Present Scenario of Renewable Energy in Bangladesh and a Proposed Hybrid System to Minimize Power Crisis in Remote Areas

Nahid-ur-RahmanChowdhury*, Syed Enam Reza*, TofaeelAhamedNitol*, Abd-Al-Fattah-IbneMahabub*

*Department of EEE, Ahsanullah University of Science & Technology, Dhaka-Bangladesh

‡Corresponding Author; Nahid-ur-RahmanChowdhury,Department of Electrical & Electronic Engineering, Ahsanullah University of Science and Technology, Dhaka-Bangladesh, +8801717 242809,nahid_aust07@yahoo.com, rsyedenam@yahoo.com, tofaeelahamed@yahoo.com, ibne_mahabub@ymail.com

Received: 02.03.2012 Accepted:01.04.2012

Abstract-Bangladesh is experiencing an acute shortage of electric power that is likely to be worsening day by day which stresses the need for the deployment of renewable energy resources to extenuate this energy crisis. Since Bangladesh is a country which is abundant in natural resources; the substantial availability of renewable energy sources in the form of solar, biomass, biogas, hydropower and wind energy can provide opportunities of sustainable energy based development. This paper presents a comprehensive study of the contemporary renewable energy scenario in Bangladesh and a proposed grid connected hybrid system by utilizing five different alternative energy resources to mitigate the rising demand of electricity especially in remote areas which can be used for domestic as well as commercial applications. In Bangladesh, nearly 72% of the population lives in rural areas and renewable energy is considered to be the right choice for providing clean energy to these remote settlements.

Keywords-Renewable energy, hybrid system, gasification, solar power, wind power, biomass, biogas, micro hydro

1. Introduction

There is no creation or extinction of energy. It can only be transformed. To get electrical energy, generally hydrocarbon resources are used. Since the energy situation in Bangladesh is extremely critical and major power stations here are run by natural gas; as a result the gas reserve has fallen to such an alarming level that if no new reserves are discovered then this reserve may last for another 6 to 7 years. So generation of electricity from the alternative sources has become the crying need for Bangladesh [1]. Bangladesh has a vast potential for renewable energy and the natural availability of alternative energy creates opportunities of growth in power sector. Not only the technologies should be developed to produce energy in an environment friendly manner but also enough importance should be given to conserve the energy in most efficient form. Government has issued its Vision and Policy Statement in February 2000, to bring the entire country under electricity service by the year 2020 in phases [2]. From an authentic study we find that in 2012, the peak power demand is about 6000 MW per day while in full summer it may grow up to 7000 MW [3]. Small hybrid system which uses renewable sources as a plant material might be an effective solution of this power crisis. As we are using several renewable sources, the reliability of such hybrid network is higher than using only one renewable source. The important feature of this type of hybrid system is; it can operate on both off grid and on grid condition. In Bangladesh, only 40% of the population has access to electricity with a per capita availability of 136 KWh per annum [4]. There are more than 87,319 villages in Bangladesh, and most of them are not connected to the national grid. In view of the dispersion of localities, the low demand, the cost of production, transmission and especially distribution of electricity would be prohibitively expensive for these regions. Decentralized and standalone systems could effectively become a viable option in these areas [5]. In the perspective of Bangladesh, several NGOs like IDCOL (Infrastructure Development Company Limited), GS (Grameen Shakti), Rahim Afrooz, BRAC (Bangladesh Rural Advancement Committee), CCDR (Center for Community Development & Research) foundations are working to develop our electricity sector [6].

2. Physical Perspective of Renewable Energy in Bangladesh

Bangladesh situated in the north-eastern part of south Asia is among the world's most densely populated nations (1099 people/km^2 in 2010) with a population of 162.20 million in 2011 [7]. Energy, and more explicitly electricity, is a prerequisite for the technological development, higher economic growth and poverty reduction of a nation. The future economic development of Bangladesh is likely to result in a rapid growth in the demand for energy with accompanying shortages and problems. The country has been facing a severe power crisis for about a decade [8]. Out of various renewable sources hydropower, geothermal, solar, tides, wind, biomass, and bio fuel can be effectively used in Bangladesh [9]. Solar energy is the most readily available and free source of energy in our country and traditionally solar thermal energy has been utilized in different household and industrial activities in Bangladesh. Several organizations have installed low capacity wind turbines, mainly for battery charging in the coastal region of Bangladesh. However, progress in the wind energy sector of Bangladesh is not impressive [10]. Micro Hydro Power Plants can be installed in the north-eastern hilly regions and in the existing irrigational canal system with a sufficient head. The only hydro power station of the country, the Karnafuly Hydro Power Station with a generating capacity of 230 MW by 7 units, is located in Kaptai across the river Karnafuly [11]. There are scopes of integrated small tidal power plants in the coastal regions. Biomass is the fourth largest source of energy worldwide and provides basic energy requirements for cooking and heating of rural households in developing countries like Bangladesh [12].

An agriculture based country like Bangladesh has huge potentials for utilizing biogas technologies. According to IFRD-there is potential of about four million biogas plants in our Country [10]. It is notable that Bangladesh Government has planned to produce 5% of total power generation by 2015 & 10% by 2020 from renewable energy sources like air, waste & solar energy [13]. Based on the information obtained, a comparative scenario of the five leading renewable energy sectors of Bangladesh is illustrated in "Fig. 1" in terms of the installed capacity [14].

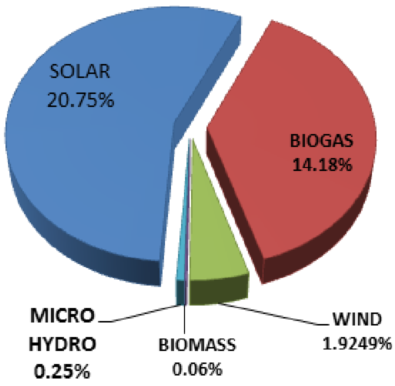

Fig. 1. Contribution of different implemented renewable sources in Bangladesh

3. Overview on Different Renewable Energy Sources

3.1. Solar Power

Solar panels are the medium to convert solar power into the electrical power. Sun beam is absorbed with the panel material and electrons are emitted from the atoms that they are bounded. This releases current thus solar power is converted into electrical power [15]. When PV cells are joined physically and electrically and placed into a frame they form a solar panel or PV module. Panels joined together form a solar array.

The sunlight impinging on panels, i.e. irradiance or insolation (incoming solar radiation), is measured in units of watts per square meter (W/m^2).We can use only 25% of sunlight radiation for PV module [16]. The PV system power output (DC) has approximately a linear relationship to the insolation. Using the solar radiation available on the tilted surface the hourly energy output of the PV generator can be calculated according to following equation:

$$P = A \cdot x^2 + B \cdot x + C \text{ (in Watts)} \quad (1)$$

Where, x= solar radiation, P=power generation, and A, B, C are constants, which can be derived from measured data. By using above formula, we can predict solar power generation at any solar radiation.

3.2. Wind Power

Wind power involves converting wind energy into electricity by using wind turbines. A wind turbine is a machine that converts the kinetic energy in wind into mechanical energy [17]. A wind turbine is composed of three propellers-like blades called a rotor. The rotor is attached to a tall tower which is 20m high. Wind comes from atmospheric changes; changes in temperature and pressure makes the air move around the surface of the earth; all of which is triggered by the sun [18].

The power output of a turbine is a function of the cube of the wind speed, so as wind speed increases, power output increases dramatically. Areas where winds are stronger and more constant, such as offshore and high altitude sites are preferred locations for wind farms [19]. We cannot convert all the wind energy into electricity: we can convert only 59%, according to Betz limit [15].The output equation for a wind generator is given by:

$$P = (\frac{1}{2}) \times \rho \times A \times v^3 \text{(in Watts)} \quad (2)$$

Where, A=area perpendicular to the direction of flow (in m^2), v=wind velocity (ms^{-1}), ρ =density of air (in Kgm^{-3}) and P=power generation.

3.3. Biomass

Biomass, as a renewable energy source, is biological material from living, or recently living organisms. Biomass covers all kinds of organic matter from fuel wood to marine vegetation. As an energy source, biomass can either be used directly, or converted into other energy products such as bio fuel [20]. Sources include forest residues rice husk, dead trees, branches, yard clippings, wood chips and even municipal solid waste, hemp, corn, poplar, willow, sorghum, sugarcane etc.

Bangladesh is a major rice producing country. It produces on the average about 35,000,000 MT of Paddy per Year. If only 20% of this paddy i.e. 7,000,000 MT could be made useful through the gasification technology; then the Power generation from Rice Husk could be of a significant amount.

By using the gasification technology the output equation for a biomass generator is given by (considering 50% efficiency):

$$\text{Pbiomass}=\frac{\text{50\% of 7,000,000 MT/year rice husk}*\text{1000 Kgs/MT}*\text{1,000}}{\text{2 kgs husk/kwh}*\text{16 hours operation a day}*\text{300 days/year}} \text{(in Watts)} \quad (3)$$

This is approximately 364 MW of power generation. Where we assume that, 2 Kgs of husk is needed in an hour to produce 1 KW of power. [1 MT = 1,000kgs]

3.4. Biogas

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Organic waste such as dead plant and animal material, animal dung, and kitchen waste can be converted into a gaseous fuel called biogas. Biogas originates from biogenic material and is a type of bio fuel [21]. Major components of biogas are 50-70% methane (CH_4) and 30-40% carbon dioxide (CO_2). It also contains several trace gases like hydrogen sulphide (H_2S), nitrogen (N_2), hydrogen (H_2), ammonia (NH_3) and carbon monoxide (CO) totaling the rest [22].

A biogas based electricity generation system consists of a digester, a biogas collection tank, a generator as well as the piping and controls required for successful operation. The biogas is produced in the anaerobic digester, where anaerobic fermentation takes place which is provided everyday with livestock manure in the form of cattle dung. Anaerobic fermentation is the fermentation in the absence of air of cellulose containing organic materials, like cattle dung, poultry droppings etc. This biogas can be used to generate power using a diesel engine with diesel as pilot fuel and biogas as main fuel. This mode of operation is known as dual fuel mode.

Assuming on average 34-40% conversion efficiency from biogas to electricity, it can be modeled using the following expression [23]:

$$e_{biogas} = E_{biogas} \times \eta \quad (4a)$$

Where, E_{biogas} represents the unconverted raw energy in the biogas (typically listed in BTUs), e_{biogas} is the total electricity that can be generated from biogas, and η is the overall conversion efficiency.

Including unit conversions, the total electricity in kWh that can be produced from biogas can be found with the following equation.

$$e_{biogas} = E_{biogas}\,[BTU] \times 0.00293\,[\frac{kwh}{BTU}] \times \eta \text{(in KW)} \quad (4b)$$

Equation (4b) was evaluated for each animal type for the lower and upper values of the efficiency range of 34-40%.

3.5. Micro Hydro

Hydropower is an eco-friendly clean power generation method. The concept of generating electricity from water has been around for a long time and there are many large hydro-electric facilities around the world. What is new to most people is the idea that this same concept will work on a smaller - and even individual - scale. In different regions there are different scale of power is defined for micro hydro. In Bangladesh it is of 5-300 KW range [17], while in some other regions it is defined for less than 100KW [24].

A hydro power scheme requires both water flow and a drop in height (referred to as a head) to produce useful power. It is a power conservation system, absorbing power in the form of head and flow, and delivering power in the form of electricity or mechanical shaft power. Indeed no power conservation system can deliver as much useful power as it absorbs. Some power is lost by the system itself in the form of friction, heating, noise etc. Net power generation from a hydro power unit could be obtained from the following expression [5]:

$$P = H \times Q \times g \quad \text{(in KW)} \quad (5)$$

Where, P=Net power generated from the unit (in KW), H=Gross water head (in meter), Q=Flow of water (in m^3/sec), g=Gravitation force i.e. 9.81 is acceleration due to gravity which can be assumed to be constant (in ms-2)

4. Present Status of Renewable Energy in Bangladesh

4.1. Solar power

Solar radiation varies from season to season in Bangladesh. So we might not get the same solar energy all the time. In "fig.2" the monthly average solar radiation pattern is shown.

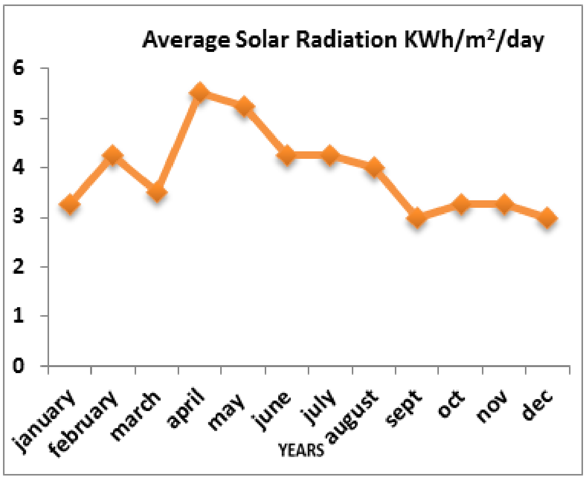

Fig. 2. Monthly average solar radiation profile in Bangladesh

Daily average solar radiation varies between 4 to 6.5 KWh per square meter. Maximum amount of radiation are available in the month of March-April and minimum in December-January [25].

According to IDCOL, the total capacity of solar energy based installations in Bangladesh appears to be 20.75 MW [26]. The amount is significant considering the upward trend of the number of SHSs (Solar Home System) installations in the country.

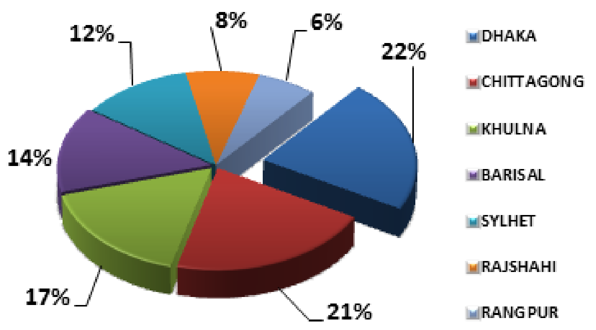

Fig. 3. Distribution of the SHSs (Solar Home System) in seven divisions in Bangladesh [27]

The "fig. 3" shows the approximate division wise SHSs installation. The figure illuminates that the distribution of the SHSs is highest in the Dhaka district whereas lowest in the newly formed district Rangpur.

4.2. Wind Power

It has been studied that the average wind speed is maximum during the month of April which is approximately 5.3 ms^{-1} and minimum in the month of December which is around 2.6 ms^{-1} in Bangladesh [15].

There is a good opportunity in island and coastal areas for the application of windmills for pumping and electricity generation. A number of small wind generators have been installed by several agencies in coastal areas. The "Table 1" below shows an overall scenario on the wind energy programs undertaken by different organizations of Bangladesh.

Table 1. Wind turbine installations in Bangladesh by different organizations [10]

Organization name	Type of Application	Installed Capacity(Watt)	Location	Present Status
Grameen Shakti	3 Hybrid	4,500	Grameen Offices in the Coastal Region	Functioning
	Hybrid	7,500	Cyclone Shelter in the Coastal Region	Functioning
BRAC	Stand-alone	900	Coastal Region	Functioning
	Hybrid	4,320	Coastal Region	Functioning
Bangladesh Army	Stand-alone	400	Chittagong Hill Tracts	Functioning
IFDR	Stand-alone	1,100	Teknaf	Functioning
	Stand-alone	600	Meghnaghat	Functioning
LGED	Wind-PV Hybrid	400	Kuakata	Functioning
	Total	19,720		

4.3. Biomass

Bangladesh is an agricultural country so biomass is available in huge amount. Cattle dung, agricultural residue, poultry dropping, water hyacinth, rice husk etc. used for biomass power generation are available in Bangladesh [2].

The "fig. 4" below indicates that the amount of rice production in Bangladesh has been increased in recent years and this amount of production has made us more optimistic in using the rice husk as a biomass fuel which is nevertheless a perfect source of renewable energy in the context of Bangladesh [28].

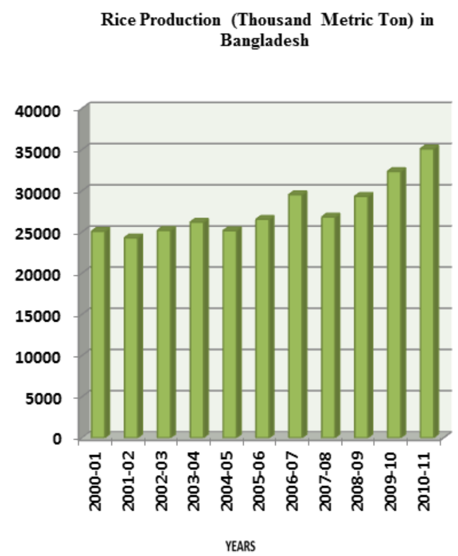

Fig. 4. Rice production (Thousand Metric Ton) in Bangladesh in past eleven years

In our studies we have focused on the biomass gasification technology using rice husk as a plant material.

By using the "equation (3)" we can calculate the total power generation Considering only 20% i.e. 7,000,000 metric ton of the total rice production of Bangladesh in the year of 2010-2011 which results in 364 MW of electricity.

To tap the unharnessed potential of biomass energy resources, IDCOL financed the first and only biomass gasification based commercial power plant at Kapasia of Gazipur district. The project, which has an installed capacity of 250KW, was initiated in 2005 by Dreams Power Private Limited (DPPL) [14]. The project started its commercial operation in October 2007.

4.3.1. Gasification

Gasification is very important in processing biomass. Biomass gasification is a process of converting solid biomass fuel into gaseous combustible form (called producer gas) by means of partial oxidation carried out in a reactor called gasifier at elevated temperatures [29].

Biomass gasification is a process of converting solid biomass fuel into gaseous combustible form (called producer gas) through a sequence of complex thermo chemical reactions. For power generation, biomass gasification technique consists of three major components; gasifier unit, gas production unit, internal combustion (IC) engine [6]. Through this technique rice could be the source of food as well as electricity. In the first stage partial combustion of biomass to produce gas and char occurs along with generation of heat. This heat is utilized in drying of biomass to evaporate its moisture as well as for pyrolysis reactions to bring out volatile matter and provide heat energy necessary for further endothermic reduction reactions to produce producer gas which mainly consist of mixture of combustible gases such as CO (carbon monoxide), hydrogen (H_2), traces of methane (CH_4) and other hydrocarbon. Normally air is used as gasifying agent, however use of oxygen can produce rich higher calorific value gas but due to cost implications is not usually preferred [6]. Reasons for selecting gasification technique:

1. Relatively cheaper option for small scale industrial as well as power generation applications.
2. More efficient than traditional rice mills.
3. Environmental benefits as Co_2 gas is reduced.
4. Time Savings for Collection of Fuel.

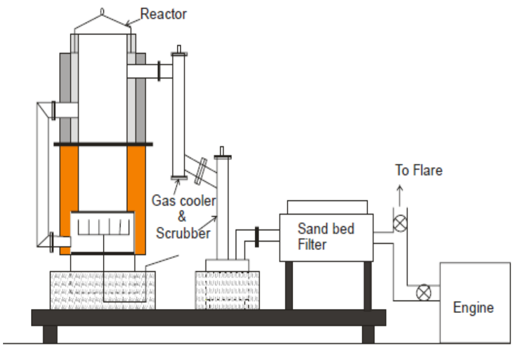

Fig. 5. Schematic representation of Gasifier

4.4. Biogas

Bangladesh has a wonderful climate for biogas production. The ideal temperature for biogas is around 35ºC. The temperature in Bangladesh usually varies from 6ºC to 40ºC and also the raw materials for biogas are easily and cheaply available everywhere in this country [30].

Bangladesh being an agricultural country, raw materials for biogas are easily and cheaply available everywhere. The Government along with several NGOs is working together for development of power production from Biogas. Grameen Shakti is one of the most uttered NGO in field of biogas. They have completed 13,500 biogas plants [31]. Recently Seed Bangla Foundation has proposed a 25 KW Biogas based Power Plant in Rajshahi [32].

IDCOL, a Government owned Investment Company fixed a target to set up 37,669 biogas plants in Bangladesh by 2012, under its National Domestic Biogas and Manure programmers (NDBMP). It has also set a target of 25 per cent of the total target of biogas plants in the northern region which is yet to be brought under the national gas grid [33]. Besides working in partnership with IDCOL, some organizations have constructed domestic biogas plants with their own funds. These are Grameen Shakti (about 3,664 plants of their own), BRAC (about 3,664 plants of their own), and some other private organizations which promote biogas plants independently [14].

Moreover, since May 2011, IDCOL along with its partner organizations; has installed 18,713 biogas plants in different parts of Bangladesh [34].

4.5. Micro Hydro

Several reconnaissance surveys and studies have been conducted in the past for installing small hydro power plants in the country, but so far only one hydro power plant has been installed. SRE under LGED has successfully demonstrated first micro-hydro power unit at Bamerchara, Chittagong. Its installed capacity was 10KW but due to inadequate water head about 4KW power was generated. SRE has also carried out a study on prospective micro-hydro sites in the Chittagong Hill Tract reasons and eight potential sites were identified with an estimated capacity of 135kW. SRE also provided technical support to promote indigenous technology (wooden water wheel which is driving locally procured generator) of micro-hydro power generation unit which was developed by member of local indigenous community named Mr. Aung Thui Khoyan [10, 35].

A recent study on Sustainable Rural Energy shows that micro hydro power plants are able to provide necessary power supply for rural areas. The study was conducted on the micro hydro power plants of generation capacity starting from 3KW up to 30KW [35]. These plants are in:

- Nunchari Tholipara, Khagrachari
- Chang-oo-Para, Bandar ban
- Bangchari, Bandar ban
- Liragaon, Bandar ban
- Kamalchar, Rangamati

- Thang Khrue, Rangamati
- Monjaipara, Bandar ban

5. Proposed Hybrid System

Our proposed hybrid system is designed for both on grid and off grid operation to reduce dependency on the national grid for electrical supply. The "fig. 7" shows the block diagram of a typical hybrid grid connected power system. The system consists of PV generators, wind generator, biogas, biomass (rice husk), micro-hydro, battery bank, battery charge controller and the dump load. The provisions for the availability of both AC and DC buses are made using converters. Here the input from solar and wind is directly fed to the charge controller to the battery bank; whereas the input from biogas, biomass (rice husk), micro-hydro is fed by converting them from AC to DC. Here the dump load is used to put power when the batteries are fully charged. Then the output from charge controller which is used to control loads and inverter. So that we may get both DC and AC output. The DC loads are directly supplied from load controller whereas an inverter is used to supply to the AC loads.

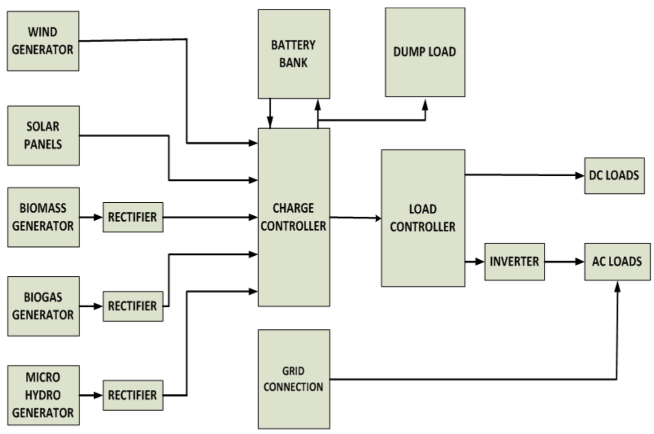

Fig. 7. The configuration of proposed hybrid energy system

5.1. Charge Controller

A charge controller's job is to regulate the voltage and current coming from and going into battery. So a charge controller takes the power from somewhere (usually a solar panel installation, wind, or solar) and pushes it into the battery at the right levels. It is used to sense when the batteries are fully charged and to stop or decrease the amount of energy flowing from the energy source to the batteries [36].

Discharging a battery, or taking the power out of it, can be controlled by a charge controller, and the point of doing so is to protect the battery. Batteries are not designed to be fully discharged. If we do run our batteries all the way down, it will ruin their life expectancy. So a charge controller can be used to protect the batteries by sensing when they are full, ½ ways done, and need to be shut off to remain protected. Since the batteries are the most expensive part of the system, by using a charge controller to protect them is usually a good idea.

5.2. Dump Load

A dump load is a secondary place to put power when the batteries are fully charged. Since the batteries are a sizeable investment in any autonomous power arrangement, they need to be protected from overcharging which will shorten their life span. Simply the dump load takes the power when the charge controller senses that the batteries are full, to protect them [36]. Once the power has been diverted, the dump load uses the power for something productive rather than lose it directly into the ground.

6. System Flow Chart and Algorithm

The proposed algorithm in "fig. 8" has been designed in such a way that the maximum utilization of our renewable resources can be made. This algorithm has been designed to operate on both on-grids as well as off-grid system especially for remote or rural areas where the supply of grid power is not continuous and the power interruption occurs in a regular interval. So, our main objective is to use these natural resources to produce electricity during the period of these intervals which means the continuation of power supply is maintained.

According to this flow chart we can see that at first we will measure the wind speed from wind generator; if the wind speed is greater than 4 ms^{-1} then the battery bank will charge, if not then it will go to measure the solar radiation. If the radiation is sufficient to produce electricity then the battery bank will charge or else it will go to measure rice husk (biomass) .If the rice husk is more than 10kgs then again the battery bank will charge or then will go to the biogas scheme. In case of the failure of biogas scheme eventually it will measure the speed of water flow of micro hydro generator. If the water flow is greater than 1000 ms^{-1} then the battery will charge or else the loads will take power directly from the grid if the grid power is available. However, in case of unavailability of the grid power, the system will again go to measure the wind speed and thus will repeat the entire process. Here the battery bank can feed electricity to the DC loads and to AC loads using an inverter in between loads and the battery bank as well. It has to be mentioned that the output voltage of the power system generator is 12v and the consumer uses 60% of the available power while the rest is being used for battery charging.

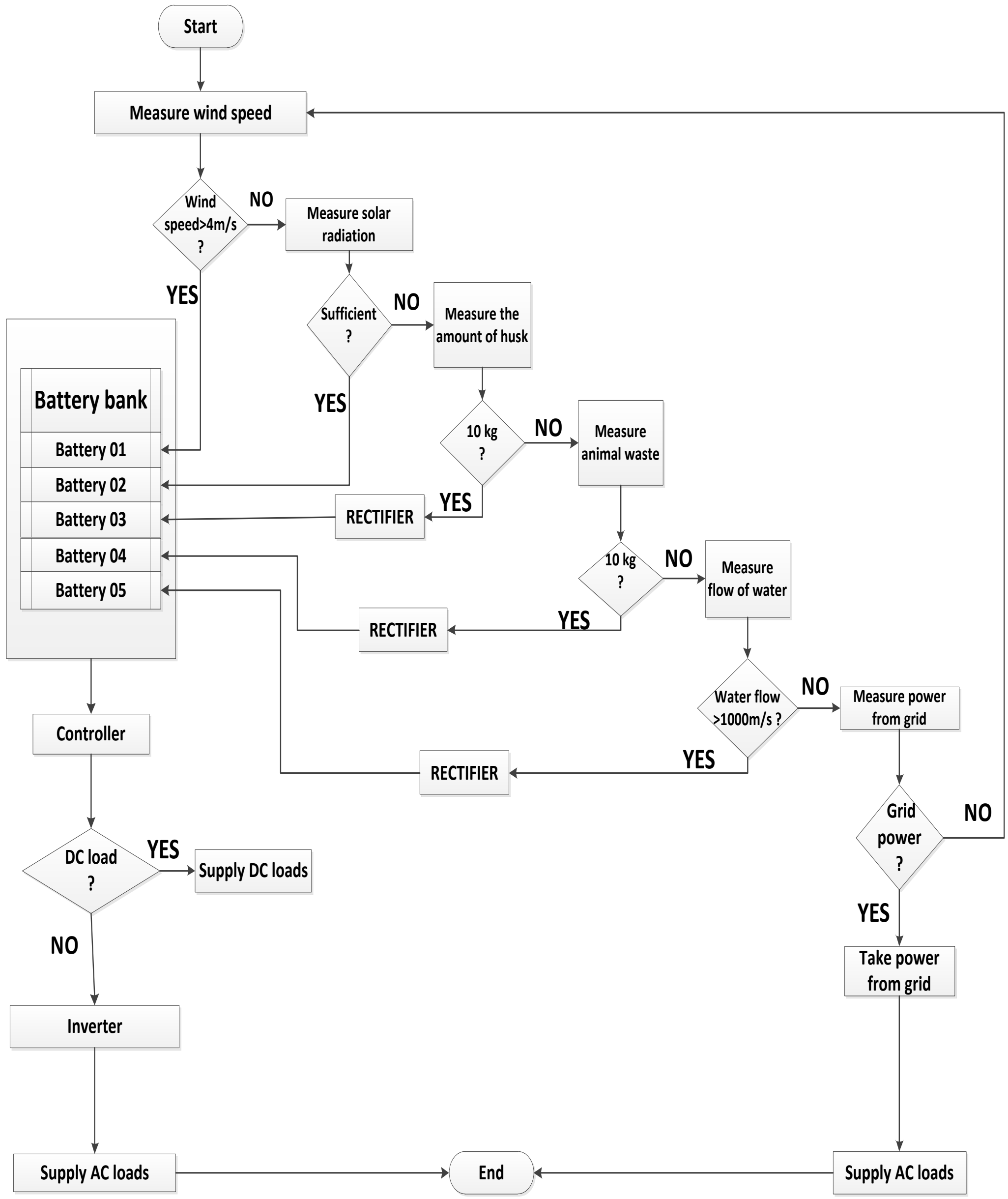

Fig. 8. Complete flow chart of proposed hybrid system

6.1. Load Sharing and Electricity Generation from Proposed Hybrid System

6.1.1. Capacity Calculation of Solar Power

The solar network will come into operation when there is a direct sun condition of the day. On average (as a general "rule of thumb") modern photovoltaic (PV) solar panels will produce 8 - 10 watts per square foot of solar panel area. For example, let us consider an area of 20 feet by 20 feet which is 400 square-feet (20 ft x 20 ft).

In our calculation we are assuming that the solar panel will produce roughly 9 Watts per square foot of area. So, the generated power is:

P_{solar} = (Area per sq- ft × watts per sq-ft)
P_{solar}= (400 × 9)
P_{solar}= 3,600 Watts

i.e. 3.6 KW of electric power. The calculation above has made in a simple way to avoid complexity of deducing different constants and associated data mentioned in "equation 1".

6.1.2. Capacity Calculation of Wind Power

In practice, the efficiency of commercially-manufactured wind rotors is typically 25% to 45%. Small wind turbines tend to have efficiencies at the lower end of this range.For instance, for a wind turbine with a blade diameter of 1.7 m and an operating efficiency of 25% at a wind speed of 6 ms^{-1}. Then, to calculate how much power the turbine can generate at this wind speed:

Rotor swept area:

Area (A) = Π ×(Diameter/2)^2 = 3.14 × (1.7/2)^2 = 2.27 m^2

Available wind power:

$$P_{wind} = (\frac{1}{2}) \times \rho \times A \times v^3$$

Where, A=area perpendicular to the direction of flow (m^2), v=wind velocity (in ms^{-1}), ρ =density of air which is about 1.2 Kgm^{-3}.

$$P_{wind} = (\frac{1}{2}) \times 1.2 \times 2.27 \times 6^3$$

P_{wind}= 294.2 watts

Then the power that can be extracted from the wind assuming 25% turbine efficiency is:

$P_{turbine}$=0.25 × 294.2 = 73.55watts

6.1.3. Capacity Calculation of Biomass and Biogas

The potential for power generation from biogas and biomass has been studied together by using gasification technique.

For instance, if 500 kgs of rice husk is used for a typical day considering only 50% efficiency and 5 hours of operation; the net power generation can be calculated by using the "equation 3" ; which is:

$$P_{biomass} = \frac{50\% \text{ of } 100 \text{ kgs/ day rice husk} * 1000}{2 \text{ kgs husk/kwh} * 5 \text{ hours operation a day} * 1 \text{ day/ year}} \text{(in Watts)}$$

$P_{biomass}$ = 10,000 Watts

This is approximately 10KW of power generation; assuming 2 Kgs of husk is needed in an hour to produce 1 KW of power.

By using the same equation and same technique (Gasification), a biogas plant can also generate 10,000W of power in a day considering 5 hours of operation and 500 kgs of animal waste as a plant material.

$$P_{biogas} = \frac{50\% \text{ of } 100 \text{ kgs/day animal waste} * 1000}{2 \text{ kgs animal waste/kwh} * 5 \text{ hours operation a day} * 1 \text{ day/year}} \text{(in Watts)}$$

P_{biogas} = 10,000 Watts

So, the generated power from the biogas plant is 10KW as well for the same amount of plant material.

6.1.4. Capacity Calculation of Micro Hydro Power

Peak power is used in the evening when the sun is not shining and the wind is not necessarily blowing. Batteries can be completely drained by morning with a solar or wind system. With a hydro system located on a year-round creek or river, power is produced steadily around the clock.

The hydro power in a stream or river can be calculated by using the "equation 5" which is as follows:

P (KW) = H × Q × g (in KW)

Where, H=Gross water head (in meter), Q=Flow of water (in m^3/sec), g=Gravitation force i.e. 9.81 (in ms^{-2})

For example, if the available flow is 0.15 cubic meters per second and the net head is 4.7 meters, then hydro power= 4.7×0.15×9.81 = 6.9 kW

To estimate the electrical power produced by a generator, the efficiency of the system must be taken into consideration. The system efficiency for electricity generation using micro hydro is typically between 50% and 60%.

Electrical Power = Hydro Power x System Efficiency

P hydro = 6.9 x 50% = 6.9 x 0.5 = 3.45 kW

6.1.5. Total Expected Capacity of the Proposed Hybrid Grid

So the total expected power generation of our proposed on-grid hybrid system is:

P_{total}(KW)= P_{solar} + P_{wind} + P_{biogas} + $P_{biomass}$ + P_{hydro}

P_{total}(KW)=3.6+0.0735+10+10+3.45

P_{total}(KW)= 27.12 KW

Thus a total expected 27.12 KW electrical power can possibly be generated from our hybrid model. The sharing of the sources depends on which renewable source is sufficient at a particular moment. Such hybrid system is useful to provide electricity in all weather conditions. The capital cost for such a system is high but subsequent running costs will be low compared with a pure diesel system. In our proposed system the grid connection helps to provide flexibility to the system and works as a back-up protection when the renewable sources are insufficient to produce electricity.

7. Conclusion

In this paper, a novel model of an effective, convenient and robust hybrid system has been proposed especially for the rural and remote areas of Bangladesh where it is difficult to provide a continuous power supply from national grid connection. A contemporary scenario of Bangladesh's renewable energy sector has been presented using data and illustrations, on the basis of careful literature review and fieldworks. It can be an excellent, cost effective and also a reliable solution to mitigate the existing power crisis if we can implement this project properly. It has a great impact on improving the socio-economic condition of rural people as well as will be a good sign of green energy technology.

References

[1] M. M. Hasan, M.F. Khan, "A comparative study on installation of solar PV system for grid and non grid rural areas of Bangladesh", Developments in Renewable Energy Technology (ICDRET), 2012.

[2] "Bangladesh Gazette: Renewable Energy Policy of Bangladesh 2008", published in November 06, 2008. http://lib.pmo.gov.bd/.pdf

[3] Overview of BPDB.www.usea.org/programs/eupp/BPDB/Overview_of_BPDB

[4] Website of Wikipedia on Electricity sector in Bangladesh.http://en.wikipedia.org/wiki/Electricity_sector_in_Bangladesh

[5] M. A. Wazed, Shamsuddin Ahmed, “Micro Hydro Energy Resources in Bangladesh: A Review”, Australian Journal of Basic and Applied Sciences, 2(4): 1209-1222, 2008.

[6] Official website of Renewable energy information network, Bangladesh. Available at: http://www.lged-rein.org

[7] Country report Bangladesh, Rabobank Economic Research Department, Jan. 2011.

[8] M. A. H. Mondal, “Implications of renewable energy technologies in the Bangladesh power sector: Long term planning strategies,” Ph.D. dissertation, Dept. of Ecology and Natural Resources Management, ZEF, University of Bonn, Germany, Jul. 2010.

[9] Bangladesh electricity production from renewable sources. Available at:http://www.indexmundi.com/facts/bangladesh/electricity-production-from-renewable-sources.

[10] Renewable Energy Prospects & Trends in Bangladesh Presented by-Mazharul Islam. Bangladesh Power Development Board.

[11] ZakariaMahbub, Husnain-Al-Bustam, SuvroShahriar, T.M. IftakharUddin, AbrarSaad, “International Journal of Engineering Research and Applications (IJERA)”, Vol. 2, Issue 2,Mar-Apr 2012, pp.896-902.

[12] Md. M. Biswas, Kamol K. Das, Ifat A. Baqee, Mohammad A. H. Sadi, Hossain M. S. Farhad, “Prospects of Renewable Energy and Energy Storage Systems in Bangladesh and Developing Economics”, Global Journal of researches in engineering , Volume 11 Issue 5 Version 1.0 July 2011.

[13] Website of Wikipedia on Renewable energy. Available at: http://en.wikipedia.org/wiki/ Electricity_sector_in_Bangladesh#Renewable_energy

[14] Md. ZunaidBaten, EmranMd.Amin, AnikaSharin, Raisul Islam, Shahriar A. Chowdhury, “Renewable Energy Scenario of Bangladesh: Physical Perspective”, International Conference on the Developments in Renewable Energy Technology (ICDRT) 2009, Dhaka, Bangladesh.

[15] Mir NahidulAmbia, Md. Kafiul Islam, Md. AsaduzzamanShoeb, Md. Nasimul Islam Maruf, A.S.M. Mohsin, “An Analysis & Design on Micro Generation of A Domestic Solar-Wind Hybrid Energy System for Rural & Remote Areas-Perspective Bangladesh.” 2010.

[16] Website of Wikipedia on Photovoltaic. Available at: http://en.wikipedia.org/wiki/Photovoltaics.

[17] Potential of micro hydro power units in Bangladesh. Available at:http://www.lged-rein.org/

[18] How wind turbine works. Available at:http://www.energymatters.com.au/renewable-energy/wind-energy/

[19] EWEA Executive summary, "Analysis of Wind Energy in the EU-25"European Wind Energy Association. Retrieved 2007-03-11.Available at:www.altenergymag.com/emagazine/2011/08/the...for-energy/1767

[20] Biomass energy center. Available at:http://www.bioenergy.psu.edu/

[21] Website of Wikipedia on biogas. Available at:http://en.wikipedia.org/wiki/Biogas

[22] Description of the biogas production in an agricultural biogas plant. Available at:http://www.bios-bioenergy.at/en/electricity-from-biomass/biogas

[23] Environmental research letters. Available at:http://iopscience.iop.org/17489326/3/3/034002/fulltext

[24] Website of Wikipedia on micro hydro. Available at:http://en.wikipedia.org/wiki/Micro_hydro

[25] KhairulAnam, Husnain-Al-Bustam, “Power Crisis & Its Solution through Renewable Energy in Bangladesh”, Cyber Journals: Multidisciplinary Journals in Science & Technology, Journal of Selected Areas in Renewable and Sustainable Energy (JRSE), and September-2011.

[26] International Energy Agency, World Energy Outlook, Executive Summary, 2008.

[27] Official website of Infrastructure Development Company Limited (IDCOL), Available at:http://www.idcol.org

[28] Rice Production (Thousand Metric Tons) in Bangladesh. Available at:http://bangladesheconomy.wordpress.com/2011/12/11/3-50-cr-tonne-rice-production-target-fixed/.pdf

[29] Biomass gasification introduction. Available at:http://www.lgedrein.org/knowhow.php?pageid=64

[30] Biogas way for Bangladesh, “The Brunei Times”. Available at:http://www.bt.com.bn

[31] A successful Renewable Energy Program in Bangladesh, “International Conference on Conservation, Energy Efficiency & Solar”, Organized by Pakistan Engineering Council and USAID October 25-29, 2010, Islamabad, Pakistan.

[32] Seed Bangla website. Available at:http://www.seedbangla.com

[33] The Financial Express. Available at:http://www.thefinancialexpressbd.com/more.php?date=2011-02-06&news_id=125260

[34] Infrastructure Development Company Limited (IDCOL). Available at:http://www.idcol.org/ biogass_installation.php

[35] Potential of micro hydro power unit in Bangladesh. Available at: http://www.lgedrein.org/ knowhow.php? pageid=55

[36] BD Charge Controller website. Available at:http://www.bdchargecontroller.com