# Consumer is Producer - A Novel Model for Electricity Generation

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*Abstract*— **The aim of this paper is to explore a new model to generate electricity with higher penetration rate of renewable energy. Conventional system to generate electricity is to generate large amount electricity at power station and then deliver to the consumer through long transmission line and distribution system. The losses and costs, incorporated with these processes, are not negligible. Another System is the Solar Home System (SHS) which is being used to replace traditional kerosene based lamp, battery based TV, fan and light bulb from 1998 in Bangladesh. But with the advancement of technology, the demand of the consumer is increasing significantly. To meet this demand it is necessary to expand national grid connection. An alternative way is to produce sufficient power using renewable resources at consuming spots. A novel method to achieve this goal has been discussed in this paper which is supported by the field study of Bangladesh University. Also a comparison has been shown with traditional power system.**

***Index Terms***— **distributed energy resources, load management, microgrid, renewable energy penetration**

## I. INTRODUCTION

Bangladesh is a small country with large amount of population. The generation of electricity is not enough to serve the population. Presently, 62% of the total population (including renewable energy) has access to electricity and per capita generation is 321 kWh which is very low compared to other developing countries [1]. Along with the centralized generation, till April 2014, about 3 million SHSs have already been installed in the off-grid rural areas of Bangladesh under the program run by IDCOL with co-operation of several. As a result, 13 million beneficiaries are getting solar electricity which is around 9% of the total population of Bangladesh [2]. Most of installed unit of SHS is in a home. Few of them are in educational institute, prayer house and market shop. An SHS is able to provide electricity for few light bulbs, small DC fan and TV, rechargeable torch light, adapter for mobile phone charging is also being used in SHS.

However, demand of the customer is increasing significantly. Many of the customers have intention to use a large TV, fridge, blender, iron, domestic water pump even AC, like a customer having connection of national grid electricity. However, extension of grid is not an easy task. Besides this, most of the power station is based on natural gas which is about 78.12% of total capacity on the FY 2013[1]. On the other hand, gas is in shortage condition and about 900 MW of generation shortfall occurs due to shortage of gas. So it will be very tough to provide more electricity generated from natural gas in future. Government of Bangladesh is trying some alternative to gas such as coal, HSD, Furnace oil based power plant as the fuel diversification program [1]-[3]. Presently, use of gas, HSD, Coal and FO are around 80%, 10%, 5%, 3% of total. On the other hand Bangladesh receives plenty of solar radiation. Wind, mini hydro and micro hydro are also available and there is scope to solve the problem of electricity generation with the combination of several renewable energy resources [4]-[7] with storage and fossil fuels based generation unit.

## II. ELECTRICITY GENERATION TOPOLOGY IN BANGLADESH

Bulk of the power in Bangladesh is generated by Bangladesh Power Development Board (BPDB) [8]. There are other independent power sources as well. All the generated power are purchased by BPDB and then transmitted by Power Grid Company Bangladesh (PGCB) to the customer's premises.

Till June, 2013 the total generation capacity of the country is 8537 MW [1]. Though, 3.11% and 11.95% energy is lost due to transmission and distribution respectively. As far as the fuel is concerned, the generation capacity is 5730 MW by Natural Gas, 1876 MW by Furnace Oil, 511 by Diesel, 220 MW b Hydro and 200 MW by Coal. Total net Energy Generation (Excluding REB) in FY 2013 [3] was 16482GWh in which 77.07% is generated from Natural gas (Table I).

TABLE I
GENERATION FROM DIFFERENT FUEL SOURCES ON FY 2013

| Fuel Type | GWh | % |
|---|---|---|
| Hydro | 894 | 2.45 |
| Natural Gas | 28119 | 77.07 |
| Furnace Oil | 5568 | 15.26 |
| Diesel | 745 | 2.05 |
| Coal | 1156 | 3.17 |
| Total | 36482 | 100 |

Energy Flow Chart FY 2013 shows that 77.91GWh of energy is produced from 34.79 Million liter of Diesel costing

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30.364 BDT per kWh of energy whereas it is 13.46 BDT for Furnace oil, 3.7 BDT for coal and 0.902 BDT for gas based generation on an average(only for BPDB Generation) [1]. As of June 2013, there is almost 3020 km of 230 kV and 6148 km of 132 kV transmission line available in the country. The number of 230/132 kV substation is 16 and combined capacity of those entire substation is 7525 MVA. Besides, there are 103 substation of 132/33 kV available throughout the country with a capacity of 11792 MVA. The distribution network is the biggest of the lot, with 3728 km, 13128 km and 21839 km of 33 kV, 11 kV and 400 V lines respectively. And of course, there are 158 substations of 33/11 kV for distribution of power around the country [3]. 40.10% of the mentioned generated power is purchased by Rural Electrification Board (REB) and distributed to the pastoral area. BPDB distributes 24.64% of the power among the urban consumers. Dhaka Power Distribution Company (DPDC) and Dhaka Electric Supply Company (DESCO) distribute 18.59% and 10.51% of the power among the consumers in Dhaka metropolitan area. Rest 6.17% of the power is distributed by West Zone Power Distribution Company (WZPDC) in Khulna and Barisal division [1].46.52% of the power is used for resident loads, 10.34% for commercial purposes, 37.42% for industries, 3.17% for agriculture and 2.56% for other purposes [1].

## III. Field Study and Possibilities

A field study has been done on several customers of existing SHS including the area of Jessore, Rangpur, Laksmipur, Mymensingh from November 2012 to April 2014. It is found that many of the remote area are yet far from the national grid. In those area most of the inhabitants use kerosene for lighting purpose. Some of them are using diesel or petrol based electric generator in group for a limited period of day due to higher fuel cost. SHS is also being used on this area. SHS system is mainly design for lighting purpose. SHS having comparatively larger size of its panel can provide also energy to TV and small fan. The users of current SHS are interested to use standard TV, fridge, fan, and small water pump. But due to lack of enough power they cannot use these appliances. An alternative way to meet their demand and to achieve same facilities as national grid is to produce enough power everywhere of the consuming spot and connect them locally. This study also shows that a typical house at village area (Nearest Electrified Village) consumes about 50~80 kWh of electric energy per month. The average free space of roof is about 40-50 $m^2$ and average usable space for solar PV application is about 18-25 $m^2$ whether the roof is South (or North) faced or East (or West) faced for slopped roof. For a top flatted roof the usable area will be the complete roof area. This area is enough to install solar PV of more than 2-3$kW_p$ [9]-[11]. It will produce more than 200-300 kWh [3] of usable electricity per month which is enough for 3-5 family of a village considering the consumption pattern of a traditional family.

A conventional power system consists of large scale power stations, transmission lines, substations and distribution lines etc., where the generation and consumption of power are not at the same location. By this system, remote areas are normally not connected with the electricity grid thus deprived from development. On the other hand as decentralized generation is known as distributed generation such as 100MW of power may be generated in a power station or it may be done by installing 1000 number of generating unit with 100kW which is situated in different location throughout the gird. It does not need any transmission network rather low voltage distribution network is used for distributed generation. However due some important factors, it is time to think about the higher penetration of renewable energy with decentralize way. These are for traditional power generation system, fuel cost for oil based plant is high sometimes it exceeds 30tk per kWh; reserve of gas is going to be diminish very soon. Besides these most of the generation units emit high amount of $CO_2$ which increases the green house effect and the global warming, cost and loss associated with evacuation system is not negligible. Moreover, interruption at any node in the grid turns into load shading and hampers a lot of user; customer is completely disconnected from the grid.

If the output of each PV panel is interconnected locally then it will provide enough energy for the entire user of the locality by means of Micro-grid [12]-[14]. A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode [7]. The discretely situated distributed energy resources (DER) are being used as a supplement and an alternative to large conventional central power station worldwide [8]-[10] and the penetration of DER at medium and low voltages is increasing [11]-[13]. The available renewable energy sources in Bangladesh can be used as DER in a microgrid which will reduce the control burden on the grid [13] and may meet a significant proportion of the national demand of electricity with a competitive price compared to the traditional power plants. The penetration of DER based microgrid is increasing in the developing country day by day. Moreover microgrid can be interconnected to any nearer microgrid in case of emergency. Interconnected microgrids have more opportunities to share generated power thus loads and load management and control. With proper technical improvement microgrid is being connected to the national grid without new transmission line [14]-[16].

Considering the points above, a new model for generation and distribution of electricity has been proposed where it is expected that T&D loss and cost will be minimized significantly, emission of $CO_2$ will be negligible with a new load management technique as well as reliable and quality power within short time.

## IV. Consumer is Producer - An Alternative Approach

Consumer is Producer (CP) model is a new technique to generate and distribute electricity with higher power quality, stability; reliability and lower T&D loss thus lower cost. It is designed as easier as plug and play equipment and within the shortest time it will be able to provide electricity to a large

amount population. Common electricity generation is accomplished by large power station with through T&D. The loss of T&D is enough to reduce the overall efficiency of power system.

The model comprises with Consumer Producer Unit (CPU), micro grid, interconnected micro-grid, and control and management unit.

1. *CPU:* The unit CPU (Fig. 1) consists with source or sources, loads, control and management system in a unit. Each CPU has its unique identification number.

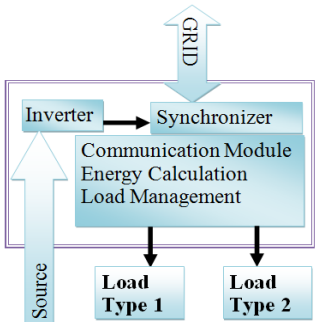


Fig. 1 Block diagram of Consumer Producer Unit (CPU)

2. *Sources:* The sources may be solar PV, biogas based generator, small wind generator, small hydro power generator, Fuel cell, micro-turbine, gas or diesel generator or any storage element such as battery, fly wheel etc.

3. *Inverter:* Whatever the output of the sources is, the output of the inverter will be AC. Inverter output is kept same as the grid.

4. *Synchronizer:* Synchronizer's task is to synchronize the output of the inverter with another CPU or with the grid.

5. *Communication module:* The task of this module is to communicate with a Master controller or central controller about the status of the CPU. It receives command from the central controller and do as the command such as to disconnect any load, disconnect itself or disconnect sources (for example diesel generator was running over the night and at the day time central controller accumulate the data of all of the CPU and decided that, now there is no need to run the diesel generator, then it will send command to the CPU of the diesel generator to stop it.)

6. *Energy meter:* It measures the amount of generated or consumed energy; calculate the bills for peak time, off peak time, demand charges etc. Energy calculation module calculates the energy incoming from grid, outgoing to grid and used amount of energy by the loads.

7. *Loads:* Loads of the consumer is categorized for a better load management such as light load, fan load, fridge, TV, computer and heavy load like AC, pump etc. Synchronizer will synchronize the output of inverter with the microgrid.

8. *Microgrid:* The micro-grid (Fig. 2) is an inter connection of several numbers of CPU.

9. *Interconnected Micro-grid:* Interconnection of several Microgrids with a central controller (Fig. 3).

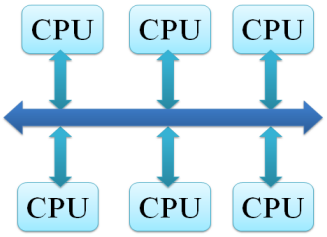


Fig. 2 CPU based Microgrid

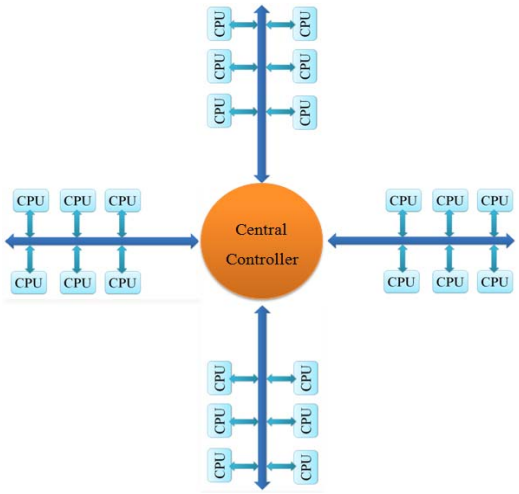


Fig. 3 Interconnection of Microgrid with central controller

10. *Micro-grid Network:* When a large number of interconnected microgrids are combined together it will form a micro-grid network (Fig. 4). The microgrid network may be considered as a unit power source that be connected with nearer T&D lines.

11. *Connection to National Grid*: There is an option to be connected with the nearest national grid (Fig. 5) when available. Through this connection it is possible to transfer power on demand.

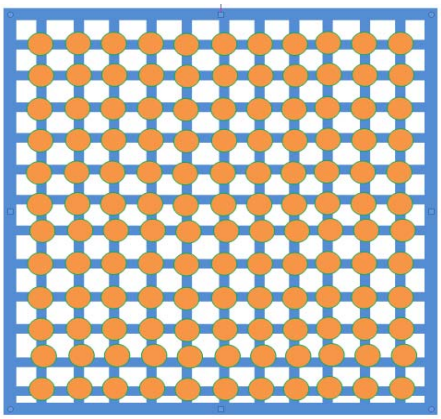

Fig. 4 Microgrid network

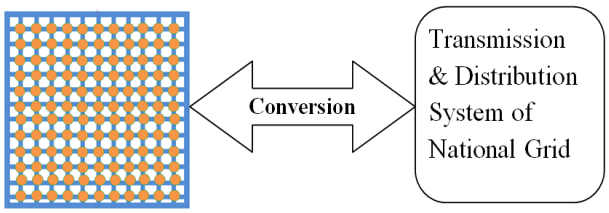


Fig. 5 Microgrid connected to national grid

The Control of voltage, frequency, real and reactive power, droop etc. can be controlled by the central controller of the interconnected microgrid. It will control the frequency, voltage and other parameters for better quality power. Each of the CPU has its own number as like as the central controller. Each Central controller will be connected with some branch of microgrid but it will control only few of the defined branches. As the loads are categorized, the central controller will send command to disconnect some types of load if generation is less than the demand. In this case the traditional procedure is to disconnect the branch completely as a result; a large number of consumers are affected.

## V. A COMPARISON WITH 'SOLAR HOME SYSTEM'

The price of an SHS ($100W_p$) is around BDT 35,000 excluding the components not related to generation (such as light bulbs, cable, DC fans etc.) Therefore, the price for $1MW_p$ will be around BDT 350 Million. There is no fuel cost, but the system price of an SHS becomes high mainly because of the larger size of the battery/battery bank, which is used for three days autonomy. However, in the proposed "Consumer is Producer" model, the installation cost for a $1MW_p$ [16] power generation system will be 60 Million BDT for panels and another 30 Million [16] BDT (approximate) for battery, alternative energy resources and controlling equipment.

TABLE II
COMPARISON OF SHS AND "CONSUMER IS PRODUCER" MODEL

| Comparison Criteria | SHS | Consumer is Producer |
|---|---|---|
| Consumer of the Business model for | The enlisted NGOs | Everyone |
| Scale of unit | 10Wp~150Wp | $1kW_p$~$5kW_p$ |
| Demand meet | Demand is forced to be limited by the size of the SHS | As much as need |
| Per $W_p$ installation Cost | Higher (400Tk. ~700 Tk.) | Lower (60 Tk. To 90 Tk.) |
| Contribution to the national grid | Nothing | Has option to be connected with the national grid |
| Contribution to the national generation | Insignificant | Significant |
| Penetration of green energy | Lower | Higher |

However, unlike the SHS for the alternative energy supply, there would be some extra fuel cost to meet the shortage as well as maintenance cost, whereas a traditional power plant requires a huge amount of fuel cost. In spite of this, if proper policies are undertaken by the government, the proposed "Consumer is Producer" model may have better performance over SHS as this model has some strong arguments over SHS. These are summarised in Table II

## VI. PROJECTION ABOUT THE INSTALLED CAPACITY

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 CP model achieve higher number of installations like IDCOL or even more. Considering the rate of the installation of IDCOL [16], the possible installation capacity of the proposed "Consumer is Producer" model could be possible to forecast. This is shown in Table III.

TABLE III
POSSIBLE INSTALLATION CAPACITY OF THE PROPOSED "CONSUMER IS PRODUCER" MODEL

| Year after starting the program | Amount of installation at the rate of | | |
|---|---|---|---|
| | 150% of IDCOL $MW_p$ | 100% of IDCOL $MW_p$ | 80% of IDCOL $MW_p$ |
| 5 Year | 303 | 202 | 161 |
| 10 Year | 3765 | 2510 | 2008 |
| 15 Year | 32451 | 21634 | 17307 |
| 20 Year | 327947 | 218631 | 174905 |

It should be noted here that, this analysis has been done considering the number of installation of IDCOL's SHS program, not the installed capacity of the SHS. To find the installation capacity of the proposed model, the number of installation has been multiplied by the unit capacity ($2KW_p$) of each CPU. This is illustrated in Fig. 6.

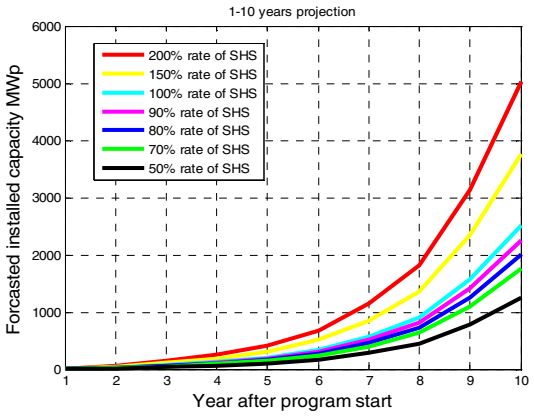


Fig. 6 Forecasted installed capacity of the proposed model based on IDCOL's installation number

## VII. Conclusion

The proposed model can be used to be an alternative and supplementary way to the traditional power system. Installation of large power plant based on renewable energy is good but scope is not available everywhere. Moreover, it also needs the evacuation system which already discussed as costly and though loss of this has been minimized. On the other hand the installed figure of SHS is large (about 3 million) but the amount is not enough and also it is not contributing to the national grid. However, SHS is not business model for the customer rather it for the NGOs. So it clear that the number of investors for a smaller system increases exponentially than a larger system. Hence, if the size and the investment are such that both of size of installation and investment is in an optimum level, production of energy will be high. As a result the penetration of Renewable Energy will increase quickly which will be hard by the traditional large system and SHS. By this way it will reduce the green house effect as well as rate of global warming. The day is not so far when people will not count the money rather the government of any country will buy green energy without counting money. Moreover, people will be motivated to produce their capita demand by themselves due to its naming. However, proper policy and steps should be taken to promote this like SHS program by IDCOL. Proper designing and debugging of the hardware system of this model will make this more convenient.

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