Technical Potential of Rooftop Solar Plant in Bangladesh

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Abstract

Technical potential of Grid-Tie rooftop power plant in Bangladesh is immense. From the technical, environmental and economic perspective, the solar panel is the best source of renewable energy power generation in Bangladesh. It is expected that, building's rooftop solar plant can provide more than 6 Giga Watt electricity in Bangladesh. In a land shortage country like Bangladesh Grid-Tie rooftop power plant has the extensive potentiality to eradicate the electricity crisis. To see the potentiality, a 1360 W rooftop grid-tie solar plant has been implemented and its performance and cost-benefit analysis has been investigated. The solar power plant has been implemented at Institute of Science and Technology, Dhaka, Bangladesh. After implementation, it is seen that, maximum 1070.6 W is received by the solar panel and 118.8 kWh electricity was generated on the month of August, 2016. Cost-benefit analysis shows that above 600 unit electricity consumption in an organization rooftop solar plant is very much profitable and the implementation cost can be recovered within 15 years.

Keywords: Power plant**,** Solar cell, Grid-Tie system, Electricity and Sustainable future.

1. INTRODUCTION

Bangladesh situated in the north-eastern part of South Asia is among the world's most densely populated nations (1266 people/Km^2 in 2017) with a population of 164.978 million in 2017. Energy, and more explicitly electricity, is a prerequisite for the technological development, higher economic growth and poverty reduction of a nation. However, in Bangladesh, total primary energy consumption in 2013 is 1.129 quadrillion Btu (British thermal unit), whereas in 1980 it was 0.128 quadrillion Btu [1]. As the statistics shows the hunger for energy is increasing and it is not only in Bangladesh but all over the world. Moreover, fossil and nuclear fuel will not last forever, and the only option is to turn to renewable energy [2]. By looking the technical, environmental and economic aspect solar panel is the best option for utilizing renewable energy. Solar energy could be a major source of power generation in Bangladesh. Bangladesh government plans to make it obligatory to install solar panel on rooftops of every multistoried and hi-rise building. Only building's rooftop solar can be generated more than 2 GW electricity alone in Dhaka city and throughout the country it may surpass 6 GW(Considering 60% of usable rooftops and keeping remaining 40% for other types of use) [4]. In a land shortage country like Bangladesh [3] Grid-Tie rooftop power plant has the extensive potentiality to eradicate the electricity crisis. To see the potentiality, a 1360 W rooftop grid-tie solar plant has been implemented and its performance and cost-benefit analysis has been investigated. To implement the 1360 W rooftop grid-tie solar power plant, five 260 W German made polycrystalline solar panel and one 60 W solar panel was used. Each 260 W solar module contained 10 rows and 6 columns that is, a total of 60 solar cells. Also, a 1500 W solar grid tie inverter, 1x6 rm (stranded round conductor [5]) DC cable for connecting panel to inverter, cable 1 × 3.0 rm (for inverter to grid connection), an energy meter and standard frame to hold the solar panels has been used to implement the 1360 W rooftop solar power plant. A German made solar panel was tested in Bangladesh Council of Scientific and Industrial Research organization for performance analysis. The performance analysis is discussed later in the paper. The implementation of rooftop solar plant is at Institute of Science and Technology, Dhaka, Bangladesh. After, implementation data were obtained, and seen that the solar plant has been working properly. Cost-benefit analysis shows, for above 600 unit electricity consumption organization, roof top solar plant is very much profitable, and shows that the technical potentiality of rooftop solar plant in Bangladesh.

2. BACKGROUND STUDY

2.1 Efficiency and Fill factor:

The "fill factor", more commonly known by its abbreviation "FF", is defined as the maximum power divided by the product of I_{sc} (Short Circuit Current) $*V_{oc}$ (Open Circuit Voltage), i.e.:

$$FF = \frac{V_{MP} I_{MP}}{V_{OC} I_{SC}} \quad \text{..........(i)}$$

FF also defines the "squareness" of the IV curve that is how close the solar cell IV curve is close to ideal IV curve.

Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun. That is:-

$$\eta = \frac{V_{OC} I_{SC} FF}{P_{in}} \quad \text{...........(ii)}$$

Here, η is the efficiency.

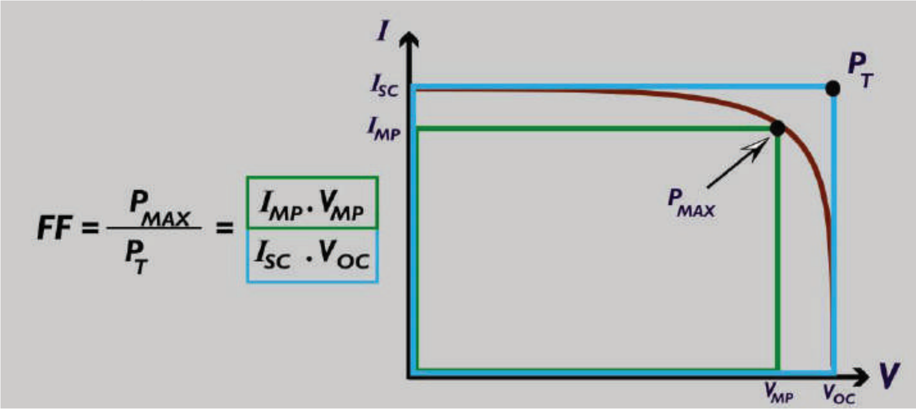


Figure 1. Fill factor and Efficiency

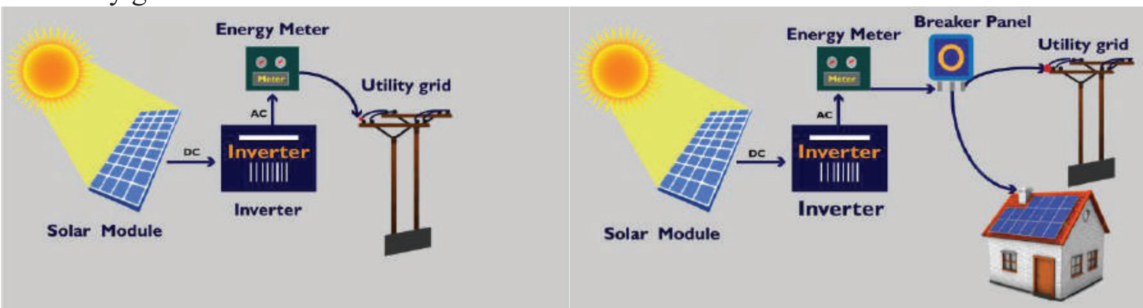
2.2 STC and NOTC

Standard Test Conditions (STC) are the laboratory conditions under which all PV modules are tested. It can be said that STC is a benchmark for comparing different types of PV modules, even if they are not from the same provider. STC specified as, an irradiance of 1000 Watts per square meter, which simulates peak sunshine on a surface directly facing the sun in a day without clouds. A surface temperature of 25°C and air mass AM 1.5 G is considered [8].

However, these are idealized conditions which don't reflect the real site conditions under which a PV module will operate. The conditions at Nominal Operating Cell Temperature (NOCT) aim to simulate reality more closely. NOCT is specified as, the irradiance is 800 Watts per square meter, which takes into account the fact that PV modules don't always face the sun. It also considers atmospheric or geographic conditions what might diminish sunshine. Solar panels heat up considerably during operation, so the temperature considered is 45 (+/- 3) °C which is way more than 25°C.

2.3 Battery less PV Grid-Tie System:

A battery less PV Grid-Tie system is a solar system which is hooked into the national electricity grid. It is an efficient system because off grid systems must store the energy, as in batteries. But in this case, being on grid, the electricity company stores the energy [9]. PV panel or Solar panel converts light to electricity (DC-Direct Current), and this DC current is converted to an AC (alternating current) current, by an Inverter which also matches the line voltage of the electricity flowing through the power line. Because the system pushes back electricity to the national grid and the electricity company keeps track of the kilowatts usage on an hourly basis, moreover the homeowner receives full retail offset or a credit on electricity bill. The only disadvantage of the system is during electricity power outage a standard grid tie system will not produce power until the grid power is available. Depending upon providing electricity to electricity grid a battery less PV Grid-Tie system can be classified into two types. The first type is shown in figure 2 (a) Here all the electricity generated by solar plant is given to the electricity grid. However, the second type of PV Grid-Tie system (shown in figure 2 (b)) home appliance utilizes the electricity generated from solar plant. When the home appliances is not utilizing any electricity or generated electricity amount is more than demand of home appliance then the extra electricity is given to the electricity grid.



(a) **(b)**

Figure 2. **(a).** Battery less PV Grid-Tie System Solely Connected to Utility Grid **(b).** Battery less PV Grid-Tie System Connected to Utility Grid and Home Appliances

3. IMPLEMENTED SYSTEM BLOCK DIAGRAM

Although the main goal always has been to provide electricity to the national electricity grid. But analyzing the Institute of Science and Technology electricity bill (4000 unit electricity consumption per month on average), and as Institute of Science and Technology is always open 7 days a week, and assuming 5KWh electricity will be generated by a 1360 W solar plant, it is beneficial that some modification in the design is needed. In this system, the output from energy meter is not hooked into the national electricity grid, it is directly connected with the output of three phase meter. In figure 4, the output from energy meter is connected with the output of three phase meter (red wire). So the solar electricity merges with the electricity that is coming from the national electricity grid. That is there is less utilization of national electricity grid electricity.

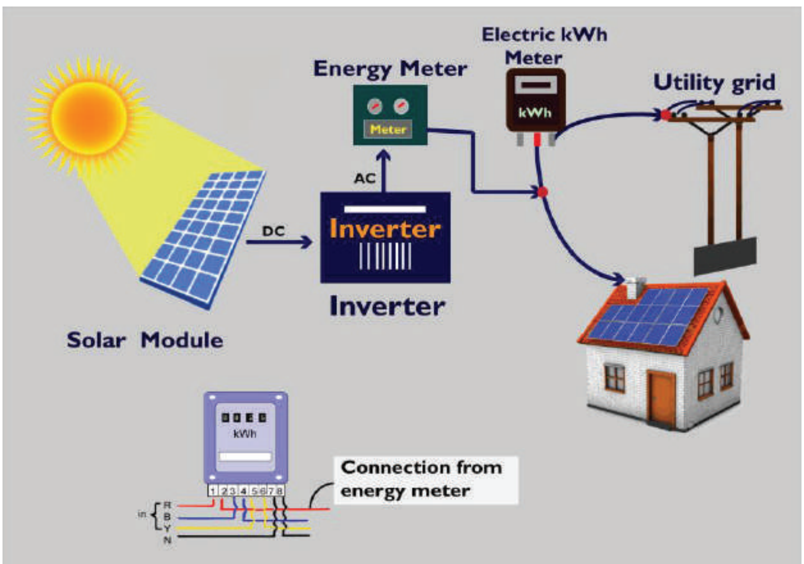


Figure 3. Implemented Grid-Tie System.

4. SPECIFICATION AND TEST RESULT ANALYSIS OF 260 W SOLAR PANEL

From five 260 W German made polycrystalline solar module, randomly a solar panel was selected for testing. The Solar World Company given specification of the 260 W solar module is given in table 1.

Table 1. Specification of 260 W polycrystalline solar panel (SW 260 POLY-33 mm frame)

Specification of 260 W polycrystalline solar panel (SW 260 POLY-33 mm frame)			
AT 1000 W/m², (STC) 25°C, AM 1.5			AT 800 W/m², (NOCT,) AM 1.5
Maximum power	P_{max}	260 W	192.4 W
Open circuit voltage	V_{oc}	38.4 V	34.8 V
Maximum power point voltage	V_{mpp}	31.4 V	28.5 V
Short circuit current	I_{sc}	8.94 A	7.35 A
Maximum power point current	I_{mpp}	8.37 A	6.76 A
Module efficiency	η	15.51 %	-

To verify the specification testing of the equipment was done in the BCSIR (Bangladesh Council of Scientific and Industrial Research) laboratory, and the obtained result are shown in the table 2.

Table 2. Practical Data of 260 W polycrystalline solar panel

Practical Data of 260 W polycrystalline solar panel			
AT 1000 W/m², (STC) 25°C, AM 1.5			AT 722.2 W/m², (NOCT,) AM 1.5
Maximum power	P_{max}	257.280 W	177.110 W
Open circuit voltage	V_{oc}	36.130 V	28.530 V
Maximum power point voltage	V_{mpp}	-	28.5 V
Short circuit current	I_{sc}	9.194 A	6.679 A
Maximum power point current	I_{mpp}	-	6.208 A
Fill Factor [%]	FF	77.4	75.1

The I-V and P-V curves of 260 W solar panel has also been shown in figure 5.

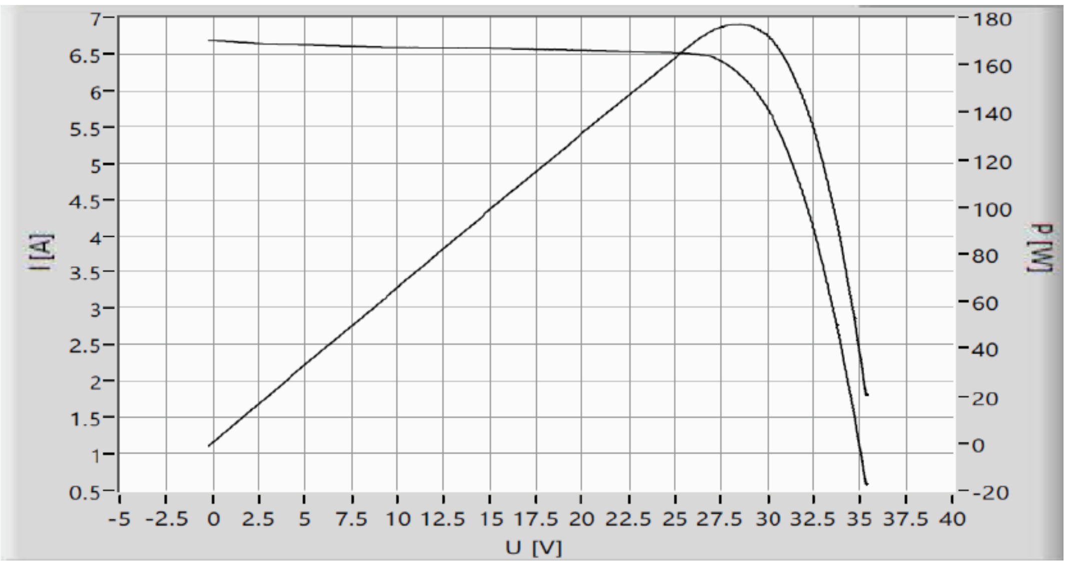


Figure 4. I-V and P-V curves of 260 W polycrystalline solar panel

It is seen from the data that, fill factor is 77.4% and 75.1% for STC and NOTC conditions, where as in specification it is 75.1%.and 74.5%. As the FF values are very close and other parameters are also very much similar to panel specifications, the solar panel has been approved for implementation.

5. IMPLEMENTATION OF THE SYSTEM

Figure 5. 1360 W rooftop solar plant at Institute of Science and Technology, Dhaka, Bangladesh

The implementation of rooftop solar plant (shown in figure 5) has been done at Institute of Science and Technology, Dhaka, Bangladesh. For implementing the 1360 W rooftop grid-tie solar power plant, five 260 W German made polycrystalline solar panel and one 60 W solar panel has been used.

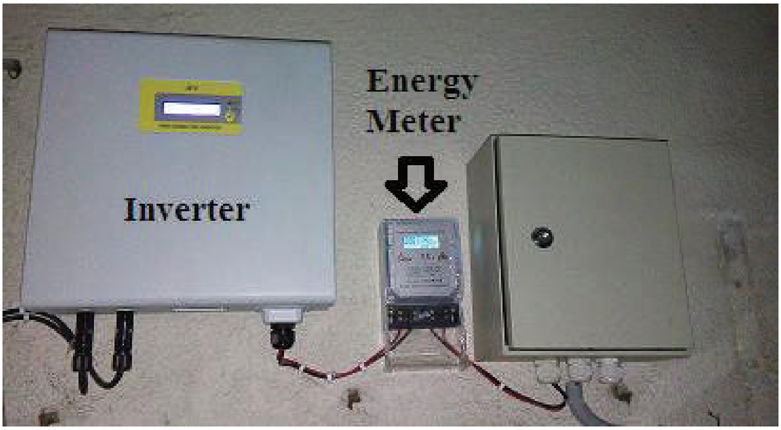


Figure 6. Inverter and energy meter

Moreover, a 1500 W solar grid tie inverter has been used in the system (shown in figure 6). This inverter converts the DC current from solar panel to AC Current and provides to the grid. Also 300 feet, 1x6 rm (stranded round conductor) DC cable was used for connecting the solar panel to the inverter. A 200 feet, 1×3.0 rm AC cable is used for inverter to grid connection. Last but not the least, an energy meter and standard frame to hold the solar panels is used to implement the whole 1360 W rooftop solar power plant. The total cost for this implementation was (2, 04, 000) two lac and four thousand Bangladesh Taka (BDT).

Table 3. Practical Data of 1360w rooftop solar power plant

Time	**9.30 (A.M)**	**10.00 (A.M)**	**11.00 (A.M)**	**12.00 (P.M)**	**1.00 (P.M)**	**1.30 (P.M)**
Day 1	440.3W	653.2W	848.2W	953.2W	1054.7W	948.4
Day 2	330.4W	551.8W	743.1W	1070.6W	500.3	770.5

After, implementation electricity generation data has been taken manually from the inverter for 2 days. The data are tabulated in table 3. Maximum power obtained is 1070.6W. Also after completion of a month by seeing the energy meter, for the month of August, 2016 total power generated by the panel was 121.8 kWh, which is very close to 4kWh or 4 unit per day.

6. COST-BENEFIT ANALYSIS

According to Dhaka Electricity Supply Company Limited, Bangladesh, above 600 unit uses of electricity cost is 9.98 Bangladesh Taka (BDT) [10] [Figure 7]. As, Institution of Science and Technologies electricity consumption is more than 600 unit (4000 unit electricity consumption per month on average), IST has to pay 9.98 taka form 601 unit to 4000 unit. In our design, as stated earlier, the output from energy meter is connected with the output of three phase meter. So the solar electricity merges with the electricity that is coming from the national electricity grid. That is there is less utilization of national electricity grid. So, the electricity generated form the power plant will not come from national electricity grid. For this reason, it is logical to think that the electricity generated from solar plant will be deducted or sold from above 600 unit. So, here per electricity unit 9.98 BDT is considered for the calculation. Although, solar panel warranty is of 25 years, for calculation purpose 20 years of life span is considers. It is estimated, 4 KWh per day electricity generation, thus for 365 days total electricity generation is 365*4 = 1460kWh or 1460 unit a Year. So total revenue is 1460* 9.98 = 14570.8 BDT. In 20 years, that is 20*14570.8 = 2, 91, 416 BDT. Which is way more than the implementation cost, which was 2, 04,000 BDT. Within 15 years the actual cost will be recovered. Moreover, this system has no or very little maintenance cost and electricity is produced using green energy.

SL	Customer Category		Per Unit Rate (Tk.)	Minimum Charge	Demand Charge	Service Charge 1ph	Service Charge 3ph
	Category-A : Residential						
		Life Line : From 1 to 50 units	**3.33**				
	a.	First Step : From 1 to 75 units	3.80				
	b.	Second Step : From 76 to 200 units	5.14				
1	c.	Third Step : From 201 to 300 units	5.36	100	15	10	30
	d.	Fourth Step: From 301 to 400 units	5.63				
	e.	Fifth Step: From 401 to 600 units	8.70				
	f.	Sixth Step: Above 600 units	9.98				

Figure 7. DESCO Electricity Charge Rate [10]

7. CONCLUSION

This study examines the technical potential of rooftop solar plant in Bangladesh. A 1360 W rooftop grid-tie solar power plant has been implemented at Institute of Science and Technology, Dhaka. Moreover, cost-benefit analysis shows that for using electricity above 600 unit, implementing rooftop solar power plant is very much profitable and within 15 years the implementation cost can be recovered. These results confirm that the rooftop solar plant has the potential to initiate significant renewable energy inputs in Bangladesh. This new understanding and technical potentiality of roof top PV plant can have an immense impact to the building and energy policy of this region. By ensuring establishing rooftop solar plants (at least 30% of roof top) in every building should be the major policy focus in Bangladesh. Surely, roof top power plant is one of the key to provide a green sustainable future and eradicate the electricity problem in Bangladesh.

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