A Noble Design Of DC Micro Grid For Rural Area In Bangladesh

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Abstract: This paper is mainly addressing the design and analysis of a DC micro grid power system in a remote area in Bangladesh. Generation of electricity is not enough to serve its demand. Majority of the islands and the rustic communities are deprived from electricity and most of them are relying on some fossil fuels for searching their required energy. The cost of fuels is high and for this reason the cost of expected generating power is increased tremendously in rustic areas. By burning fossil fuels, increasing carbon dioxide (CO_2) is rocketed into the atmosphere. It has raised national and international concern and efforts to develop alternative renewable sources of primary energy such as solar, biomass, wind, hydro and other green power technologies are being used to provide sustainable, affordable and comfortable sources of energy. In Bangladesh Solar Home System (SHS) has reached a great number of installations by the effective programs run by Infrastructure Development Company Limited (IDCOL) which has been started about 12 years ago. SHS is popular when it replaces any lamp run by kerosene or wax. However, demand of customer increases day by day and old customers as well as new customers is searching a bigger power source than as in SHS. As a result it cannot meet the increased demand of customers with an affordable price. This paper also aimed to mention how to serve the increased demand of a customer with an affordable price by means of DC micro grid system.

Keywords: DC Micro Grid, Load Pattern, Renewable Energy

1 INTRODUCTION

Renewable energy may be one of the best options in meeting the gap of power sector ever increasing demand in the country if proper technologies and policies are applied. Bangladesh has already made tangible improvement in this initiative sector to provide electricity to a sizeable population of rural areas [IDCOL PDB REB]. Many rural people live in isolated places where Rural Electrification Board in Bangladesh (REB) provides electricity connections [REB]. Approximately 400000 (0.4 Million) new consumers are added per year; it would take about 40 years to provide electricity connections for all people in Bangladesh [1]. This paper set to develop and implement this initiative step. It has researched into alternate forms of power which idea can fulfill the total demand of power of those areas [2]. We are experienced with a wide range of renewable sources e.g. wind, solar, biomass, biogas, hydro and geothermal etc. The solar PV system will be only a best solution to the electricity crisis with diminishing of nonrenewable energy. Solar energy is the best choice due to the project's amazing location and the immense amount of sunlight that it receives on each day. Bangladesh is one of the sunniest part of the world [3].

2 PRESENT ELECTRICITY CONDITION IN BANGLADESH

Electric power is one of the most congenial terms of energy and also a key point of economic betterment for any country in the world [7]. According to worldwide calculation of electric consumption at present, approximately 1.4 billion people more than 20 percent population all over the world does not access to electric connection. All of those people live in remote areas in Asia and Africa [8]. Nowadays almost 49 percent of Bangladeshi people are under the connection of the electric power grid that means 51 percent people are does not access to power grid connection [9]. 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 [10]. 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 - mainly solar energy.

3 SUMMERY OF ALL THE RENEWABLE ENERGY RESOURCES

Renewable energy is type of energy whose source is not finished and the sources is replenished over time. Such as sunlight, hydro power, biomass, wave and tidal energy, geothermal and wind energy etc.

3.1 Solar

In **Solar** system the sunlight is converted into electricity by means of solar cell. Solar cell is a semiconductor device that release electron when photon falls on the p-n junction with enough light energy. The sunlight is one of the sources of renewable energy.

3.2 Hydro

Hydro power is a type of energy that comes from the force of falling water. The force of the falling water is very strong and makes a rotation of the turbine and electricity is generated. Hydro power is a source of renewable energy. The main advantages of this type of energy are neat and clean and environmental friendly.

3.3 Biomass

Biomass energy system can be defined as organic materials which are burned and also it can be used as a source of fuel. The main source of these types of energy is wood such as saw-dust, any type of waste from wood, cattle farm waste like cow manure. Biomass system is used in biological material or

the living organism where biomass is converted into bio fuel. It is also one of the sources of renewable energy.

3.4 Wave & Tidal

Wave and Tidal energy is a form of energy that can be converted into electricity. These types of energy are also generated by the river or surge of oceanic fall and rise of wave and tides. It is also a form of renewable energy.

3.5 Geothermal

Geothermal energy is thermal energy generated and stored in the earth. Thermal energy is the energy that determines the temperature of matter. From earth surface 4000 miles down to the earth's core, the core temperature reached more than 9000℃ which can be converted into electrical energy. Geothermal energy is also one of the sources of renewable energy. [21]

3.6 Global Statistics

Renewable energy accounted for 16.7% of the total energy consumption in the world. 11.44% renewable energy comes from biomass, 3.34% from hydropower and 1.92% from others. [21] Renewable energy sources are does not contain power resources which are derived from some fossil fuels and does not waste products from those sources, or does not waste products from any inorganic sources. [12]

3.7 Bangladesh Statistics

In Bangladesh the produced renewable energy is almost 0.45% only of the total energy consumption but globally the source of renewable energy more than 16.7% of the total energy consumption. The policy of renewable energy has been approved in December 2008 for exploring and producing electricity from the renewable energy resources to meet the electricity crisis across the country. The policy encourages both the all types of private and public sectors to develop alternative sources of energy to meet up to 10 % of total electricity demand through renewable energy such as solar, wind, biomass and hydro power by 2020 at a cost of about 1.5 billion dollar. The Infrastructure Development Company Limited (IDCOL) recently approved the financing help for a 100 KW solar photovoltaic based micro-grid. The production of electricity under renewable energy is given at Table 1[13]

Table1. Present Electricity Production by using Renewable Resources.

Division	Number of SHSs Installed
Barisal	265,320
Chittagong	278,730
Dhaka	374,587
Khulna	158,409
Rajshahi	200,480
Sylhet	151,914
Total	1,429,440

The renewable sources could reach electricity to the rural people and help in poverty reduction. However, it cannot meet the ever growing demand for more power by the industries, service sectors, and the growing urban population economically. [13] In a large number of rural areas, which area are deprived from power grid electricity and those area is not economically viable. This paper suggest that the practical implementation of a solar micro grid and alternatively used for rural electrification. It is now about 60 percent of rural households in Bangladesh have no access to power grid electricity. Every people's life becomes almost standstill after sunset. Nowadays approximately more than 50,000 solar home systems are being installed and also it is going to be a large sector in the world. Currently, maximum number of villages especially in the isolated areas is going to start and enjoy the electricity produced by solar panels, thanks to the PV scheme. [14]

4 Background of the Research

For research purpose, a survey was done in a remote village Vulbaria in the district of Natore. It is a small village with no more than 4,000 to 4,500 inhabitants, located in the community of Natore district 25 miles away from Shingra Thana. The village has one primary school with only 6 classrooms, one Alia Madrasha and one Mosque. There are no electricity connections in this village; people need to alternative solutions for energy, such as firewood and oil lamp. Education rate of this village is approximately 67 percent. The nearest grid electricity line is around 5 kilometres far from this village. Apart from this, a local power supplier is serving electricity to about 100 consumers by means of diesel generator. But the location of the local power supplier is almost 3 kilometres away from this village, so the villagers are not get electricity connection from the local supplier also. More than 150 households are installed Solar Home System (SHS) out of 500 households. The total number of cows in this village is around 6 to 7 hundreds.

Figure 1. *The Area Map of this Research Proposal*

Biogas plants installed in this area is about zero. There are only two numbers of poultry firm in this village and totally 6*00-700* numbers of cow. The poultry waste and the cow dung can be used to generate biogas. So this can be used as an operational subsystem of the addressed DC Micro Grid system. There is a small river named Nagar. It contains water only for few months around the rainy season so micro hydro is not possible at that area. The speed of wind is less than 0.5 ms^{-1} which is not possible to run the micro wind generator, finally it can't be installed at that area. The villager has 500 numbers of houses whose are densely situated. House to house average distance is about 2-2.5 meter. Currently total 150 numbers of households are using Solar Home system. Most of them are using 60 Wp solar packages. The survey

reveals that the demand of present user increasing day by day. Most of them are lower incomer.

5 BASIC MECHANISM OF A SOLAR CELL

Currently solar panels provide energy to private residences, businesses and cities with large scale demands. Large scale solar power conversion has many problems. The most of the problems are the wide variation of voltage and current whose oscillate directly with the amount of sunlight. This problem can be solved by storing the energy produced during peak periods in batteries. Another solution of this problem is to create a micro grid system. The output energy produced by the solar PV system is not used directly but through the micro grid system [2].

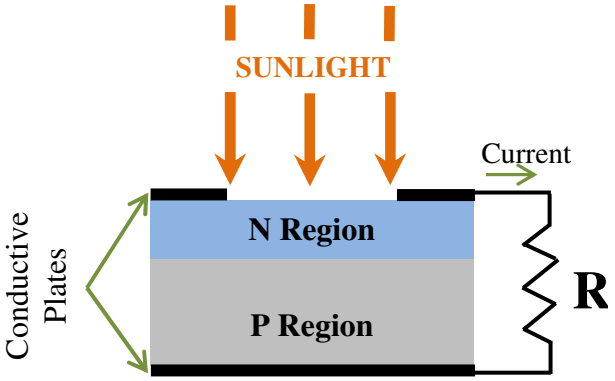

Figure 2. *Internal Structure of a Solar Cell*

The main basic equipments of a solar PV system are solar cell. Only this cell can converts sunlight into electricity. Actually to produce high rate of electricity we must be connected the solar cells are in series-parallel configuration. The equation of the current and the voltage from the equivalent circuit of the arrays are given below in equation (1),

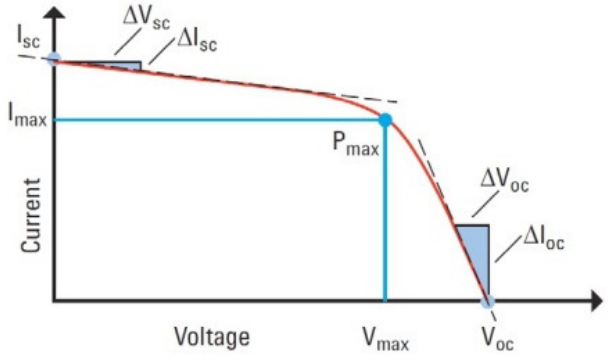

Figure 3. *I-V Characteristics Curve of a Solar Cell*

Figure 3 and figure 4 both of them are illustrated the I-V characteristics curve that means the current and voltage curve of a solar cell. If there is no connected load to a solar cell which is already sitting in the sun then V_{OC} will produce current but does not flow, where V_{OC} represents the open circuit voltage. If both of the terminals of a solar panel are short circuited then the current I_{SC} will flow but at this time the output voltage remains zero, where I_{SC} represents the short circuit current. [5] When the load will connect, we consider the current and voltage curve of the solar cell and also the voltage and current curve of the load to find out how much electricity is delivered to the consumer or load. The MPP which is situated in the knee point of the current and voltage curve, where MPP represents MPP are represented as maximum voltage (V_m) and maximum current (I_m). [6] the maximum power point. The related voltage and current of Site selction and Study of Present Energy system

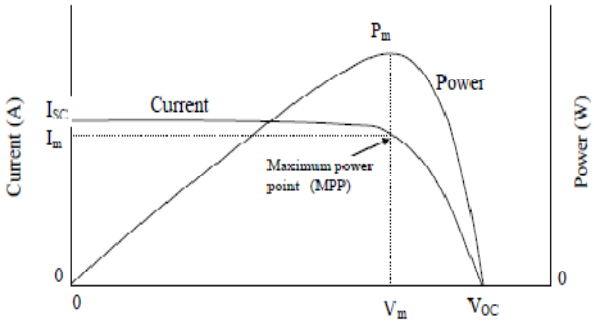

Figure 4. *Describe I-V Characteristics Curve of a Solar Cell*

$$I = N_p I_{PH} - N_p I_s [\exp (q (V / N_s + IR_s / N_p) / KT_c A) - 1] - (N_p V / N_s + IR_s) / R_{SH} \quad (1)$$

In this equation N_p represents the parallel connection of a solar module and N_s represents the series connection of a solar module. The efficiency of a solar photovoltaic is more sensitive to small charge including in R_s and has an insensitive variation including in $R_{SH.}$ [4]

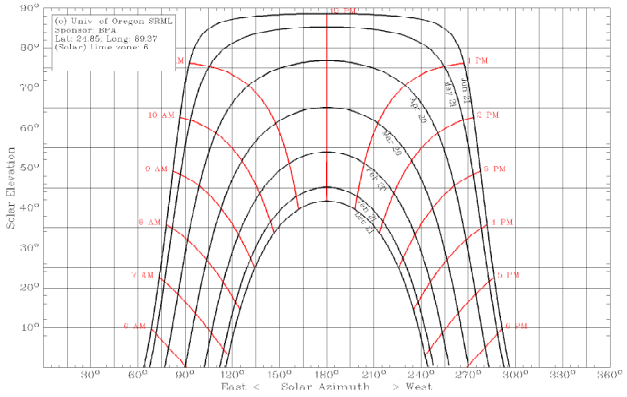

Figure5. *Graph of Sun Path of the Site*

Sun path diagram for the selected site generated from Solar Radiation Monitoring Laboratory, University of Oregon. Solar output of a 1 KWp panel at Bogra nearer to the site. From NREL PV watt Table 2 illustrated the calculation of Cost of energy per kWh.

Table2. *Specification station and PV system near the site (Bogra)*

Station Identification	
City:	Bogra
Country/Province:	BGD
Latitude:	24.85° N
Longitude:	89.37° E
Elevation:	20 m
Weather Data:	SWERA
PV System Specifications	
DC Rating:	1.00 kW
DC to AC Derate Factor:	0.770
AC Rating:	0.77 kW
Array Type:	Fixed Tilt
Array Tilt:	24.9°
Array Azimuth:	180.0°
Energy Specifications	
Energy Cost:	35 Taka/KWh

Table 3 *represents 12 years solar radiation, AC energy & energy value.*

Table3. *Monthly Solar Radiation, AC Energy & Energy Value@ 35 Taka/KWh in Bogra*

Results			
Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value (BDT)
01	5.32	113	3955.00
02	5.64	107	3745.00
03	6.13	125	4375.00
04	6.19	122	4270.00
05	5.44	112	3920.00
06	4.83	096	3360.00
07	4.19	086	3010.00
08	4.40	091	3185.00
09	4.61	091	3185.00
10	5.25	107	3745.00
11	5.28	106	3710.00
12	5.22	111	3885.00
Year	**5.21**	**1267**	44345.00

Most of the household's appliances or the inhabitants have wattage label on the back or the bottom. This label is listed the maximum amount of energy the consumers can draw.

6 ELECTRICITY FROM BIOGAS

Principle of generating electricity from Biogas plant:
In the biogas plant generally have a pit where slurry and other wastage are stored primarily and mixed it when needed. The bio fuels are generally liquid or gaseous and solid fuels that are made from live or currently dead organic material are called as biomass which are composed of ancient biological materials. The solid or liquid biomasses are naturally used in the digester for generating biogas. The main core of that plant is digester which is a container and where the biomass is decomposed by microorganisms which is in darkness and also under the anaerobic conditions. The digester is generally heated approximately 98-42 ° C and this stage is known as mesophilic and when it reached 55 ° C it is known as thermophilic.

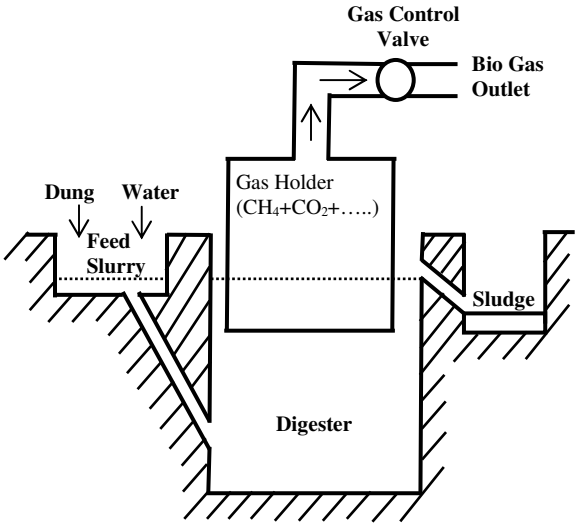

Figure6. *How does produce electricity by using biogas plant*

The generated gas is collected under the air-tight container directly and can be conducted into CHP (Combined Heat and Power) station where it is burned in combustion engine for generating electricity. The generated biogas can be used in cooking, lighting, moving automobiles and energy production. [22] There are almost 1500 number of cows in the village. The villagers can collect at least 3000 kg cow dung per day. It is calculated by recent statistical value one cow can produce 142 kilograms methane gas in a year, so 1500 cows can produce at least 2,13,000 kilograms methane gas per year, that means it can produce 17750 kilograms methane gas per month.[23] All of the collected cow dung is fed into anaerobic digester.

6.1 Anaerobic Digester
An anaerobic digester is that kind of digester which is built to hold about 21 days of farm waste at roughly 100_0. The bacteria convert that waste into various sorts of products. Methane gas is one of them.

6.2 The Generator
The fuels of biogas that can turn spin an electric generator to produce electricity.

6.3 Electricity
Cow dung from one cow can produce electric energy which is sufficient for two 100 Watt bulbs for 24 hours in a *d*ay.

6.4 Dry Solid Waste
The digested manure is processed through a mechanical separator. The odorless solids can be used to replace sawdust or sand as bedding for the animals. The gas obtained from the cow dung contains 55 to 65 percent methane, 30 to 35 percent carbon dioxide with some hydrogen; it is composed 1.8 to 2.4 percent Nitrogen (N_2), 1.0 to 1.2 percent phosphorus (P_2O_5), 0.6-0.8% potassium (K_2O). The heating value of this gas is around 600 BTU per cubic foot. [24] At present the Infrastructure Development Company Limited (IDCOL) already approved to give the financial support for implementing 400 KW rice husk gasification based electricity generation facility along with a precipitated silica plant at chilarong, thakurgaon sadar, Thakurgaon. (web site of IDCOL)

7 BLOCK DIAGRAM OF THE POWER GRID

The following block diagram has been established for the Noble Design of a DC Micro Grid and it implies the basic principles of the Grid.

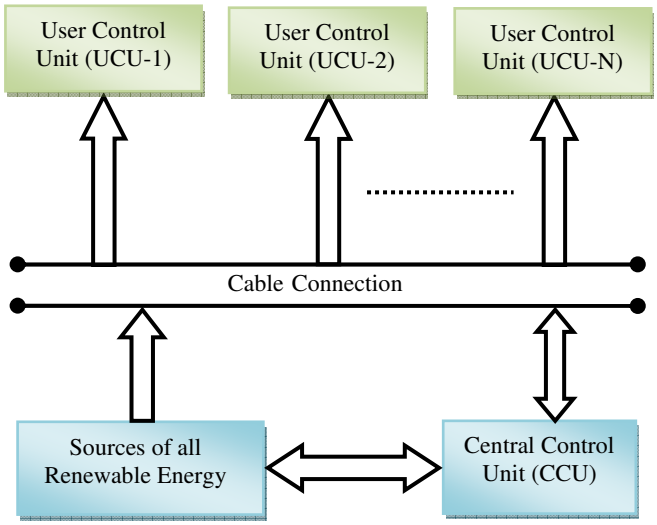

Figure7. *Block Diagram of DC Micro grid*

This system also includes collection of solar energy, either by a thermal or solar PV process. By using this types of project user can get electric power by surmount some steps. Firstly solar module collects the sun power and converts it into DC power which is transmitted into the Central Control Unit (CCU). Secondly central control unit deliver DC power to the User Control Unit (UCU) as per demand and the meter is provided for measuring consumed energy. This system includes three operational subsystems most of them are battery, biogas plant and diesel generator [8]. The load management system is a very important parameter. Traditional load management is done by load shading in Bangladesh. A new technique for load management is discussed here. The system can able to identify how much load can be operated by the produced electricity. If load become more than the accumulated generated power then it automatically disconnect the specific overed load, so this is an intelligent operational system.

8 METHODOLOGY

Discussion of AC and DC Micro Grid

A micro power grid is emerging as one of the amazing solutions to the integrating of various sorts of ***imparted*** renewable power sources with the grid of utility. Although the underlying power grids are AC grids, nowadays the loads of electricity comprises of power and electronic based equipments and also the distribution of the renewable energy formation make the DC micro power grids more attractive. However, individually AC micro power grid and DC micro power grid requires the multiple altercations of energy at the user for the DC and AC loads respectively, the resulting forms are less efficient systems. [9]

9 SYSTEM OPERATION OF AC & DC GRID

DC AC grid comparison:

In the starting of the electrical age, the power or energy was generated as a DC current and voltages were low. The loses of resistance in a transmission line that made impracticable to transmit and distribute the electricity only for more than a shortage number of localities. With the improvement of transformer, AC power has taken over the load formerly supplied by DC. At present the electricity is generated, transmitted and distributed in the forms of AC system for an economical proposition. The transformer allows the transmission and distribution of AC energy at high voltages. This has greatly reduced the current in the conductors and the resulting line losses. However, for certain applications, DC distribution is absolutely necessary. The solar photovoltaic panels, fuel cells and batteries are generated DC power, residential, commercial and industrial facilities are projected to increase DC loads that do not require first converting to AC. It is proved that DC transmission system is cost effective only over distances of more than 500 miles.

DC Distributor

There are fed by the feeders on this basis DC distributors are classified as follows

- **i)** Distributor fed at one end
- **ii)** Distributor fed at both ends
- **iii)** Distributor fed at the centre
- **iv)** Ring distributor

These are describing as follows

- **i)** Distributor Fed at One End

These types of feeding distributor are connected to the supply at one end and loads are taken at different points along the length of the distributor. It is also called singly fed distributor. In this distributor loads I_1, I_2 and I_3 tapped off at points C, D and E respectively.

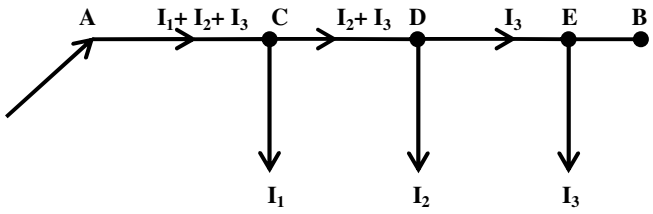

Figure8. *Distributor Fed at One End*

- **ii)** Distributor Fed at Both Ends

These types of feeding the distributor are connected to the supply mains at the both ends and loads are tapped off at different points along the length of the distributor. The following figure Illustrated that loads I_1, I_2 and I_3 tapped off at points C, D and E respectively.

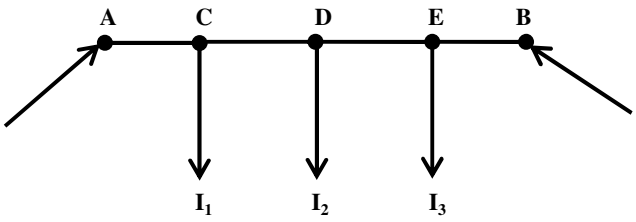

Figure9. *Distributor Fed at Both Ends*

iii) Distributor Fed at The Centre

This type of feeding the centre of the distributor is connected to the supply mains. It is equivalent to two singly fed distributors. Each and every distributor is having a common feeding point and length equal to half of the total length.

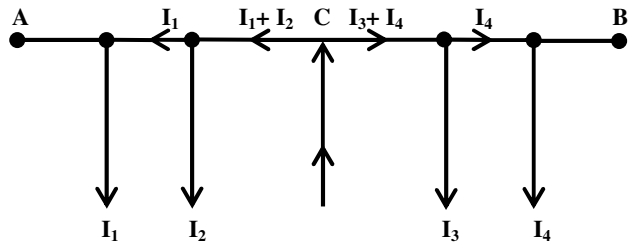

Figure10. *Distributor Fed at the Centre*

iv) Ring Distributor

In this types of feed the distributor are connected to a closed ring which is as illustrated in the following figure. It is equivalent to a straight distributor fed at both ends with equal voltages.

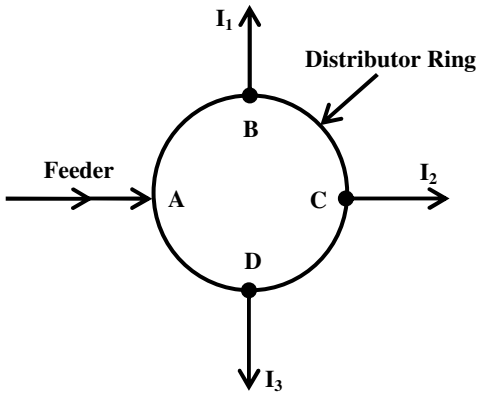

Figure11. *Ring Type Distributor*

For these types of DC micro power grid will be used DC distributor fed at one end. The concentrated loading

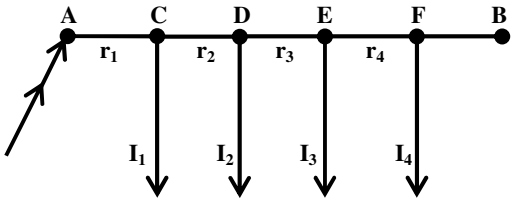

Figure12. *Distributor Fed at One End of DC Micro Grid*

This figure represents a single line diagram of a 2 wire DC distributor AB fed at one end A and having concentrated loads I_1, I_2, I_3 and I_4 which is tapped off at points C, D, E and F respectively. Suppose that, r_1, r_2, r_3 and r_4 be the resistances of both wires of the sections AC, CD, DE and EF of the distributor respectively. Therefore,

Current fed from point A = $I_1+ I_2+ I_3+ I_4$
Current in section AC = $I_1+ I_2+ I_3+ I_4$
Current in section CD = $I_2+ I_3+ I_4$
Current in section DE = $I_3+ I_4$
Current in section EF = I_4

Voltage drop in section AC = $r_1 (I_1+ I_2+ I_3+ I_4)$
Voltage drop in section CD = $r_2 (I_2+ I_3+ I_4)$
Voltage drop in section DE = $r_3 (I_3+ I_4)$
Voltage drop in section EF = $r_4 I_4$

So, the total voltage drops in the
Distributor = $r_1(I_1+ I_2+ I_3+ I_4) + r_2(I_2+ I_3+ I_4) + r_3(I_3+ I_4) + r_4 I_4$

It is easy to see that the minimum potential will occur at point F which is farthest from the feeding point A. [25]

10 CONTROL STRATEGY OF THE GRID

Any source that is not available always for due to some causes is known as intermittent source. An intermittent source is quite predictable. To exemplify, wave and tidal energy, solar photovoltaic system, biogas power plant etc. In the solar PV system electricity production is depended on the amount of sunlight and it does not produce electricity at night. Due to intermittency, the power system may have some fluctuation on frequency, voltage and other important parameters. To obtain constant power, the effect of intermittency must be overcome. Using battery is a simple way to overcome this. Moreover other renewable energy sources may be interconnected to the system. Besides this standby sources are biogas, diesel or other fuel based generator is also necessary for long term unavailability of intermittence sources. For an AC micro grid, frequency control is important as well as voltage control. Where as in a DC micro grid there is no option to control the frequency. The source and load management system are essential to get constant power and robust control system. The source management system is discussed bellow with the figure 13. The main source of energy in this system is solar PV system. This system contains three operational subsystem like battery, biogas plant and diesel generator. When we run this program at first it find out the availability of solar energy. If solar energy is enough then it run's the system without the help of any subsystem. If solar energy is Not Enough (NE) then it can identify the battery subsystem and receive the amount of shortage power and keep in running the system. If the solar and battery subsystem are combinedly Not Enough

(NE) then it can search biogas plant and receive the amount of shortage power and keep in running the system.

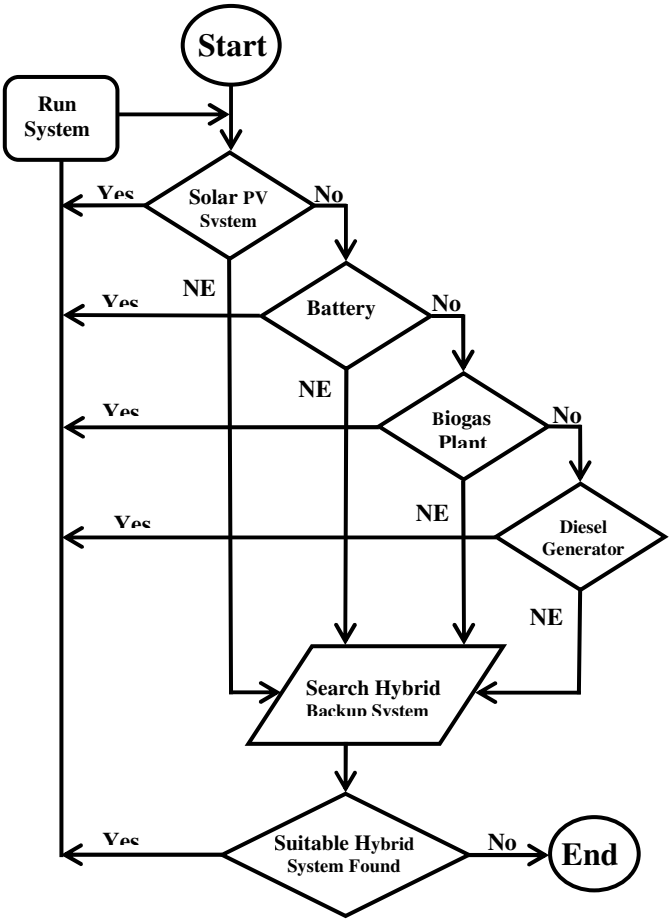

Figure13. *Flow Chart of the DC Micro Grid*

If the solar, battery and biogas plant subsystem are combinedly Not Enough (NE) then it can search the diesel generator and receive the amount of shortage power and keep in running the system. If the solar, battery, biogas plant and diesel generator subsystem are combinedly Not Enough (NE) then it stop (End) the running system.

11 DIESEL GENERATOR BACK-UP

The proposed solar DC micro power grid contains a subsystem operation like diesel generator subsystem operation.

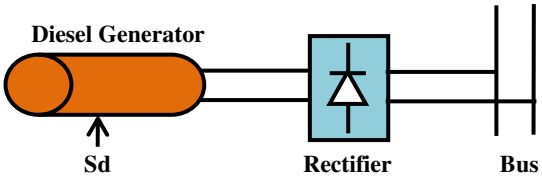

Figure9. *Diesel Generator Operational Subsystem*

A diesel generator means which generator is fueled by diesel and the generator is PMSG (Permanent Magnet Synchronous Generator). This system has controlled by a signal sd which is denoted by switch of diesel generator. With the help of sd switch we can ON or OFF the generator. For converting output voltage from AC to DC we use three phase diode rectifier bridge. In this project we use diesel generator primarily for giving the backup power when all types of sources are failed to supply power for existing demand. [10]

12 LOAD FORECASTING AND CALCULATIVE TERMS

In an average 5 pieces bulb is enough for each an every family at the village. An LED bulb of 5 Watt is sufficient to illuminate a space to study, gossip, kitchen work and others. 5W of LED bulb will provide around 550 lumen of light energy. [26]

The bulb will run for 3 hours per day usually.

So, 5 pieces bulb * 5 Watt = 25 Watt
Daily 3 hours equivalent to 75 Wh
For 100 families = 100*75 = 7500 Wh
= 7.5 KWh

The natives of that village are also interested in to run fan, television, computer and others loads whose are approximately 10 KW. If these loads will run for 5 hours per day then the consumption will be 50 KWh. Therefore the total consumption of the village will be 57.5 KWh. Just about the panel generation factor (PGF) is 3.5 for Bangladesh.

In this case panel needed = 57.5 /3.5
= 16.43 KW (Approximately)

It is safe to use 17 KWp panel in order to future extension.

12.1 Implication Cost

In this village many households use non-renewable energy like kerosene and other fuels. The cost of kerosene oil is approximately are given below:

Per households if use 5 lamps, 3 hours per day then need kerosene at least 03 litters per month.

Price of 03 litters kerosene = 80*03
= 240 BDT

On the other hand if one households use 5 electric lamps (5 W), 3 hours per day by using solar technology then consumption will be 150 Wh then monthly consumption will be 150Wh*30 equal to 4500 Wh.

Monthly consumption cost = 4.5*35 BDT
= 157.5 BDT

So it is clear that the solar energy is more beneficial than the cost of any non-renewable energy sources.

CONCLUSION

The performance of this project or the electric generation system is released heavily. We should consider the ability of produce electric power with a negative emission of CO_2. The people of those villages basically in the remote areas and also the people of islands will be influenced to get the electric connection by under this project. Lust but not the least the major pros and cons of a photovoltaic system is that it can be

used expanded as our need and wide range of specific applications

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