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. Energy is crucial input in the process of economic, social and industrial development. Energy plays a vital role in our daily life. But the conventional source of energy to produce electricity is decreasing day by day significantly. In this regards non-conventional or renewable energy resources such as bio-energy, Solar, Wind, Ocean and Geothermal are taking this challenge. A large proportion of the world's population lives in remote rural areas and far away from grid. The installation and distribution costs are considerably higher for remote areas. Moreover, there is greater transmission line losses and poor supply reliability. There is growing interest in harnessing renewable energy sources since they are available in abundance, pollution free and inexhaustible. Not only that, The combining of technologies means 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. A hybrid system is a dynamic system that exhibits both continuous and discrete dynamic behavior a system that can both flow and jump.**

Keywords*—*hybrid solar & biomass design, renewable energy, carbon trading

I. Introduction

Bangladesh is a developing country in the southern Asia of Asian Country. Bangladesh, with its 152 million people in a land mass of 147,570 sq km, has shown tremendous growth in recent years. A booming economic growth, rapid urbanization and increased industrialization and development has increased the country's demand for electricity. Presently, 62% [1] of the total population (including renewable energy) has access to electricity and per capita generation is 321 KWh [2], which is very low compared to other developing countries. The power supply is not sufficient to meet the peak demand in Bangladesh. In the rural areas, only about 25 percent population have grid electricity connection where about 75 percent of that out of grid electricity. At this time, the country is facing a dour electricity exigency due to growth of almost each and every sector. According to the Rural Electrification Board in Bangladesh the present peak and off peak hour the scarcity of electricity is almost 15-20 percent of generation. Due to the limitations of use natural fuels and also the shortage of fossil fuels, the government already has focused on the renewable energy and about its technology and hybrid system.

II. 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 [3] [4]. There are a variety of technologies that have been developed to take advantage of solar energy. Name of Some Technologies are :

1) Concentrating Solar Power (CSP)
2) Solar Photovoltaic (PV)
3) Solar Thermal
4) Solar Fuels

The major components of the system 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 basic unit of photovoltaic technology is photovoltaic or solar cell. A typical crystalline silicon (c-Si) PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer (100 - 350 microns) of boron-doped (P-type) silicon. An Electrical field is created where the these two materials are in contact, called P-N junction and the direction of Electric Field from n to p side. When sunlight strikes the surface of a PV cell, Each photon frees exactly one electron which is directed by the electric field and flows toward the load. Multi or Poly crystalline silicon solar cell is more widely used due to lower cost of manufacturing and ease of availability. PV panel manufacturers generally guarantee 90% of initial performance after 10 years and 80% after 25 years [5].

Solar cells are generally very small, and each one may only be capable of generating a few watts of electricity and voltage of around 0.6V. About 40 or 60 or 72 cells are typically connected in series to make a module. Typical output range of a module from 100 W to 360 W, but most commonly used wattage is 245-250 W in a 60 cell configuration. The modules are in turn assembled into PV arrays up to several meters on a side.

A. 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. The lifespan of the battery depends on many parameters related to the way they are operated and to external conditions, in

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particular the ambient temperature. For instance, typical lead-acid batteries designed for solar energy applications will lose between 15% to 20% of their lifespan [3] [5] the number of charge/discharge cycles they can perform) for each 5C above the standard temperature of 25C. In addition, the deeper the battery is discharged at each cycle (depth of discharge), the shorter its lifespan. This implies that to reach an optimal battery lifespan, one has to install a large enough battery to achieve a suitable depth of discharge. Considering the battery cost (around 20% to 30% of total system cost), we need to provide good attention to select it.

B. Charge Controller

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. It disconnects the loads when the battery voltage fall below a critical voltage. The charge controller must also ensure that the connected loads do not over-discharge the battery, thereby damaging it. Most "12 volt" panels batteries need around 14 to 14.5 volts to get fully charged.

The rectifier and charge controller component should be chosen so that both the PV and the genset can charge the battery. The rated charging current should match the battery maximum charge current. The charge controller should be able to manage the various charge steps, including regular equalization and float charge to maximize battery lifespan.

C. Solar Inverter

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 on-board 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. An inverters lifespan can extend to more than ten years, but this component is a high-technology product and the replacement of a failing component has to be undertaken by a technician from the supplying company.

D. Biomass Power Plant

Using biomass solely for electricity generation is seen as an inefficient use of biomass. Typically overall efficiency of Biomass Steam Turbine Power Plant is 18% 24%. 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.

When steam passes through a turbine it only loses a portion of its thermal energy. When it exits the turbine it still has a relatively high thermal energy and normally this heat is vented to the atmosphere through smoke stacks. Combined heat and power systems (CHP) focus on capturing this heat and using it for productive purposes [6]. By attaining a higher efficiency in energy creation, CHP can result in energy cost savings, waste heat reduction and lower CO_2 emissions. Processing plants that require high amounts of heat and electricity such as pulp and paper mills are ideal for this application. The key to a successful CHP plant is that there must be a demand for the heat that is captured from the electricity generating process. 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%.

III. Analysis and Design Result a Typical Context of Power Needs in Rural Areas

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

A. Plant Capacity and Energy Forecast

The Required Plant Capacity is 60 KW from this typical solar biomass hybrid system shown in Fig. 1. 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. (Assuming Daily Operation Hour of Biomass Plant is 12 to 14 Hrs). About 150 Units fo energy will be stored in the Battery Bank to meet demand at Night.

B. 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) [3] [4]

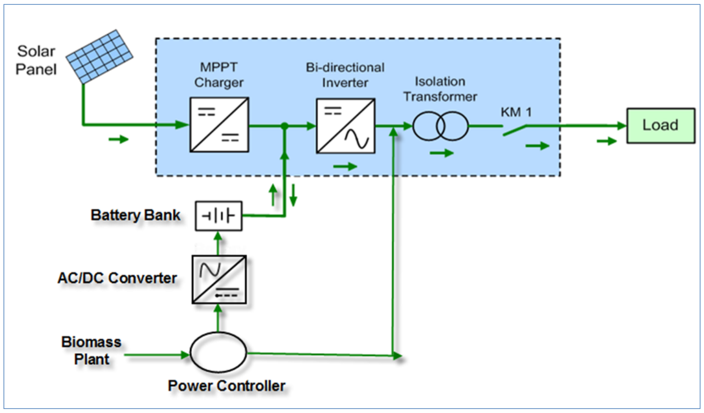

Fig. 1: Block Diagram of Solar-Biomass Hybrid System.

- 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 $= \frac{Watt\ Hours}{System\ Efficiency \times Solar\ Irradiation} = \frac{200000}{66\% \times 5}$ $= 60640\ Watts$
- Panel Rating Selected= 240 W
  Therefore, the number of Panel/Module is required = (60640/240) = 253.

C. PV Array Sizing and Characteristics

For PV array sizing, PVsyst has been used here [7]. The literature covered by [10] [9] are also another strong basement of this calculation. Here, Poly crystalline silicon solar cell and 60 cells Module/Panel has been considered with specification of

- Power, $P = 230 - 250W$
- Open circuit voltage $V_{oc} = 36 - 37V$
- Voltage at maximum power point, $V_{mpp} = 29.5 - 30V$
- Short circuit current, $I_{sc} = 8.75A$
- Current at maximum power point, $I_{mpp} = 8.0A$

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. The series parallel combination of solar PV module is shown in Fig. 2.
Area Required for PV Array: $20 \times 60 sq\ meter$ (Including 70% Spacing within each Module, Module Size: $1m \times 1.6m$). Operating Characteristics:

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

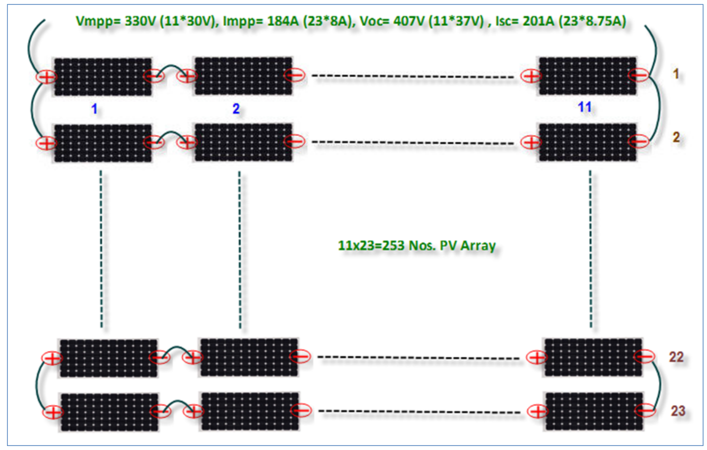

Fig. 2: Series Parallel Combination of Solar PV Module

D. 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.

E. 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 $= \frac{150000KWh}{0.89 \times 0.85 \times 0.6 \times 240V} = 1377Ah$. Counting the safety margin, the battery could be selected as 1500Ah, 2V instead of 1377 Ah.
- Total number of battery required $= \frac{240V}{2V} = 120$
- 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 $100in \times 108in \times 32.7in$.

F. 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,

$$P = VI \tag{1}$$

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.

G. 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 $= \frac{2\times10^4 KJ}{16800KJ/Kg} = 1.19Kg.$
- For 10 Hours effective operation (300 KWh generation), Biomass Requirement is$= 1.19Kg\ per\ KWh \times 300KWh = 357Kg$

H. 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= $Tk.[(12\times1,82,500)(2.36\times1,09,500+ 3,50,000+96,000)] = Tk.14,85,580(\$18,570)$
- 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 [12]. 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

IV. 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 [4] [8]. 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:

- CO_2 emission from Biomass per unit generation (During Construction & operation) = 7 tons/TJ= 26 gram/Kwh; [1tons/TJ= 3.612 g/Kwh]
- CO_2 emission from solar pv plant per unit generation [During Construction % operation] = 20 tons/TJ = 72 gram/kwh.
- Generated power from biomass per year $= 300X365 = 1,09,500KWh.$
- Per year we can generated power per year $= 200X365 = 73,000KWh.$
- CO_2 emission from biomass per year $= 1,09,500 * 0.026kg = 2.85\ tons/year = 2.85\ Carboncredit.$

- CO_2 emission from Solar PV per year $= 73,000 * 0.072 = 5.25\ tons/year = 5.25\ Carboncredit$.
- From total hybrid system, the carbon emitted per year $= 2.85 + 5.25 = 8.10\ tonnes/year$

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	

Installed Off-Grid Solar PV System in Bangladesh [11] in shown in Table V.

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

If the same energy $(1,09,500KWh + 73,000KWh = 1,82,500KWh$)/per year is generated through conventional energy resources like coal, Gas, Oil etc. Then carbon dioxide emitted per year & the possibility of earning money (approximate and average) through carbon credits per year are given in Table IV.

Therefore, it seems that the total cost [installation & Operation] for an off-Grid Solar PV system [including Battery System] is decreasing gradually.

V. CONCLUSION

There are many remote villages in Bangladesh which are far away from the main grid so those are still un-electrified. 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. As we know that the reserve natural gas in Bangladesh is diminishing quickly, Government should take proper steps to promote the renewable energy activities. Both sun light and the biomass are available in Bangladesh abundantly. It can be concluded that solar and biomass hybrid system is a viable green technology source for rural electrification.

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