A Novel Model of Electricity Generation to Change the Direction of Grid Expansion and Power Flow Network

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***Abstract*—The aim of this paper is to explore a new model of electricity generation with a different topology of grid expansion and different direction of power flow network as well as higher penetration rate of renewable energy. Conventional system to generate electricity is to generate large amount electricity which reaches to the consumer end through long transmission line and distribution systems. The expansion of grid follows "generation, transmission, distribution and consumer" network. Expansion of grid nearby the existing one is not so difficult. However, it needs longer time to reach electricity to a residency of remote area because of higher cost associated with long transmission and distribution line. Unavailability of electricity is one of the most important reasons to deprive the population of remote area. It is possible to confirm electricity to the citizens of a remote area by producing small scale electricity at or nearby the consuming spot instead of bearing it through long transmission and distribution lines. Interconnection of multiple small scale generation units may form a different network in comparison to traditional power flow network. A novel method to achieve this has been discussed in this paper. The analyses have been done mainly based on the condition, environment, data and other factors of Bangladesh. This work is not to replace the traditional grid expansion topology rather to assist it with an alternative way.**

Keywords*—*electrification, grid expansion, microgrid

I. Introduction

Once upon a time, the electricity generation was decentralized and smaller. In course of time, the introduction of large power station and long transmission system make the generation possible to be located outside from the city and far from the locality [1]. The efficiency of energy conversion is also increased over time. Recently, loss due transmission and distribution systems has also been decreased [2] [3]. Extensive research is going on this topic. The grids are being interconnected and making larger regional grid connecting several countries. Advantages with several dimensions make the larger centralized generation popular over small decentralized generation system. There is no doubt that, the centralized generation is better in several ways. However, expansion of grid to the remote area is yet dependent the generation of power from large power stations and evacuate it through long transmission and distribution line [4]. Reaching electricity to remote people through this topology is associated with higher cost and most importantly the elongated time. For this reason, expansion of grid to the remote area is being slower in remote area than that of closer area of electrified region. Rural electrification is one of the cornerstones for development and the first step of modernization. Over the last two decades, hundreds of millions of people have attained modern energy access. However, almost one-fifth of the world's population have no access to electricity, and more than 75% of them are living in developing Asia and Sub-Saharan Africa [5]. In this context, a generation model: Consumer is Producer, has been proposed in an attempt to attain higher rate of electrification [6]. A detailed study of this model through this paper may further pave the way for a new way of grid expansion.

II. Common Electricity Generation Topology

Generation of electricity accomplished by mainly three ways. The large power stations which is connected with national grid. Fuel based small generator are available at the smaller region of remote area which is delivering electricity by means of local grid. Stand alone power generation system with no connectivity with any grid are also available [6] [7]. These are described here.

A. Centralized Large Power Production

Hydro turbine, steam turbine, gas turbine based large power stations are used for power generation. The duration of installation is usually long, around two or more years. These power stations are connected to the grid through switch gear and substations. The energy reaches to the end user by means of long transmission and distribution lines. This is a proven, accepted and popular technology. However, it is subjected to installation of long transmission and distribution lines thus involving longer installation time and higher installation cost [2] [3].

B. Smaller Power Production

Due to unavailability of grid connection, people are using the topology of electricity generation like the first era of electrification in many remote areas that is small generator based on fuel. These are being used for a market, village or a

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small group of people. The users are interconnected through a small local grid. This type of grid is also available in large ships. Cost of electricity is a little bit higher than that of previous one [8].

C. Stand Alone Power Production

The sources of power that is not connected with any grid in any way are the stand alone system. Individuals are mainly users of it. Very small power generators, mainly small scale renewable energy generators are the main resources for stand-alone power generation. Solar Home System (SHS) is a perfect example of it. It has reached the number one fastest growing program in the world [9].

III. Common Grid Expansion Topology

The expansion of grid may be done within the electrified region or to the nearby area of the electrified region. Besides these, expansion of grid to the remote area is also accomplished. These are discussed here.

A. Expansion of grid within the electrified region

This includes the expansion of grid due to increased load and due to new developments, house and industries within electrified area. It needs only additional low voltage level distribution line and distribution transformer for expansion [2] [3]. Economic benefit and profit to investment ratio of this type of expansion are very high. Return of investment is quick.

B. Expansion of grid nearby the electrified region

Expansion of grid nearby 5 km of the electrified region needs installation of substation, as well as primary and secondary level of distribution [2] [3]. Profit to investment ratio of this type of expansion is also high. Return of investment is quick.

C. Expansion of grid to the remote area

The rate of expansion of grid to the remote area which is more than 10 km from the electrified area is very low. It needs installation of new transmission lines, substations and distribution lines [8] [9]. Cost associated with this is very high. The rate of return of investment is slow.

IV. Direction of Grid Expansion

Direction of grid expansion (DGE) may be defined as the direction of how the grid is expanding within a large region. The expansion normally takes place to the nearer area of electrified region. The far the area from the grid, the late the area to be electrified. The DGE is normally the direction of electrified area to non electrified area. However, DGE for the local grid is different from that of national grid. It's DGE will be non-electrified area to non-electrified area. However, as the area covered by local grid expands outwards, it is closer to the national grid. Thus the DGE of local grid is actually nonelectrical region towards electrified region. Inter connection of several local grid will make a larger grid. As a result, the distance between national grid and local grid will be decreased. Due to more interconnections among the local grids, the probability of interconnection between local grid and national grid will be increased [10]. In this case, the expansion may be done from the national grid side or from the local grid side [6].

This discussion about DGE may be elaborately described by replacing the term " national grid and local grid" with "local grid and stand alone system". In this case, a stand-alone system can only be interconnected to each other thus DGE will be similar to DGE of local grid. If DGE is considered as stand-alone system towards national grid, it will provide a quick rate of grid expansion for the remote area. This is explained by figure 1. Figure 1 is showing the illustration of grid expansion with time-line indicated by different tile numbers 1, 2, 3, 4, 5 of the figure. Thus there are mainly two DGEs, national grid to remote area and another is remote area to national grid.

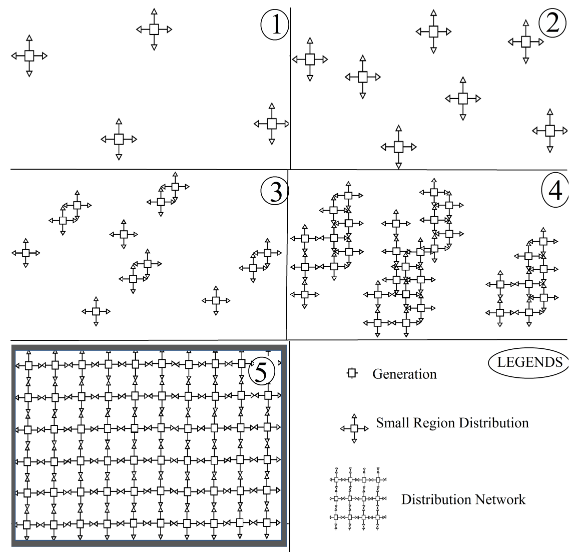

Fig. 1: DGE for remote area to national grid

V. The Proposed Model

"Consumer is Producer (CP)" model has been discussed elaborately in [6]. The producers are the consumers according to this model. The concept is to start electrification from the consumer end, which is opposite to that of the conventional system. Interconnection of two or more users is easier for a smaller region. Therefore, CP model might become the optimal fit for the remote area, where the availability of electricity is more important than the price of electricity. Few modification of this model will make it possible for urban areas as well.

The unit size of the proposed model is larger than that of SHS. However, it is still very small compared to the size of larger traditional power plant. In addition, neither SHS model nor the traditional larger power plant is suitable as power business for the mass scale participation of common population. Moreover, these markets are almost locked for the common people. Hence, if the investment and policy are such that both size of installation and investment remain at an optimum level, the production of energy will be high. Thus, this model will have a higher level of installation capacity within minimum possible time which will result in a quick expansion of grid to the remote area. The model is summarized here with Fig. 2 to Fig. 6 (redrawn with permission) paragraphs showing how the consumer producer units (CPU) form local grid, the expansion of the grid and the merging of this grid in the national grid.

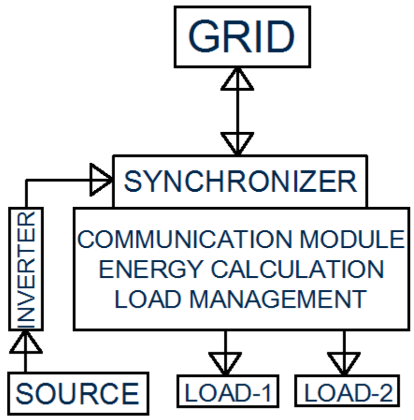

Fig. 2: Consumer Producer Unit (CPU)

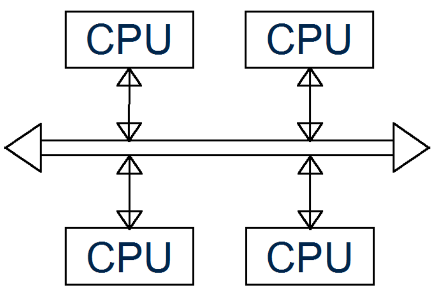

Fig. 3: Interconnection of CPU, forming local grid

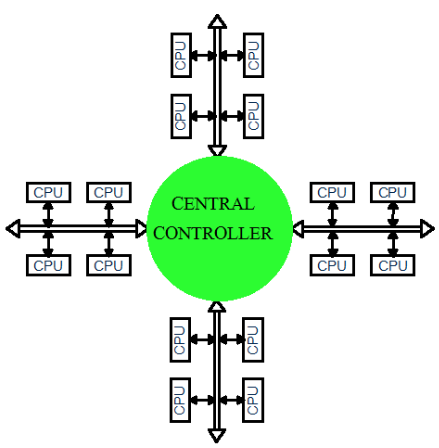

Fig. 4: Interconnection of local grid

A CPU (Fig. 2) consists of energy sources, inverter, synchronizer, communication module, energy meter and several types of loads. Each CPU has its unique identification number. The inter connection of several CPUs form a microgrid. The formation of a microgrid by several CPUs is shown in Fig. 3 id. After that an Interconnected Microgrid can be formed via connecting several microgrids using a central controller as shown in Fig. 4.

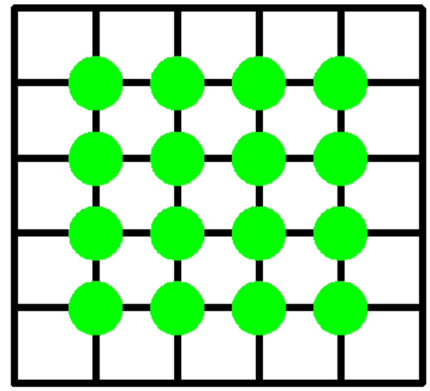

Fig. 5: Microgrid Network

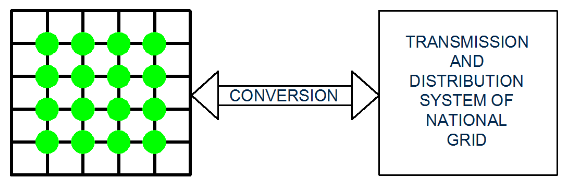

Fig. 6: Reaching to National grid through New Grid expansion topology

When a large number of interconnected microgrids are combined together, it will form a microgrid network. The microgrid network may be considered as a unit power source that will be connected to the nearest transmission and distribution lines. This is shown in Fig. 5. Furthermore, an option is provisioned for this microgrid network to be connected to the nearest national grid when available. This is shown in Fig. 6. It is possible to transfer power to the grid on demand through this connection.

The proposed model of electricity generation is claimed to have the following criteria:

1) Suitable for the remote area considering the area, density of population, load profile, availability of alternative power resources.
2) Minimization of the cost and loss due to evacuation.
3) Easy to install and maintenance. Easier installation as like as plug and play, thus minimum installation time.
4) Economically feasible and cost effective.
5) Creation of market for the common people. As a result, acceleration of general people into the power business should be possible. Thus, it will offer a higher rate of installation.
6) Decrease the carbon emission as well as lower greenhouse gas emission and decelerate the higher rate of global warming.
7) Reliable load management system as well as source management system.

8) Reliable for an extremely critical condition of the power system.
9) Minimum installation and running cost.

VI. Projection Based on Solar Home System Model

The average consumption of a typical family is around 1200 KWh [11] per year. The size of rooftop size is enough to install 2-3 KWp [6] of solar PV panel. Analysis of “PVwatts”, an online software offered by National Renewable Energy Lab (NREL), available at [12], shows that 2-3 KWp solar PV panel is able to produce to about 2600 KWh to 3900 KWh [12] of electrical energy over the year in Bangladesh. This energy should be enough to supply the energy for 2 to 3 families. This could be considered as the smallest unit of new grid expansion model. Inter connection among these units will expand the area coverage of electrified region. Interconnections of these units are the key to form a large and expanded electric grid [6].

IDCOL started the Solar Home System (SHS) program in 2003 to ensure access to clean electricity for the energy starved off-grid rural areas of Bangladesh. The program supplements the Governments vision of ensuring Access to Electricity for All by 2021 [9]. About 3.71 million SHSs have already been installed under the program in the off-grid rural areas of Bangladesh till May 2015. As a result, 16 million beneficiaries are getting solar electricity which is around 11% of the total population of Bangladesh. IDCOL has a target to finance 6 million SHS by 2017, with an estimated generation capacity of 220 MW of electricity [9].

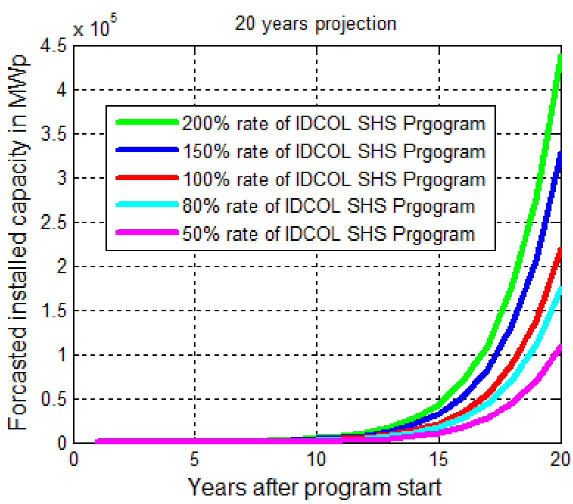

Fig. 7: Forecasted installed capacity of the proposed model based on IDCOL’s installation number.

The SHS program of IDCOL has claimed to be the fastest growing program in the world. This was possible because of the appropriate policy that was undertaken. Thus, the policy taken to enhance any program is very important. Proper policy with subsidy and easy purchase would able to make the proposed DGE model achieve higher number of installations like IDCOL’s SHS or even more. Considering the several arguments discussed in this section and the rate of the installation of IDCOL, the possible installation capacity of the proposed topology could be possible to forecast. To find the installation capacity by the proposed topology, the number of installation has been multiplied by the unit capacity (2KWp) of each stand alone power generation capacity [9] [6]. This is illustrated in Fig.7.

VII. Conclusion

The “Consumer is Producer” model is an optimum model for the proposed Grid Expansion topology. It can be used to be an alternative and supplementary way to the traditional Grid Expansion topology. Installation of large power plant based on renewable energy is good, but the scope for the implementation is not available everywhere. Moreover, larger power stations also need the evacuation system, which proves very costly although loss of this has been minimized [2] [3]. Hence, involvement of consumer into the large power stations is tough. On the other hand, the installed figure of SHSs is large (more than 3 million), but the amount of generated electricity is still not enough and is not contributing to the national grid [9]. However, SHS is not a business model for the customers, rather for the NGOs. Generally, the number of investors for a smaller (capital) system increases more than that for a larger system. In spite of this, the market of SHS is almost locked for the common people. Hence, if the investment and policy are such that both size of installation and investment remain at an optimum level, the production of energy will be high. As a result, the penetration of renewable energy would increase quickly, which will otherwise be difficult to achieve by incorporating the traditional large system and the SHSs. Extensive use of the new GE topology will reduce the green house emission as well as the rate of global warming.

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