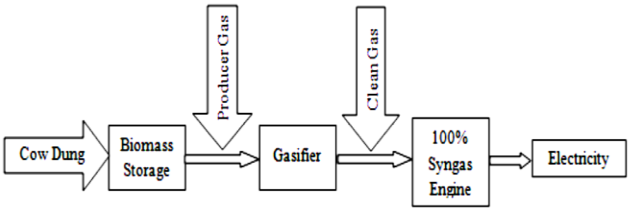

Fig.3. Electricity Generation by cow dung gasification

5. Design of Biomass Plant

Biomass is the most exciting and rising choice to provide future energy requirements. Even if not all biomass can be applied to create electricity, only small fraction of it can be operated to generate significant amount of demanded energy. As the efficiency of this technique is limited to the operating and investment costs are large, effecting in low financial returns. Biomass power plants have abilities typically ranging between 2-50MWe. The larger plants profit from reasonably superior energy efficiencies (usually up to 22-23 %) but have to see the test of meeting a require for large amounts of biomass, a resource distinguished for its growing shortage, high cost and seasonal change. Biomass particles size ranges varies from 4-5 cm to few mm. In this technology feedstock must be preferably free caused by the heat required to vaporize the water within the particle, though most moisture content up to 30% to 50%were mentioned as proper. The biomass crops are Rice husk, wheat husk, Wood chips and Saw dust.

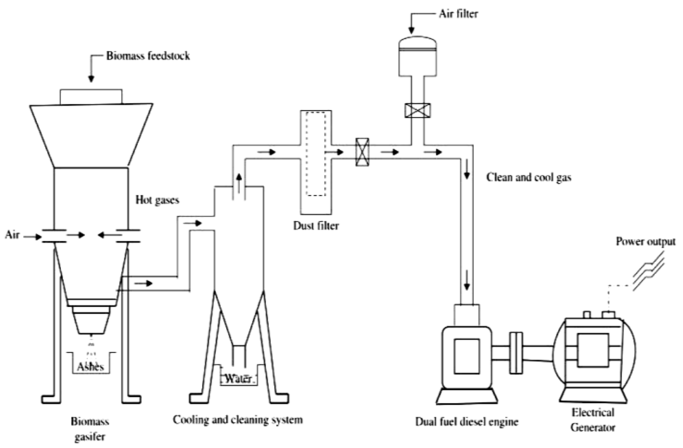

Fig.4. Biomass Gasifier plant

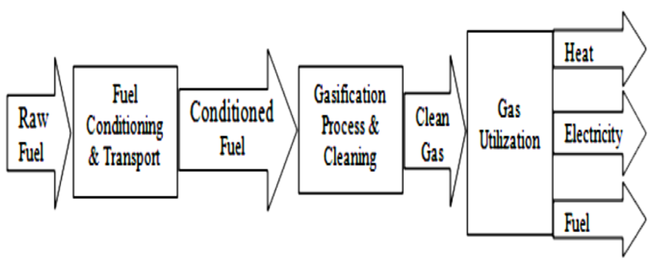

Fig.5. Basic process steps of a biomass gasification plant

6. Analysis of Load Estimation

6.1 Domestic load of the village

TABLE.2

Sl. No.	Gadget	Number	Rating(W)	Total rating(W)	Duration(hrs)	Load(KWh)
1	CFL	300	15	3000	8	24
2	Fans	300	60	12000	8	96
3	Water pumps	7	1500	10500	4	42

6.2 Community load of the village

TABLE.3

Sl. No.	Gadget	Number	Rating(W)	Total rating(W)	Duration(hrs)	Load(kWh)
1	**T.V.**	1	300	300	8	2.4
2	**Computer**	1	600	600	4	2.4
3	**TFL**	4	55	220	8	1.76
4	**C.D player**	1	100	100	8	0.8
5	**Fans**	6	60	240	8	1.96

6.3 Energy Consumption of Village

For community hall propose the load used per day is 9.28. For street lighting we are applying 30 T.F.Ls and these are conducting 8 hrs per day, so these use 13.2KWh per day. So the total units used per day are 185 units.

7. Analysis and Design Results

7.1 Design of PV Panel

Total load = 25KWe

Period of operation or duration = 7Hours. Then, Total Watt-Hour = 25×7= 175KWhr. The period of the solar panel introduced to the sun = 7Hours (9am and 4pm averagely). So solar array wattage = 25 KW. Thus solar panel of 25,000W will be required for this design. If solar panel of 150W is to be apply the number of panels to organize in parallel to achieve 25,000 Watt will be:

No. of panel= 25000W/150W=167. This shows 167 of 150 Watt solar panel will be involved for this design.

(i) Charging Controllers

For this design of 25KW solar power supply P=IV

Where, V is the voltage of the battery 12 V, I is the charging current and P is the power supply rating = 25KW

Normally 8 hours per day is the sunshine existing hours, from solar PV array maximum units can create is 25 X 7= 175 KWh, if solar PV array can create 70% of its rated capacity then it can create 122.5KWh per day, in day time directly we are giving to the consumers from solar power plant, so minimum 72.5KWh directly we can distribute it without storing and remaining 50KWh is we have to store in the battery banks. Hence I = P/V= 50000/12=4166Amps. Here the value 5KA current charging controller is required to charge the battery banks.

(ii) Battery capacity

Watt-hour capacity = 50 kWh.

To construct the chosen battery to last long it is supposed that only a quarter (¼) of the battery capacity will be made applied of so that it will not be over discharged thus the required battery capacity will be 50,000 X4 = 2,00 kWh. At present the selection of battery hour depends on A-H rating of the storage battery capacity. As for 500Ah, the number of 12V battery batteries that will be needed is 2,00,000/(12 X 500)=34 batteries. So, for this design and to evade too much weight and occupying unnecessary space, 34 batteries will be required.

(iii) Inverter

Here the total load is 50KWh. It is always advisable to size the involved inverter to be 10KW as designed for solar panel ratings. So 10KVA pure sign wave inverter is suggested so as to extend the lifespan of the inverter.

7.2 Biomass power plant

(i) Biomass resource availability

In Khalardda the biomass availability is 0.76 kg/cap/day Population of the village is 2364. The total biomass availability in the village is around 720 kg, from this we can produce the enough power, to satisfy the load necessity of Khalardda village.

(ii) Plant rating

Now we are installing the power plant is 15 KW and we are attaching the synchronous generator, so it will provide the rated voltage and frequency. The gasifier can produce gas 12hrs/day and 180 units minimum per day can produce from it. Biomass plant is working at peak loads and solar is working at daytime. We are storing solar power through batteries and one controller also we are set so that it will manage the power flow to the consumer load.

7.3 Biogas Power Plant

Four five animals preferably generate 2m^3 gas/day.
Minimum 45kg dung involved to generate 2m^3 gas daily.
Calorific value is 4700-6000kcal/m^3 i.e. 20-24 MJ/m^3. Inflammable in air is up to 6-25% of biogas mixed with air to burn. The total unit production is 185 units from biogas power plant at this village.

TABLE.4

Material	**Amount of gas (m^3/kg)**	
	Winter	***Summer***
Cattle dung	0.036	0.092
Pig dung	0.07	0.10
Poultry dung	0.07	0.16
Night-soil	-	0.04

TABLE.5

Material	**Composition of gas in percentage (%)**		
	CH_4	CO_2	H_2S
Cattle dung	55-80	40-45	0.01
Night soil	65	35	0.6

TABLE.6

Gas production per day (m^3)	**Amount of wet dung (kg)**	**No. of animals**
2	30-40	2-3
3	40-50	3-4
4	50-60	4-6
6	80-100	6-10
8	120-150	12-15
10	160-200	16-20

TABLE.7

Fuel	**Unit**	**Calorific value**	
		MJ	**kcal**
Electricity	**kWh**	3.6	860
Biogas	**m^3**	20	4700
Cattle Dung	**kg**	8.8	2100
Firewood	**kg**	20	4700
Butane	**kg**	46	10900
Kerosene	**Litre**	38	9100

8. Economic Consideration

8.1 TABLE.8 Biomass

Plant capacity	15 kW
Cost of installation	Rs. 7,50,000
Maintenance cost	Rs.15,000
No of consumers	286
Operation hours	12hrs
Fuel efficiency	1.5 kg of crop residue/kWh
Cost of fuel	Rs. 0.40/kg ($6.7/t)
Operating period	20 years

8.2 TABLE.9 Biogas

Plant capacity	15kW
Cost of installation	Rs. 8,20,000
Maintenance cost	Rs. 16,400
No of consumers	286
Operation hours	12hrs
Fuel efficiency	2m^3 gas/day
Cost of fuel	Rs. 0.40/kg
Operating period	20 years

8.3 TABLE.10 Solar Plant

Plant capacity	25 kW
Cost of installation	Rs.44,25,000
Maintenance cost	44,250
No of consumers	286
Operation hours	7hrs
Operating period	15 years

8.4 TABLE.11 Cost Estimation

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

9. Hybrid System Cost

9.1 Biomass

Total installation cost of biomass = Rs 7,50,000
Maintenance cost of the biomass plant = 2 % of the installation cost total cost (installation and maintenance) of the plant = 7,50,000 + (0.02 X 7,50,000) =Rs.7,65,000
Operating years = 20 years
Per day we can create = 180 units
So, per unit cost =7,65,000/(20 X 180 X 365) = Rs 0.582.
Total cost per unit generation = Installation and maintenance costs of plant + operation cost of plant = 0.582 + 1.39 = Rs 1.972

9.2 *Biogas*

Total installation cost of biomass = Rs 8,20,000
Maintenance cost of the biomass plant = 2 % of the installation cost total cost (installation and maintenance) of the plant = 8,20,000 + (0.02 X 8,20,000) =Rs.8,36,400
Operating years = 20 years
Per day we can create = 185 units
So, per unit cost =8,36,400/(20 X 185 X 365) = Rs 0.619.
Total cost per unit generation = Installation and maintenance costs + operation cost = 0.619 + 1.39 = Rs 2.009

9.3 Solar Plant

Total installation cost = 180 X 25,000 =44,25,000 .(per watt installation cost is Rs.180)
Maintenance cost of the solar PV plant = 1 % of the installation cost = 44,25,000 + (0.01 X 44,25,000)= Rs.44,69,250
Operating years = 15 years.
Per day we can create = 122.5 units.
Per unit cost = 44,69,250/(15 X 365 X 122.5) = Rs 4.5350

9.4 *Hybrid*

Per unit cost of hybrid system = (2400 X 1.972 +2400X2.009+ 1102.5 X 6.588)/(2400 +2400+ 1102.5)
= Rs 2.465

As for the hybrid energy system we have per unit generation and distribution cost is not beyond Rs 4. As the main grid connection has minimum per unit tariff is Rs5.50.
So, as compared to the conventional energy, the cost of generation for hybrid energy system is also less.

10. Conclusion

A few of the remote villages are far and wide from the main grid so they are still unelectrified. For the distance problem, losses extend and transmission line installation cost increases. This paper consults the renewable hybrid system with solar PV and biomass-biogas which eases in defeating all the above problems. In this paper the load requirement of Khalardda village is estimated and beneficial to complete this load the energy demand is anticipated. This procedure can apply for improvement of the village in irrigation, natural calamities and farming. It can be resolved that solar and biomass-biogas hybrid system is a viable green technology source for rural electrification.

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