A Novel Load Distribution Technique Of Dc Micro-Grid Scheme On Pv-Diesel Hybrid System For Remote Areas Of Bangladesh

Syed Enam Reza, Mou Mahmood, A. S. M Kaikobad, Ehasanul Kabir, Nahid-ur-Rahman Chowdhury

Abstract:- This paper covers the development of a new smart distributed DC Micro-grid system, especially in rural areas in order to utilize energy available from distributed, renewable generators. The proposed DC micro-grid system is hybrid in nature and it utilizes the proper use of renewable as well as fossil fuel resources. It is normally fitted for residential and small commercial applications as well as for powering sustainable rural communities where the electricity from main grid is not available. In dc grid system we can store the excess amount of power during the low load demand period which is economical compared to the ac grid system which needs to keep their inverters switch on all the time.

Key Words:- Load *distribution technique*, Dc micro grid, PV-Diesel hybrid, Smart grid.

I. INTRODUCTION

Energy generation is one of the key factors in driving the socio-economic growth of any country. In Bangladesh, increasing demands for energy has already exceeded the capacity from existing plants from conventional sources of energy. Thus access to electricity is very limited where Per capita energy consumption is about 237 KOE [1]. There are still lots of area where there is no supply of electricity [2]. Attention is being focused on renewable energy sources and to harness electricity from them to meet the national energy demand. In Bangladesh solar photovoltaic (PV) systems are being widely deployed in rural areas and large scale coverage in rural areas with renewable energy sources is being actively considered with mini-grid structure. Such a grid system can implement smart grid techniques by the efficient management of the power grid systems in many countries around the globe [3]. In recent years, a large number of distributed generators such as PV cells, fuel cells, wind turbines etc. have been installed into the bulk power system. However, it could cause problems like voltage rises, instability problem, requirements of reactive power and protection problems when they are connected to the conventional i.e. ac power distribution systems [4]. One of the solutions is to construct a new electric power system and a dc micro-grid can really be an effective solution to this problem. This paper presents a 10 kW PV-diesel hybrid dc micro grid system with a proper pattern of load distribution strategy in a small community to provide electricity to those priority sectors which are considered to be the life blood of rural economy. This is due to the reality that off grid electricity in rural Bangladesh is not expected to be low cost solution.

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II. SMART GRID

The term “smart grid” is somewhat qualitative since there are various proposed implementations that have varying levels of sophistication. However, standard among all implementations is the use of advanced sensor and communications technologies to enable better use of assets, provide improved reliability and enable consumer access to a wider range of services[5]. In power sector it is incomparable to the existing grid in the aspects of smart central generation, transmission, substation, distribution and metering. It can penetrate various energy sources including renewable energy for flexible management of power system. This can be achieved in many ways from active demand side management (DSM) to temporary storage technologies, whether dedicated to electricity or sourced through a symbolic supply.

A. Why Smart Grid

One of the key aspects to a smarter grid is the ability to make decisions on how to operate the power system on both the supply-side and the demand-side. The right information is essential in order to make the right decisions and this is ubiquitous throughout the entire smart grid system. Some advantages of implementing the smart grid on power system are as follows:

- To deal with the mounting energy demand of the world.
- To lessen the cost of power disturbances and system losses throughout the world.
- To reduce CO_2 emission by enhancing green energy generation and consumption.
- To stop Electricity price hiking by controlling demand and supply.
- To provide reliable services for a long period by removing aged infrastructure and employees.
- To introduce customer-side applications.
- To integrate the renewable and distributed energy resources.

B. Smart Grid Platform for Bangladesh

The power system in Bangladesh is very complex and quite aged with lots of lacking. But, there are many scopes to convert the power grid of Bangladesh to the smart grid. To address the power crisis and other problems, it is the high time to initiate the plans to form grids which are more smart, receptive and flexible than present power grids. In Bangladesh,

not only by integrated communication techniques but also by increasing the usage of renewable resources the implementation of smart grid technology can be achieved. In prospective to the socio-economic condition of Bangladesh; smart grid will enable consumer empowerment to manage their energy usage and financial savings.

III. MICRO GRID

In recent days, an interest is increasing rapidly about the small-scaled grid system based on several tens of Photovoltaic power generation. Such a grid system, which is called as micro grid, has advantages to increase an operational efficiency and economics when it is connected to grid or supply a secured electric power at islands, mountains and remote areas without connecting grid. The micro grid is divided into ac micro grid and dc micro grid, which is classified by whether, distributed sources and loads are connected on the basis of ac or dc grid. ac micro grid has a benefit to utilize existing ac grid technologies, protections and standards but stability and requirement of reactive power are the inherent demerits of it. On the other hand, dc micro grid has no such demerits of ac micro grid and assures reliable implementation of environment-friendly distributed generation sources [6].

IV. SCENARIO OF INSTALLED SOLAR HOME SYSTEMS (SHS) IN BANGLADESH

The Solar Home Systems **(**SHS) system consists of a 20-100 watt peak (WP) PV array, a rechargeable battery and a charge controller. Both the array size and sunlight availability determine the amount of electricity available for daily use. With an appropriate sunlight regime, the system has proven to be competitive for remote households. The SHS is thus implemented in many developing countries. So far, in Bangladesh, up to 29 April 2012; Infrastructure Development Company Limited (IDCOL) has installed 1,429,440 Solar Home Systems (SHS) throughout the country [7] which clearly has been proved to be a very successful program in Bangladesh to address the lighting demands which replaces the kerosene lamps particularly in rural areas. But still the main weakness of SHS is its extremely limited output which cannot be utilized in any cottage industry, whatever small the power requirement is.

V. THE PROSPECTIVE OF PV-DIESEL HYBRID SYSTEM IN BANGLADESH

A study indicates that the remote settlements located in Bangladesh are prospective candidates for the deployment of the proposed PV–diesel hybrid system for electricity generation due to the favourable daily average solar irradiation which varies between 3.8 and 6.5 kWh/m^2 and the diesel price is almost the same all over the country [8]. Utilizing this system for electricity generation in comparison with the diesel generator-only situation would decrease the operating hours of diesel generators and consequently would reduce the diesel consumption and would lead to reduction in emissions of Greenhouse Gas (GHG) while the diesel generators may be used as a backup for the emergency. Since Bangladesh is geographically situated between 20.30-26.38° north latitude and 88.04-92.44° east longitude [1]; a formidable solar irradiation is available in almost all seasons makes the solar power as a viable proposition. The Fig. 1 below gives a limpid view of the solar irradiation profile all over Bangladesh.

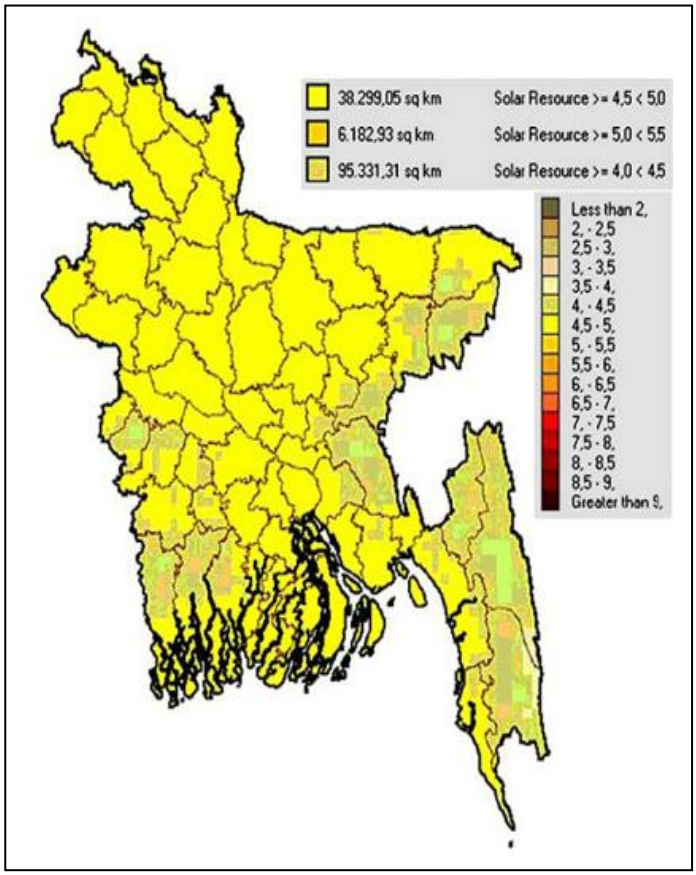

Fig. 1. Solar isolation potential of different regions of Bangladesh

A. Best Practice of PV-Diesel Hybrid System

Out of several installed PV-hybrid systems an example has been presented below. This system is used for a village power supply for a holiday resort in South Spain installed in 2003 [10]. The number of inhabitants depends on the holiday season as it supplies a holiday resort. The system is driven by SOC control. If the status of the battery is less than 30% due to the Steca PA15 control automatically starts the diesel genset which charges the batteries till 90% SOC have been reached.

Fig. 2. A dc PV-diesel hybrid system with 8kwp PV, 20kVA-diesel, 48 @1500Ah battery and 16kw inverter power for home users in Spain [10]

VI. THE DC MICRO GRID MODEL

In this system, a PV-diesel hybrid concept with dc grid has been proposed [9] where the PV panel is not placed in any central location but distributively placed on roof tops at conventional locations. The number of solar PVs placed on a roof is such that they can be connected directly to the grid. The diesel generator is needed to give support to the system during bad weather and reduce the battery storage for the system. Diesel generator is placed at a convenient location and in case of higher demand; several diesel generators could be installed at the same place as per increased load demand. Diesel generators would be connected to the grid via ac-dc converters. A battery may be placed to store the power generated from diesel generator. Each consumer is connected to the grid and is metered for the energy consumed. Schematic diagram of a dc micro grid and a typical setup inside the consumer premises is shown in Fig. 3. A consumer will have a dc-dc converter to convert the high grid voltage to nominal 12V and charge a battery set up individually at the premises to store energy. It may be mentioned here that the charge controller to protect the battery is built inside the converter. During the day time, solar panels will produce output to be stored in the batteries of the individual customers. The size of the batteries will be deduced as per their energy demand. The customer has two options so far the household loads are connected-he/she can use all dc loads or can use an inverter (similar to an IPS) to have 240V ac load in his house [9]. This option will be useful when the actual power consumption by some of the consumers (well off consumers) are high and rich enough to use household gadgets like fridge, TV etc.

The power flow component of the dc micro grid is:

$$P_{DC\text{-}GRID} = P_{PV} + P_{DG} \quad (1)$$

Where, $P_{DC\text{-}grid}$ is dc grid power, P_{PV} is Photovoltaic source Power and P_{DG} is diesel generator power.

Since energy storage elements control power balance of dc micro grid by charge and discharge, so the power flow is bidirectional and the reference power for the elements is:

$$P_{BATTERY} = P_{DC\text{-}GRID} - P_{LOAD} \quad (2)$$

Where, $P_{BATTERY}$ is the battery which stores the power, $P_{DC\text{-}grid}$ is dc grid power, and P_{LOAD} is the power consumed by the load.

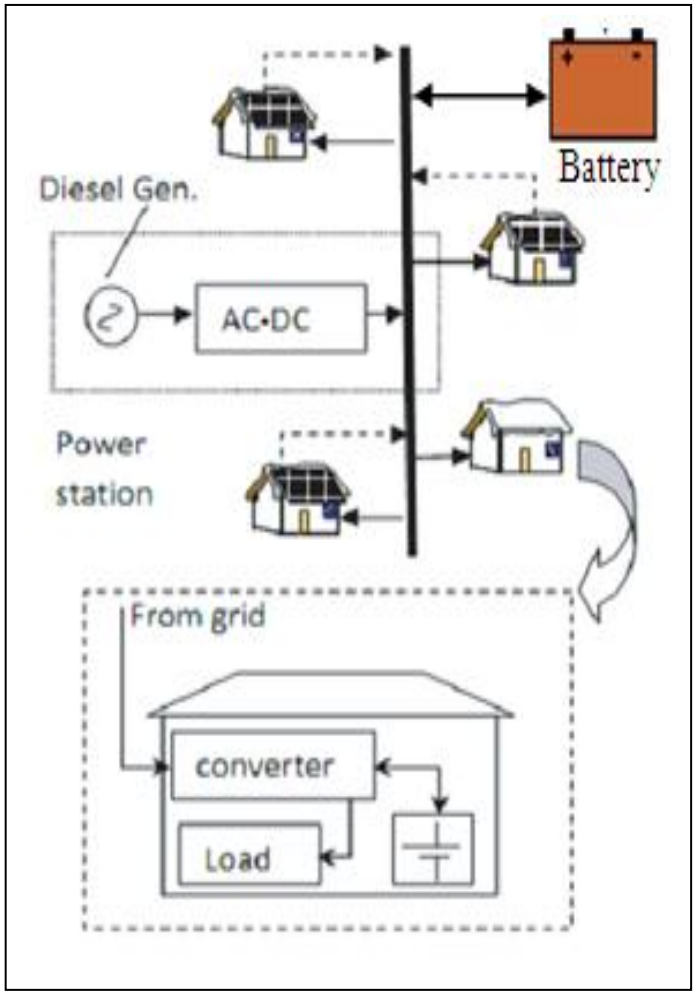

Fig. 3. The schematic diagram for the dc micro-grid. Dotted arrow marks show the connection from the PV panels to the grid.

VII. ADVANTAGES OF DC MICRO GRID OVER AC MICRO GRID IN RURAL ASPECT OF BANGLADESH

In the perspective of rural areas there are some advantages of dc micro grid over conventional ac micro grid which are as follows:

- Since Bangladesh is a densely populated country; a high quality of power is required for such agricultural dependable society and dc grid can assure it. For example, if a blackout or voltage sag occurs in a bulk dc and ac hybrid power system, most inverters might be tripped. So, it is difficult for ac micro grids to keep a super high quality power supplying continuously in islanding operation.
- A significant part of the system is transferred to the consumer's premises; reducing the initial cost of the power company and overall maintenance of the system.
- Since the cost of the battery and inverter is taken away from the power company, the overall maintenance is simplified so as the cost of energy (can be as much as 40%)
- In addition to this small scale rural industries like irrigation, rice husk can use the high voltage (240 V dc) directly without using dc-dc converter.

- Reliable grid supply is ensured as the customers store their required energy in their own batteries.
- It can also be mentioned that there would be a smooth transition from the SHSs to the hybrid dc micro grid as the old household gadgets and the battery can still be used.
- At last but not the least, the ac micro grid has some inherent problems such as synchronization, stability, need for reactive power while dc grid system is immune to those.

Moreover, it is to be mentioned that the dc micro grids can be turned into a viable proposition due to its low cost over ac micro grids since the energy cost comparison between an ac and dc grid has been shown in previous research work [9].

VIII. Load Profile For The Proposed Dc Micro Grid System

The system is designed to serve 24 hours in a day and it is especially for densely populated rural areas so the transmission loss can be minimized. The system is designed to focus on 30 households, a primary school, a small business community and agricultural loads. In our estimation, the total system comprises of 104 energy saving CFL bulbs, 42 fans, 22 televisions, 2 computers, 3 water pumps and a paddy husker. The electrical load patterns are shown in Table I for the aforementioned loads. The most economically feasible system for this type of small community be composed of 8 kW PV array as a whole installed in separate places associated with consumers own batteries and 2 kW diesel generator as a backup installed in a central place along with the battery bank (10 numbers of batteries) of which each has a nominal voltage of 2 and capacity of 800Ah, to store the grid power. Since the dc grid system has been used; the excess of power will be stored in the battery during the light load periods unlike ac grid system and thus will reduce the transmission loss.

TABLE I
Estimated Load For A Typical Rural Community

Load Name	Load Types	Device watts(w)	Time of Operation	Hours of Daily Use	No. of Units	Total (watt)	Total AC Watt-hr
School	Light (CFL) Fan (56" sweep)	11 60	8am-12pm 8am-12pm	4 4	7 7	77 420	308 1,680
Residential	Light (CFL) Fan (56" sweep) TV (14" CRT) Mobile charger	11 60 80 0.35	5pm-10pm 6pm-6am 6pm-10pm 9pm-10pm	5 12 4 1	85 30 20 200	935 1,800 1,600 70	4,675 21,600 6,400 70
Agriculture	Water Pumps Paddy Husker	746 800	12am-6am 12pm-4pm	6 4	3 1	2,238 800	13,428 3,200
Small Business	Light (CFL) Fan (56" sweep) Computer TV (14" CRT)	11 60 120 80	5pm-9pm 4pm-9pm 4pm-9pm 4pm-8pm	4 5 4 5	12 5 2 2	132 300 240 160	528 1,500 960 800
Total						8,772 watt	55,149

DC watt-hrs per day=Total AC watt-hrs per day/ Inverter efficiency

IX. Proposed Distribution Strategy Of Load Pattern

In our proposed load allocation scheme we have estimated a load management plan for 30 households, a primary school, a small business community and some agricultural loads. We know that the electricity is imperative for the growth of agricultural sector especially for pumping water which can be done from 12 am to 6 am. Since the education plays a vital role for the development of a nation thus a slot for this has been provided and the schooling loads should be fed by electricity from 8 am to 12 pm. However, another important part in agriculture is paddy husking, which can be started at 12 pm and will end at 4 pm. Meanwhile, the residential and the small business like grocers should be supplied with electricity in between a period of 4 pm to 10 pm at night compromising the day time.

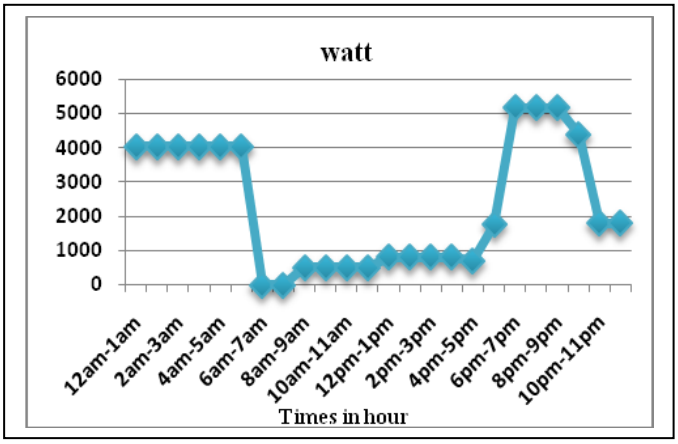

Fig. 4. Distribution of Load pattern during 24 hours period

From our proposed load distribution strategy; the line graph in Fig. 4 shows that the peak electricity demand is at the night hours asking for more than 5 kW of power which mainly stands between 6 pm to 9 pm, to supply the household and business TV, fan and lighting loads. However, afterwards this demand falls slightly for a short period of time since the shops are expected to close after 9 pm. Conversely, during the midnight period when the electricity demand is low; water pumps are switched on for the agricultural purpose where a constant 4 kW power is required for the prescribed number of load units. However, from 6 am the demand starts falling exponentially and came into a state of almost ground zero level and continued to fluctuate in between 0.5-0.8 kW of power demand as the demand of electricity during the day period is minimum which causes the battery to charge sufficiently. The load distribution strategy is planned in such a way that during the day period the battery will be fully charged utilizing the solar power to mitigate the demand for the upcoming peak hours.

X. CONCLUSION

In this study a PV-diesel hybrid dc micro grid has been proposed for typical rural areas of Bangladesh. Moreover, possible load profile pattern for a small community and its proper time scaling utilization have also been prescribed. In addition to this, the imperativeness of dc micro grid in the light of the rural economic development of Bangladesh and its merits over the ac micro grid has also been addressed. Previous research has also shown its cost effectiveness over the conventional ac system. It is evident that, such dc micro grid can ensure reliable power supply to the consumers and thus providing the continuity of services. However, the efficiency and power flow strategy of PV-diesel hybrid system for such a micro grid needs to be investigated which will be our future study plan. By implementing such PV-diesel hybrid dc micro grids in rural areas; the dependency on the national grid can be reduced and also a proper use of renewable energy can be ensured to have an environmentally sound society. Several independent grids like this can really play a significant part to solve the electricity crisis of Bangladesh especially in rural communities.

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