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Conference Paper · September 2015

DOI: 10.1109/ICGET.2015.7315078

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3rd International Conference on Green Energy and Technology (ICGET) 11~12 September, 2015, Dhaka, Bangladesh

A Hybrid of 30 KW Solar PV And 30 KW Biomass System for Rural Electrification in Bangladesh

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Abstract

This paper is mainly addressing the design and analysis of a hybrid Solar and Biomass System for rural electrification in a remote area in Bangladesh by Decentralized Distributed Generation & Rural Power Distribution Management. A large proportion of the world's population lives in remote rural areas and far away from grid. Hybrid technology provides interesting opportunities to overcome certain technical limitations and to mitigate fuel price increases, deliver operating cost reductions, and offer higher service quality than traditional single-source generation systems.

Solar Technology

Sun is the primary source of energy. It is renewable, inexhaustible and environmental friendly. Bangladesh is blessed with large amount of sunshine all the year with an average sun power of 500W/m2/day [1] [2]. There are a variety of technologies that have been developed to take advantage of solar energy. A solar system Commonly includes :

1. **Storage Battery**
2. **Charge Controller**
3. **Solar Inverter**

Biomass Power Plant

Using biomass solely for electricity generation is seen as an inefficient use of biomass. Only a small portion of the total energy created from burning biomass actually gets converted into electricity. Combustion of biomass produces heat, which is used to generate steam, which in turn rotates a turbine to create electricity. Biomass particles size ranges varies from 5 cm to few mm.

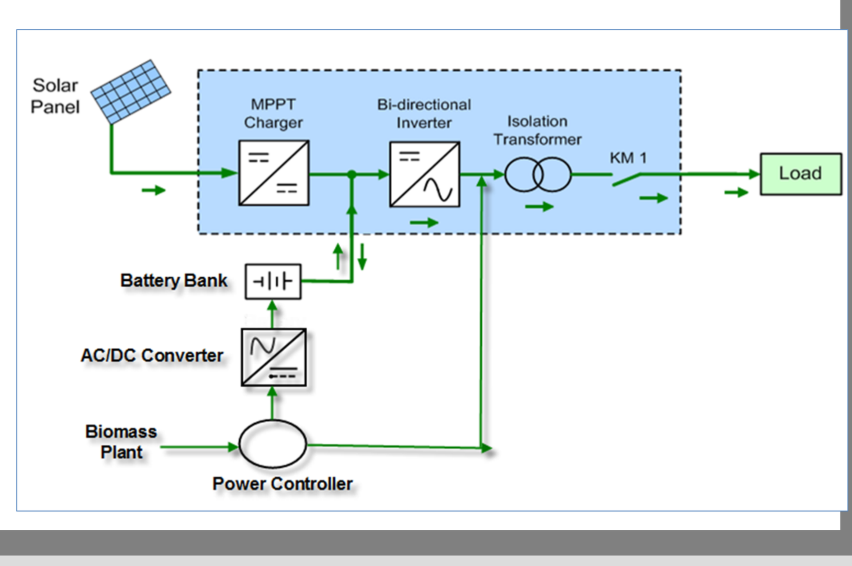
Analysis and Design

The typical load curve for a rural village is generally composed of a prominent peak in the evening corresponding to lighting use, a morning/midday peak, and a base load. The base load is generally present in the morning, and in some cases extends to night hours. In many cases the peak load is two to five times higher than the highest power level of the base load. The energy demand in rural areas during night hours is quite limited (or non-existent in small villages) and hence the load level during the night is generally very low compared to the evening and morning peaks. This is shown in Tabel I.

TABLE I: LOAD ESTIMATION

Details	Number	Rating (Watt)	Total Load (Watts)	Hrs of Operation	Energy (WH)
Compact fluorescent lamps (18W)	450	18	8100	12	97200
Fan	150	70	10500	12	126000
TV	50	80	4000	6	24000
2-Pin	150	150	22500	6	135000
Water Pumps	8	1500	12000	6	72000
Street Light (TFL)	30	30	900	12	10800
		Total	58000		465000

Plant Capacity and Energy Forecast The Required Plant Capacity is 60 KW from this typical solar biomass hybrid system shown in the following figure. The total units that will be consumed per day are 465.0 KWh or Units. The target is to generate 200 Units by Solar Plant % 300 units by Biomass. About 150 Units Battery Bank are needed to store the energy of demand at Night.



Design for Solar Plant

The design consideration of Solar PV power plant is given below:

- Total watt = 30 KW
- Total Watt Hours = 200 KWh
- Solar Irradiation= 5.00 (For Bangladesh) [1] [2]
- AC Cable loss= 1%
- Inverter efficiency= 89%
- Diode and Connection Loss=0 .5%
- DC wiring loss= 2%
- Soiling efficiency= 96%
- System availability = 99%
- Temperature increase loss= 4%
- Battery efficiency= 85% [Typical value are taken]. Thus, considering these above loss, final efficiency of this system= 66%.
- Solar Panel Capacity Required $= 60640\, Watts$
- Panel Rating Selected= 240 W Therefore, the number of Panel/Module is required = (60640/240) = 253.

Array Sizing and Characteristics

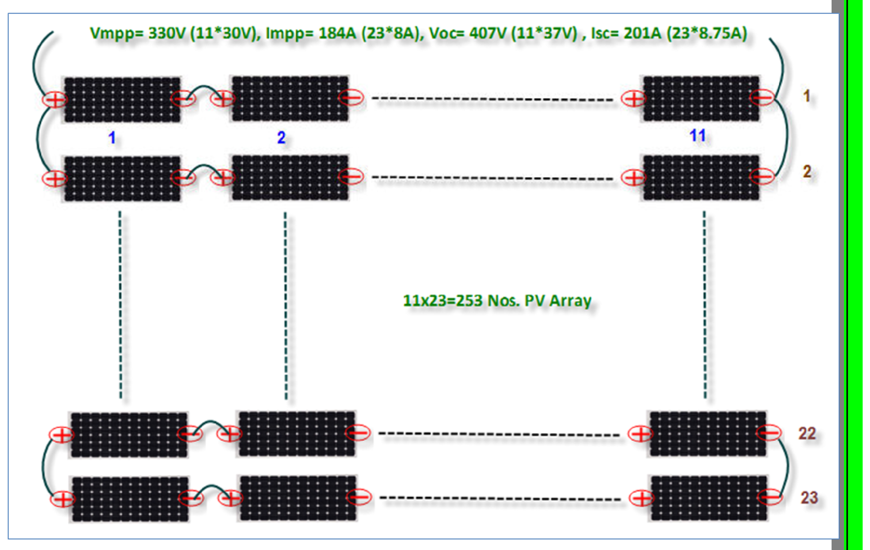
For PV array sizing, PVsyst has been used here [3]. The literature covered by [4] [5] are also another strong basement of this calculation. Here, Poly crystalline silicon solar cell and 60 cells Module/Panel has been considered.

11 Modules will be connected in series (Say, These makes a row), Then such kind of 23 rows will be connected in parallel and make an Array.

Area Required for PV Array: $20 \times 60 sq\ meter$ (Including 70% Spacing within each Module, Module Size: $1m \times 1.6m$).

Operating Characteristics:

- $Vmpp = 330V(11 \times 30V)$
- $Impp = 184A(23 \times 8A)$
- $Voc = 407V(11 \times 37V)$
- $Isc = 201A(23 \times 8.75A)$



Inverter Size

Total Watt Required = 30 KW. It is good practice to oversize the inverter from the actual requirement. Thus, the inverter size will be equal to $30 \times 1.3 = 40KW$. Output of Inverter= 415V AC, 3Phase, 40 KVA pure sine wave inverter is recommended in other to prolong the lifespan of the inverter.

Battery Size

For a storage of 150 Units of energy at Battery for Night and autonomy of one day. Specificatio of the battery is as follows:

- Inverter efficiency= 89%
- Battery loss= 85%
- Depth of discharge= 60%,
- Battery Voltage (Volts) = 240V
- The size of battery = 1377 Ah. Counting the safety margin, the battery could be selected as 1500Ah, 2V instead of 1377 Ah.
- Total number of battery required =120
- Each battery dimension $= L \times W \times H = 8.27in \times 10.8in \times 32.7in$
- Maximum charging current= $185A$.
- Area required for battery, excluding spacing is $100in \times 108in \times 32.7in$.

MPPT Charge Controller

The rated charging current should match or close to the battery maximum charge current. The design consideration of $30KW_p$ solar PV power supply,

$$P = VI \quad (1)$$

Where,

- I is the expected charging current
- V is the voltage of the battery
- P is the power supply rating= 30KW

Hence $I = P/V = 30000/240 = 125Amps$, which is less than the Maximum grid charging current of Battery.Thus, a rating with 125 Amps charging controller has been selected to charge the battery banks.

Biomass Requirement and Resource Availability

The target is to generate 300 units (KWh) of energy from 30KW Biomass Plant. Assuming daily operation hour of biomass plant is 12 to 14 Hrs,

- Overall system efficiency $= 18\%[6]$
- Calorific value of biomass $= 4000Kcal/kg = 16800KJ/Kg.[Note : 1Kcal = 4.2KJoule]$
- input energy for 1KWh of output energy is $= \frac{1KWh}{22\%} = 5.55KWh = 2 \times 10^4 KJ.$ Note: $1KWh = 1KW \times 3600second = 3.6 \times 10^3 KJ$
- For 1 KWh generation, Biomass is needed per hour is $= \frac{2 \times 10^4 KJ}{16800KJ/Kg} = 1.19Kg.$
- For 10 Hours effective operation (300 KWh generation), Biomass Requirement is$= 1.19Kg\ per\ KWh \times 300KWh = 357Kg$

Simple Pay Back Period from Hybrid System

In calculation of Simple Pay Back Period from Hybrid System,the followings are assumed.

- Total Installation Cost: $Tk.35,00,000 + Tk.96,00,000 = Tk.1,31,00,000.$
- Selling Rate of Per Unit Cost (to Government)$= Tk.12/unit.$
- Per Year Generation $= 1,82,500Units$ [1,09,500 Units by Biomass & 73,000 Units by Solar]
- Fuel Cost/per Unit= $1.18kg/KWh \times Tk.2.00/kg = Tk.2.36/unit.$
- Maintenance Cost for Biomass Plant $= Tk.3,50,000.$
- Maintenance Cost for Solar Plant = $Tk.96,000$
- Total Return= Tk. 14,85,580 ($18,570)
- Simple Pay Back Period (S.P.B) $= \frac{1,31,00,000}{14,85,580} = 8.82\ years$ (It could be assumed as 10 years)

Here, Government needs to pay Tk. 12 ($0.15) /unit from Hybrid System, whether normally Government has to pay around Tk. 20 ($0.25) /unit from Diesel/Heavy Fuel Oil (HFO) System [7]. The summary of Biomass plant and PV power plant are shown in Table II and Table III.

TABLE II: SUMMARY OF BIOMASS PLANT

Plant capacity	30KW
Cost of installation	Tk 35,00,000 ($ 43,750)
Maintenance cost	Tk 3,50,000 ($ 4,375)
No of consumers	150
Operation hours	12~14 hrs
Fuel Requirement	1.19 kg of crop/kWh
Cost of fuel	Tk 2.00/kg ($ 0.031)
Operating period	20 years

TABLE III: SUMMARY OF SOLAR PV POWER PLANT

Plant capacity	30KW
Cost of installation	Tk 96,00,000 ($ 1,20,000)
Maintenance cost	Tk 96,000 ($ 1200)
No of consumers	150
Operation hours	6.0~7.0 Hrs
Operating period	20 years

Carbon Reduction Potential

A Carbon Credit is a generic term for any tradable certificate or permit representing the right to emit one tonne of carbon dioxide or the mass of another greenhouse gas with a carbon dioxide equivalent (tCO_2e) equivalent to one tonne of carbon dioxide [2]. Certified Emission Reductions (CERs) are a type of emissions unit (or carbon credits) issued by the Clean Development Mechanism (CDM) Executive Board for emission reductions achieved by CDM projects and verified by a DOE under the rules of the Kyoto Protocol. The design considerations are:

TABLE IV: EMISSION OF CO_2 PER YEAR & THE POSSIBILITY OF EARNING MONEY

CO_2 emission Rate	Carbon credit /Per year (tonnes/ year) for 1,82,500 KWh Generation	Money will be earned through carbon credits ($) per year N.B: CER Rate $0.70	Average money ($) can be earned through carbon credits per year
From Coal: 1400 gram/ KWh	[(1400*1,82,500)/1000000] =255.5	[(255.5-8.10)*0.70] =173	128
From Oil: 1150 gram/ KWh	209.9	141	
From Natural Gas: 600 gram/ KWh	109.5	79	

TABLE V: INSTALLED OFF-GRID SOLAR PV SYSTEM IN BANGLADESH

Name of Solar PV System (Off-Grid)	Capacity	Installed Year	Total Cost per Watt (Tk/Wp)
32.75 kWp at WAPDA Building, Dhaka.	32.75 kWp	December' 2009	BDT 500 Tk./ Wp
20.16 KWp Solar PV System at the Office of the Prime Minister, Dhaka.	20.16 kWp	December' 2009	BDT 500 Tk./ Wp
37.5 kWp Solar Roof Top System on15th floor of Bidyut Bhaban, Dhaka.	37.5 kWp	2011-2012	BDT 300 Tk./ Wp
27.2 kWp Solar Power System at Chandpur 150 MW Combined Cycle Power Plant.	27.2 kWp	2012-2013	BDT 300 Tk./ Wp

Conclusion

There are many remote villages in Bangladesh which are far away from the main grid so those are still unelectrified. Due to the distance problem, losses increases and installation cost for transmission and distribution line goes high. This paper discussed the renewable hybrid system with solar PV and biomass which helps in overcoming all these problems in a cost effective way. In this paper the load requirement of this village is calculated and in order to satisfy this load the energy requirement is predicted.

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