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PV based Micro-Generation in Bangladesh: An Approach towards Smart Grid

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Abstract— **This paper wishes to discuss about the possibilities of implementing PV based micro-generation in Bangladesh. Power crisis is a major problem for the countries like Bangladesh to develop her industrial, economic and social condition, as Bangladesh is trying to trying to shift from agriculture based economy to industry based economy. Presently, Bangladesh has a more or less stable power system, but the demand of electrical power is raising day by day. The power system has various unavoidable losses and smart grid aims to decrease the power system losses, thus increasing efficiency, detect and solve problems automatically and efficiently using real time system information. This paper will also try to identify the problems for implementing smart grid in Bangladesh and will try to provide probable solutions.**

Keywords— ***Energy management, Power system interconnection, power system security, power system, power distribution, Smart grid.***

I. INTRODUCTION

Renewable energy is actually will be the main source of power in the future. In Bangladesh, the main source of renewable energy is the Solar Energy. PV based generation systems can be implemented here to meet the daily increasing demand of electricity. Also, the world is advancing towards Smart Grid day by day. In general, a smart grid is considered to have a power generation, transmission and distribution system including an intelligent bidirectional communication system to monitor, maintain and control the efficient power flow through the power system [1]. An important feature of smart grid is the integration of renewable generation in the power system [2]. In recent days, most of the natural resources like coal, gas etc. are running out. So it is important to maximize the use of the produced electrical energy. Smart grid comes with different possibilities of reducing system loss and maximizing the usage of electrical power [3]. It also puts emphasis on reducing natural pollution by incrementing the possibility of using renewable energy and integrating it with the power system. Most of the developed and developing countries are now advancing towards smart grid. Bangladesh also should give importance to implementing smart grid for better efficiency, reliability and security [4] [5]. And, implementation of PV based micro-generation scheme can be a big leap towards the implementation of smart grid in Bangladesh.

PV based generation is a part of power generation from solar power. In Bangladesh, it is a very good source of renewable power. But it is important to understand and estimate the demand and possible generation within some specific condition. Here, the main condition in this thesis, the estimation and design is only valid for basic residential requirements. Also, it has been tried to find out the extra generation from the system which can be supplied to the grid. So, filling up the basic need of a home and then supplying the extra power to the grid if possible, so that we can become less dependent on power generation from fossil fuel. Here, a small survey has been done in the village of Jeupara (24°37' N, 88°06' E) of Rajshahi district to understand the usage pattern, then using the usage pattern, a system has been designed in HOMER 2.68 Beta Version to find out the possibilities to make a home independent of conventional grid supplied power and also generation of some extra power.

II. POWER SYSTEM PROSPECT IN BANGLADESH

The power system of Bangladesh is still depending on the generation from fossil fuels like coal, gas, oil etc. recently, the govt. of Bangladesh has signed up an agreement with Russia to set up a nuclear power station in Bangladesh to meet the future demand. At present, the established generation capacity is 14,322 MW, Electricity demand is 7000MW – 7500MW, 9622km circuit for transmission and 311,841km distribution line, Grid substation capacity is 23,087MVA. Bangladesh has electricity customer of 16.1 million, per head generation 348KW-hr and 68% of total population is under the reach of electricity distribution [7].

Now, out of 100% of total demand of electrical power, 71.39% is generated from natural gas, 16.84% from different types of oil, 1.58% from coal, and 2.81% from water. Bangladesh now imports 7.38% power from other country (From India through HVDC transmission line) [7].

In the economic year of 2015-2016, the transmission and distribution loss was 14.13%, where only distribution loss was 11.96%. In 2014-2015, the transmission and distribution loss was 13.34% and distribution loss was 11.19% [7].

In 2013-2014, maximum generation capacity was 10,416MW and maximum generation was 7365MW where in 2014-2015 the maximum generation capacity was 11,265MW and maximum generation was 7418MW [8].

Government has a plan to increase its power generation from renewable sources, especially from PV based systems. In present days, total 41MW PV system is under construction. Nearly a total of 60MW solar park project is under planning in different areas of Bangladesh [8]. But all these implemented, ongoing and under planning projects require land acquisition.

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As Bangladesh is a small country, it is a hard work to do the acquisition as many people may lose their valuable land and it also takes time and big budget to provide them a place to live and providing them a job to make the earning. So we must think new ideas so that people do not have to face these unwanted problem and be a part of generation process, where they may be able to make some extra income by implementing solar panels on rooftop to save land.

III. PROSPECT OF SMART GRID IN BANGLADESH

Energy shortage is a worldwide concern. Like other developed and developing countries, the electrical power demand is increasing in Bangladesh. But it is not possible to build power stations rapidly. In Bangladesh, the electric power grid is designed for conventional one way delivery system. So there are faults and deregulations in the system. Smart grid ensures an energy efficient system. Recently conventional grid has been modernized since last few years. Automated power plants using SCADA system and microcontroller based smart relays has already been implemented. So minimizing the power crisis can be achieved using the smart grid. The major requirement of smart grid is an automated network of broadband connection.

A. Integration of Information System

Smart grid operation requires real time information. Real time information can be acquired only by using proper information and communication system. So, integrating information and communication system with the grid is the first step towards smart grid. This communication system can have three groups, load group, network group and generation group. Efficient operation can be ensured by the cooperation among these three groups.

B. Measurement of Phase and Other Advanced Measurement Units

In smart grid, power flow is measured automatically and the data is sent to the control center quickly with some additional information which may increase the power quality. Phase measurement unit is used for determining the quality of power. There must be a phase difference in the two ends of a long transmission line to transfer power. But is the phase difference is too high then the power will not be transmitted. In today's transmission system, the number of measurement of phase is very few. With more measuring equipment at the key points can improve the control and stability of smart grid.

C. FACTS and Other Control Devices

Now a days, very few utilities use FACTS. In smart grid FACTS can be used more to solve various transmission problem in a cost effective way. The control of FACTS requires advanced communication and system level control technology. Also many advanced technologies can be used to turn a high voltage transmission system into a self-healing grid.

D. Distribution System Automationk

In smart grid distribution system all current comes to one point and then distributed to the loads as per demand. Here, some utilities may have sensors and remote control switches to isolate any problem or fault.

E. Selective Load Control

At present, when a fault occurs, the only way to isolate the fault is to isolate the whole feeder, which may shut down most of the healthy part of the system. The smart grid can have the option of selectivity which can prioritize the load and can control the power flow to the load by the priority, isolating the fault.

F. Smart Meter

Smart meter is an intelligent computer based metering device which can be used as an electric meter also a sensor to the information network. It can sense the power system, detect power quality, can have remote switching function, can store and send the data to the nearby stations and it can also do the job of automatic billing as per the policy.

G. Integration of Renewable Energy

The world is moving towards renewable energy generation day bay day because of less availability of fossil fuel, natural pollution etc. In present power systems, it is hard to integrate renewable power to the grid or system because it is unpredictable. So sudden stoppage of renewable generation can cause a major fault in the system. Smart grid has the potential solution to this problem. Smart grid can predict from forecast and can control the generation and connection of the renewable power generator to the grid.

IV. CHALLENGES REGARDING SMART GRID INTEGRATION

Implementing smart grid in an age old established power system is never easy. It becomes harder in countries like Bangladesh where the power system is really vulnerable and may not suit to the smart grid at the beginning, which may cause disaster. The following problem may occur while implementing smart grid:

a) Smart grid is communication based power system. The security of the systems related to the communication is to be maintained.

b) Network security of distributed systems across meters, substations.

c) Authentication of the home devices like smart meters, its detection and monitoring.

d) Network access management for both customers and officials to manage information.

e) Security policy management.

f) Network and web security as they are the backbone behind communication.

g) Adaptation of Service Oriented Application (SOA) architecture in communication.

h) Format bridging, transformation and routing.

i) Handling a wide variety of data format

j) Network hacking.

k) Availability and price of sensing and communicating equipment.

l) Probable shortage of skilled manpower in operations and maintenance.

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V. PROBABLE SOLUTIONS TO THE PROBLEM AND POSSIBILITIES

It is not possible to design a perfect electrical power system. But it can be made less vulnerable and more efficient than the present system by smart grid. The following steps can be the solutions to the problems:

A. Probable solutions

a) Shortage of skilled manpower can be fulfilled easily. Bangladesh has many government and private institute who are highly capable of creating manpower in the field of science, engineering and technology. Also Bangladesh has many technical and vocational training institutes who can produce technicians in the field of power generation, transmission and distribution.
b) Bangladesh already has a big manpower in the field of ICT. Smart grid uses a very high level of accuracy in data transfer through the network using various protocols. These people can be trained to make skilled professionals in maintaining smart grid.
c) The communication between different entities in smart grid is done by the communication network. The entities work depending on specific control signals. It is very much possible to hack into the network and sending false signal, which can even cause a blackout. IT professionals should have the skill to stop these type of problem.
d) The sensing and communicating equipment should be of high capacity and its quality should be good. Good quality equipment can ensure the reliability and efficiency of smart grid.
e) Increasing the use of renewable energy can decrease pollution. There are also many remote places in Bangladesh where it is not possible to build any power plant or very much hard to establish a transmission line. So the possible solution to this problem is setting up small scale renewable energy sources.
f) Big power plant can have renewable energy sources too to power up its DC power dependent equipment like sensors, relays, circuit breakers, battery backup and its charging unit and internal electrification, so that the portion of generated power used to produce DC can be transmitted in grids.

B. Possibilities

Bangladesh has the possibility of shifting to smart grid. It will first ensure quality, reliable power as well as it can create employment opportunity.

The possibilities are described below:

a) Bangladesh mainly has centralized power system, which makes the control of power flow complex and one area can be out of service easily due to fault, because there is no overall selectivity prioritizing. So the power system can be a combination of centralized and decentralized system, like distributed generation but centralized control.
b) Bangladesh can set up new industries to produce sensing and communicating equipment, smart meter etc. to be able to use it at low price. The price will be obviously less than the price of importing. This will create employment opportunity in the industries, equipment designing, quality control and other field.
c) Bangladesh has been working on modernizing the power system, transmission and distribution system by using up to date equipment for better control. So it will not be too much hard to implement the smart grid. The only thing will be the technique of controlling. The control will become automatic which will increase system reliability and efficiency.

With more efficiency, more consumers can be added to the grid, which will help in industrializing and thus improving the economy of Bangladesh.

VI. GENERATION FROM SOLAR POWER

So, here we can think of a different issue. What if the consumers can also sell power to the system? Here, a consumer may also sell power to the system. The population of Bangladesh is approximately 16,00,00,000.00. If we consider each family has four members, then,

$$\text{No. of families} = \frac{160000000}{4} = 40000000 \quad (1)$$

If every family can produce extra 50W of power after their own consumption, then,

$$\text{Total power generation} = 40000000 * 50 = 2000000000\text{W} = 2000\text{MW} \quad (2)$$

This generation can be increased easily. The government of Bangladesh is now emphasizing on renewable energy, especially solar energy because of need, shortage of fossil fuel, problems regarding establishing grid line in remote places and also for various international agreements. But the setup cost of solar energy is very high. So people are not really very much encouraged for using solar power. But if government gives people the chance to make income, they will take the chance very easily. If this can be done, a big different energy market can be established in Bangladesh. Then people will have the real opportunity to be a part of power generation. This can control the monopoly in power market and power can be made available. This can also create a huge employment opportunity in renewable energy generation, research and development, set up and servicing, market study. This increase in power generation will increase the use of various appliances. Employment opportunity in this field will increase too.

To do so, it needs to be studied. The study can be on generation techniques, pricing, billing, and inserting this power to the grid and many other field. It also requires monitoring and regulatory bindings to control the process and the control should be kept to the government.

We know, fossil fuel based plants, or nuclear power plants can provide stable power. Renewable powers are not stable, also, they are not regular power source. Like, solar energy cannot

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be found at night. Also, the intensity of light varies. And in case of wind power, the wind flow is never stable. So, these renewable sources cannot provide stable, uninterrupted power, which is very hard to integrate in present power system. Smart grid is the solution to this problem. The efficient and reliable control system helps to integrate the renewable power to the system, as they can take the weather forecasting information and make decision from the information. Smart grid can control when the power generation form other stable sources should be increased or decreased depending on the availability of renewable sources.

This will also lead to decentralization of the power generation, which will help the local industries. Local industries may also choose to receive power directly from the local generation, which will ensure the availability of power more. This can also decrease the transmission and distribution loss of the power system.

VII. UNDERSTANDING USAGE PATTERN

To design a system, we must know the possible demand to meet. To understand the demand of power, a survey has been done among 100 families in the village of Jeupara of the Rajshahi district of Bangladesh. This survey aims to understand the basic need of a family in that region so that we can understand how much power generation from PV is needed to meet a family demand and possible extra generation which can be supplied to a grid. The survey questionnaire and their answers in average is given below:

- How many lights do you use? Ans: 4(avg.)
- How many fans do you use? Ans: 3(avg.)
- Do you use television? Ans: Yes(100%)
- What is your monthly electricity bill? Ans: 435tk(avg.)
- Do you use solar panel? Ans: Yes(10%), No(90%)
- Do you want to use solar panel in the future? Ans: Yes(66.67%), No(33.33%)
    - The 10% who answered yes in the previous question, they were not asked this one.
    - The participants who answered no in this question, they answered high price of solar system as the reason.
- Will you use solar system if you can earn money from it? Ans: Yes(90%), No(0%), Not sure(10%).
    - The 10% participant who answered “not sure”, they want to know more details, as how the system will work, if there is any harm factor or not etc.

VIII. SIMULATION

Depending on the theory/idea of generation, a simulation has been done to understand the possible output and extra output from a family.

Using this data, a simulation has been done using the HOMER 2.68 Beta version. The simulated circuit diagram is given below:

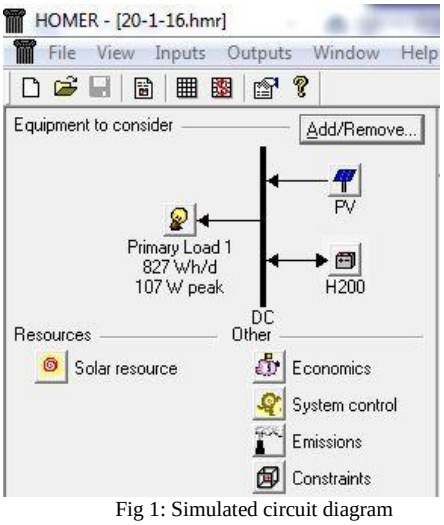

Fig 1: Simulated circuit diagram

Here, the primary load section holds the data of the loads, estimated from the survey. The PV section holds the data of PV size and solar input data. The H200 is the battery unit taken from the software battery package which can support the system to reserve the extra electricity produced, which extra electricity can also be sent to any local micro-grid or national grid by fulfilling required connection condition.

Now, we have estimated the usage of a family at different times of the day depending on the survey done in the area stated before. So, the following table shows the load estimation at different time of a day (Considering each light: 3W, each fan: 8W, each TV: 20W):

TABLE I. LOAD DEMAND

Hour	Load (kW)
00:00 – 01:00	0.024
01:00 – 02:00	0.024
02:00 – 03:00	0.024
03:00 – 04:00	0.024
04:00 – 05:00	0.039
05:00 – 06:00	0.039
06:00 – 07:00	0.039
07:00 – 08:00	0.059
08:00 – 09:00	0.059
09:00 – 10:00	0.033
10:00 – 11:00	0.033
11:00 – 12:00	0.041
12:00 – 13:00	0.016
13:00 – 14:00	0.016
14:00 – 15:00	0.016
15:00 – 16:00	0.016
16:00 – 17:00	0.019
17:00 – 18:00	0.023
18:00 – 19:00	0.023
19:00 – 20:00	0.053
20:00 – 21:00	0.053
21:00 – 22:00	0.053
22:00 – 23:00	0.053
23:00 – 00:00	0.053

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The following table shows the solar input and environmental data of the surveyed area, which has been taken form the solar home system training manual of IDCOL [6]:

TABLE II. AVERAGE ENVIRONMENTAL DATA [6]

Month	Clearness Index	Average Radiation (kWh/m²/day)
Jan	0.466	3.16
Feb	0.565	4.46
Mar	0.526	4.88
Apr	0.507	5.28
May	0.495	5.46
Jun	0.376	4.22
Jul	0.399	4.42
Aug	0.394	4.18
Sep	0.388	3.74
Oct	0.427	3.53
Nov	0.559	3.92
Dec	0.494	3.17
Scaled annual average:	4.2 kWh/m²/d	

The following image shows the graphical view of the solar resources (as per the input in the Table 2):

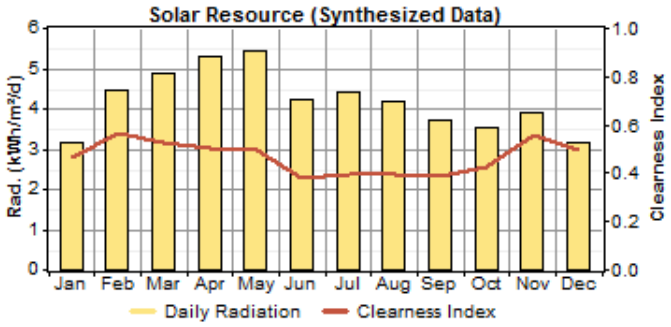

Fig 2: Solar resources.

The following table shows the data of the battery unit used in the system:

TABLE III. STORAGE UNIT DATA

Quantity	Values	Unit
Nominal capacity	1.60	kWh
Usable nominal capacity	1.12	kWh
Autonomy	32.5	hr
Lifetime throughput	2720	kWh
Battery wear cost	0.571	$/kWh
Average energy cost	0.00	$/kWh
Energy in	205	kWh/yr
Energy out	177	kWh/yr
Storage depletion	0.360	kWh/yr
Average energy cost	27.9	kWh/yr
Annual throughput	190	kWh/yr
Expected life	14.3	yr

IX. OUTPUT AND RESULT

After Successful simulation, it has been found that after fulfilling the basic needs of a family, a family can produce extra electricity. The following table shows the electrical output of the system:

TABLE IV. ELECTRICAL OUTPUT

Quantity	Values	Unit
Rated capacity	1.00	kW
Mean output	0.150	kW
Mean output	3.59	kWh/d
Capacity factor	15	%
Total production	1311	kWh/yr
Minimum output	0.00	kW
Maximum output	0.997	kW
PV penetration	434	%
Hours of operation	4374	hr/yr
Levelized cost	0.0399	$/yr
Excess electricity	980	kWh/yr
Unmet load	0.00	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	1.00	%

So finally, we get the following result:

- Excess electricity: 980kWh/year
  - Excess electricity/day: 2.68kWh (apprx.)
- Power rating=980/(15%∗365∗24)=0.74kW
  - [eq. $kWh=kW*Capacity\ Factor*365\ days*24\ hours$]
- So, one family is equivalent to 0.74kW Power Plant.

So, per day power generation (using the data from (1)): 40000000*0.74kW= 29600000kW= 29600MW. (3)

X. CONCLUSION

The world is now facing the shortage of energy. The situation of Bangladesh is not so different. As the generation cannot be increased rapidly, it is better to minimize the losses and optimize the power transmission and distribution. The system we are following today is saturated and the losses are minimum. So the only way to reduce the losses is shifting to smart grid. As renewable energy generation, thus green energy is a big part of smart grid, and also in the context of future fuel crisis if the field of power generation, PV based micro-power generation can be a very good solution to meet future energy demand. There will also be losses in the smart grid because there is no system without loss. But smart grid has the potential to study to minimize the losses more and more. It also gives the consumer the independence of selectivity within regulation. And, smart grid can decrease the pollution and work on environment safety by integrating renewable energy easily. So, through this paper, it has been shown that in Bangladesh, it is possible to produce enough electricity from solar power in household, which can be used to meet the family need,

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