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Design and Analysis of a 100 kWp Grid Connected PV Solar Plant at a Coastal Area of Bangladesh

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Abstract

In Bangladesh, the usage of electricity is continuously increasing. Govt. is also trying to increase the electricity production by installing new power plants to meet the additional power demands. Most of the power plants are natural gas-based, coal-based or nuclear power-based. Considering the greenhouse effect; solar power plants could be one of the best solutions to meet the additional power demands as well as it has a lot of financial and environmental benefits. In this paper, modeling and analysis of a 100 kWp PV solar plant using PVsyst software will be discussed briefly. Important factors such as required area, the performance ratio of the arrays, total energy production per year and losses will also be discussed.

Keywords: Photovoltaic, Solar plant, PVsyst, Irradiation, Solar plant in Bangladesh, Grid-connected PV

INTRODUCTION

Solar energy is abundant and cost-free energy and also sun hour is predictable, that's why solar is considered one of the best renewable energy sources [1]. The use of solar energy is rapidly increasing as environmental issues play a vital role here [2]. The total electricity production capacity of Bangladesh is now more than 20,000 MW but only a little amount of them are generated by renewable sources [3]-[4]. Few big cities have installed solar PV systems to power up the street lights. There are some major drawbacks of the gas-based, or coal-based power plants such as, the overall installation costs, site selection, environmental issues, etc. [5]. Considering all these drawbacks solar power plants could be a suitable and smart solution. Grid-connected PV, off-grid solar PV and pumping solar PV [6] could be installed to reduce the burden of peak demand on conventional power plants. In addition to clean and pollution-free energy, solar photovoltaic systems are also comparatively cheaper than conventional power plants [7]. A lot of research is undergoing to develop a more efficient and convenient solar PV module. Now, most of the renowned companys' solar modules have efficiency in between 20%-23% [8]-[10]. There are a lot of research opportunities in the solar field to develop the system more efficiently.

The main objective of this work is to design and simulate a 100 kWp solar PV plant in the coastal area of Bangladesh. Many coastal areas are still not fully electrified. So solar PV could be a useful source as well as cost-effective for the coastal people. The simulation and design of the 100 kWp will be performed by a widely used tool called PVsyst [11-12]. Using this PVsyst tool, some important factors will be discussed which will assist to install solar modules to get higher performance from the PV modules. This 100 kWp solar PV will be performed as a grid-connected solar plant, so there will be no battery storage system to store the solar energy during night-time.

DESIGN AND ANALYSIS

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Geographical Data

To design and analyze a 100 kWp solar plant, the very first and most important thing is to select the location of the solar plant. For this paper, the area was selected to be a coastal area in the Patuakhali district, Bangladesh. The details of the area are described in Table 1.

Table 1. Geographical details of the proposed site.

Country	Bangladesh
District	Patuakhali
Location	Char Chapli
Latitude	21.82 °N
Longitude	90.21 °E

The table 1 represents the important geographical data of the PV solar installation site. These data were considered as the input of the 100 kWp solar PV design.

Grid Connected 100 Kwp Solar PV

After the geographical data input, some else important data were put in the PVsyst as input to design 100 kWp solar PV. Tilt angle is one of the most important facts to install any solar module. It represents the alignment angle of the PV module against the parallel line concerning the ground.

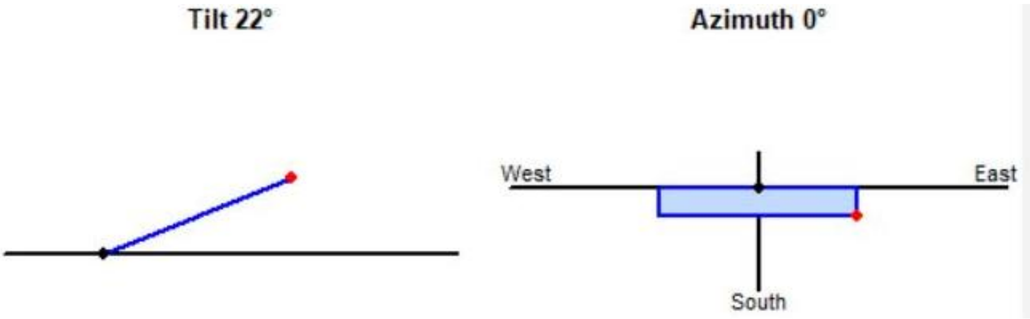

Figure 1. Orientation of the PV modules.

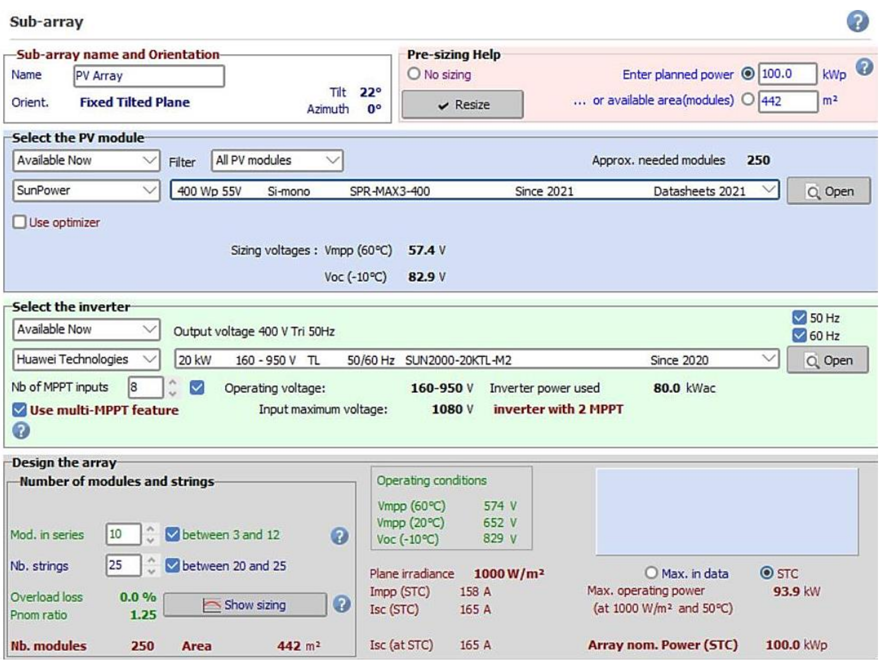

Figure 2: Full system design.

The optimal tilt angle was found 22°. At the 22° tilt angle as shown in Figure 1, the transposition factor FT and the loss with respect to the optimum were found 1.06 and 0.0% respectively.

For the total power of 100 kWp, Sun power 400 Wp, 55 V, Si-monocrystalline solar modules were used as described in Figure 2. To get 100 kWp, a total of 250 PV modules were needed. The approximate required area was calculated as 442 m^2.

The number of modules in series and number of strings calculated was 10 and 25 respectively.

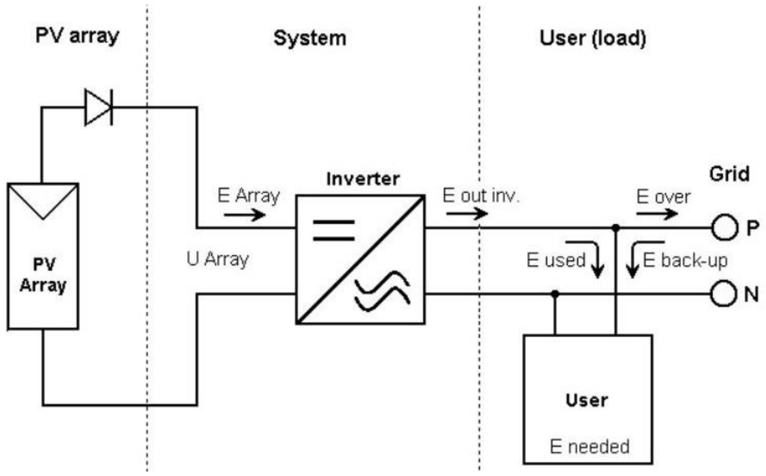

Figure 3. Simplified sketch of the grid-connected solar plant.

Simulation and Findings

The Simulink of 100 kWp solar PV was performed at a fixed tilt angle using PV Syst software. The simplified sketch in Figure 3 is also generated from PVsyst software. At first, all the necessary data i.e. geographical data, PV modules specifications, modules combinations, string combinations, inverter specifications, etc. were inserted into the model. Then the simulation process was done.

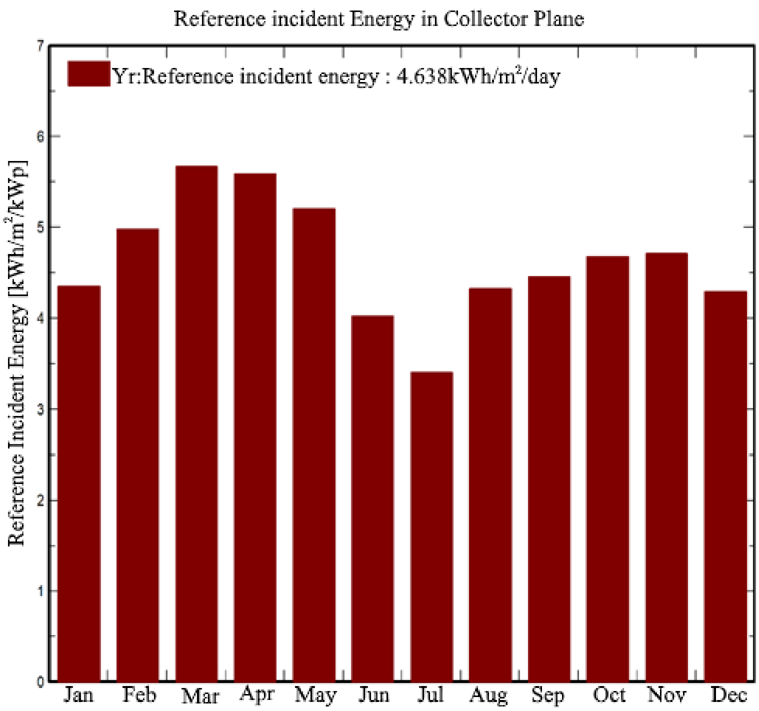

Figure 4. Month-wise Incident Energy [$kWh/m^2/kWp$].

The Figure 4 depicts the amount of solar energy incidents in the collector plane around the year. It is easily visible that the energy incident isn't evenly distributed throughout the year. The reference incident energy was found as 4.638 kWh/ m^2/day. The maximum energy incident was found in March as almost 5.8 kWh/m^2/kWp, and the minimum energy incident was found in July as around 3.5 kWh/m^2/kWp.

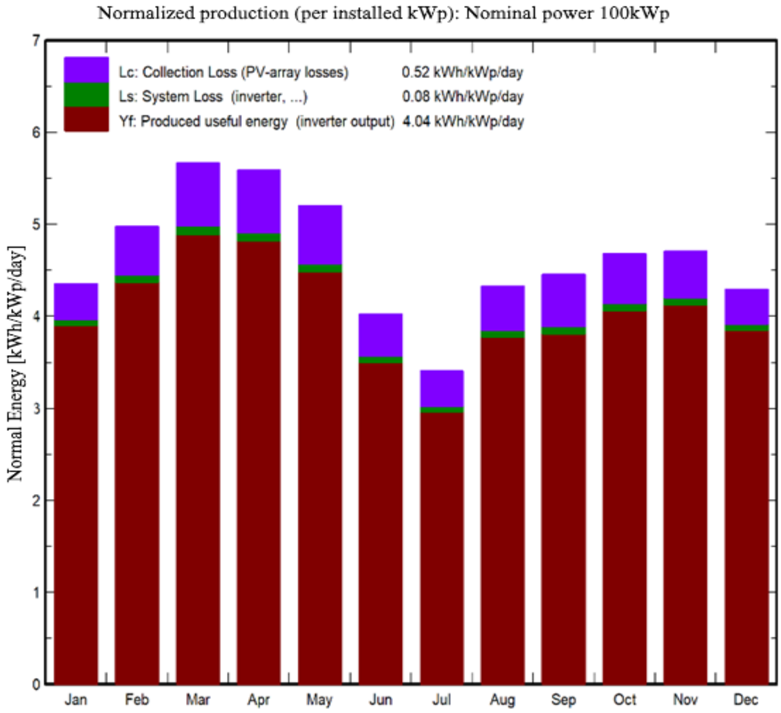

Figure 5. Month-wise Normalized Energy Production [kWh/kWp/day].

Figure 5 illustrates the production of useful energy by the PV arrays throughout a year and also represents the loss factors of the PV modules including system loss as well as the PV-array losses. The Figure 5 says that the most useful energy was produced in March and April and the values were almost 5 kWh/kWp/day. But in July, the useful energy was reduced to approximately 3 kWh/kWp/day. Analyzing Figure 5, it can be concluded that March, April, May, February, November, and October, these six months generate more useful energy than the rest of the six months.

Table 2. Balance and main results.

	GlobHor KWh/m^2	DiffHor KWh/m^2	T_Amb °C	GlobINC KWh/m^2	GlobEff KWh/m^2	EArray KWh	E_Grid KWh	PR ratio
January	111.4	61.04	19.79	135.0	132.4	12305	12087	0.895
February	121.3	61.95	23.30	139.4	137.0	12469	12236	0.878
March	163.5	79.77	27.13	175.8	172.5	15456	15158	0.862
April	168.7	89.46	29.04	167.7	164.0	14742	14463	0.862
May	171.7	99.25	30.00	161.2	157.2	14176	13909	0.863
June	130.8	91.25	29.09	120.7	117.3	10711	10511	0.870
July	113.0	80.60	28.77	105.6	102.6	9372	9194	0.871
August	139.0	93.01	28.82	134.2	130.8	11931	11711	0.872
September	127.4	58.96	28.34	133.7	130.9	11663	11427	0.855
October	130.9	71.21	27.90	145.2	142.2	12838	12595	0.867
November	116.6	56.59	24.67	141.2	138.7	12620	12383	0.877
December	108.1	60.81	20.98	133.1	130.6	12150	11937	0.897
Year	1602.6	903.92	26.50	1692.9	1656.1	150433	147610	0.872

The Table 2 represents some of the most important data of the simulation including Global horizontal irradiation, Ambient Temperature, Effective energy at the output of the array, Energy injected into the grid, Performance Rato. The table 2 shows that April, May, June have the highest ambient temperature and December, January, February have the lowest ambient temperature.

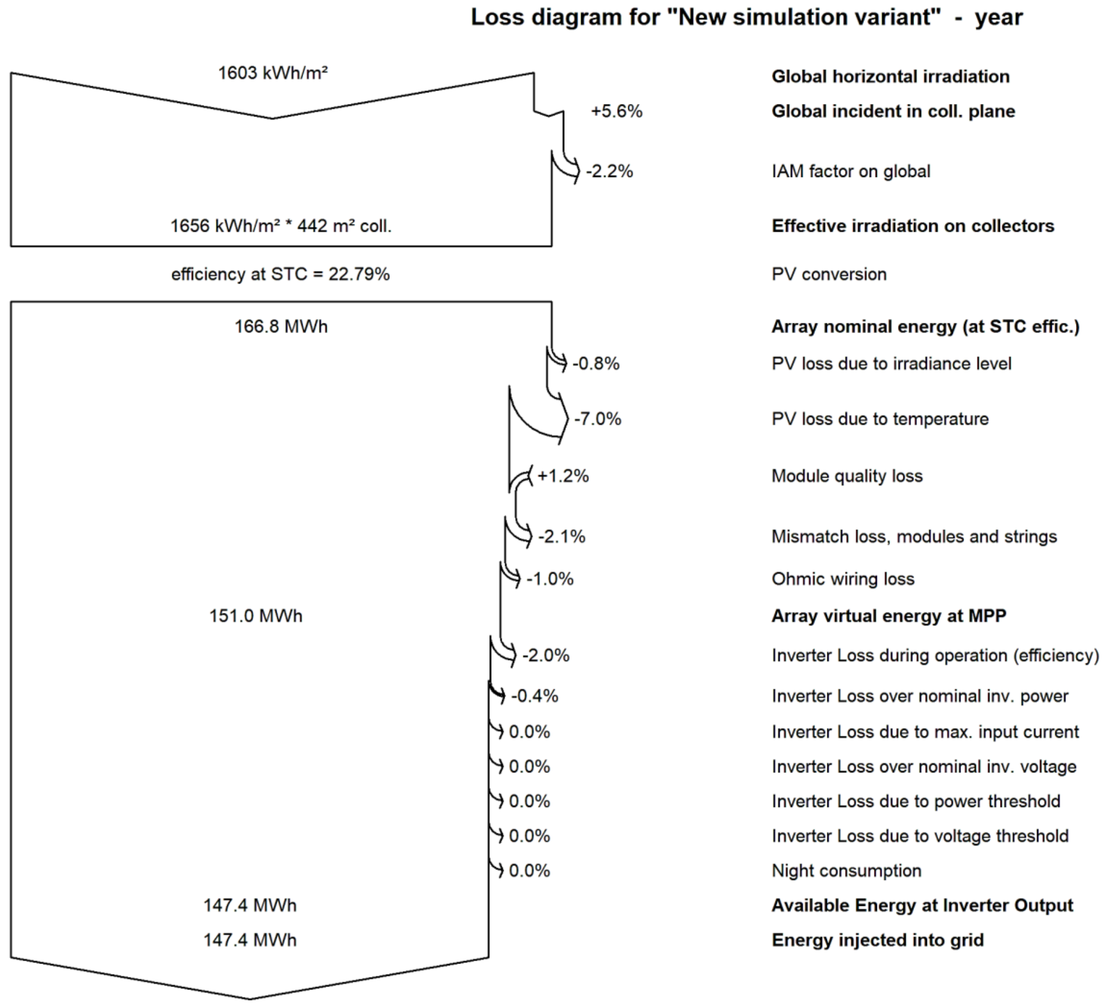

Figure 6. Details loss diagram.

Maximum effective energy was found in March (15456 kWh) and in July effective energy was found lowest (9372 kWh). Highest energy injected into the grid was found in March (15158 kWh) and the lowest energy injected into the grid was found in July (9194 kWh).

The performance ratio varies from 0.897 to 0.855 throughout the year. In December, the performance ratio was observed as 0.897 which is the highest percentage of the PV array through the year. The minimum performance ratio was observed in September as 0.855.

The total amount of produced energy was obtained 147.6 MWh/year and the specific production was found 1476 kWh/kWp/year.

The nominal energy of the PV arrays at the standard testing condition (STC) was calculated as 166.8 MWh. After considering all the PV array losses, (including irradiance loss, temperature loss, module quality loss, array mismatch loss, and ohmic wiring loss) as illustrate in Figure 6 at maximum power point (MPP) the energy was calculated as 151 MWh. This can be considered as the inverter input energy. The available useful energy or the output energy of the inverter can be found by subtracting the inverter losses from the inverter input energy. After considering the inverter losses (inverter efficiency, inverter loss over inverter power, etc.) the useful energy was found as147.4

MWh. This 147.4 MWh energy can be injected into the grid over the year.

CONCLUSION

The design and simulation of a 100 kWp grid-connected solar PV plant have been done successfully. 400 Wp, 55 V, Si-monocrystalline PV modules were considered in this 100 kWp PV design at Char Chapli, Patuakhali, Bangladesh (21.82 °N, 90.21 °E). At that location, the optimum tilt angle was observed as 22° to get the maximum output and minimum array losses.

The overall design and simulation of the 100 kWp solar PV plant can be concluded as:

- Energy production is maximum in March, April and minimum in June, July.
- The yearly average performance ratio was calculated as 0.872. Highest performance ratio was obtained in December as 0.897 and minimum in September as 0.855.
- Maximum effective energy at the output of the array was found in March as 15456 kWh and lowest in July as 9372 kWh. Total yearly effective energy at the output of the array was obtained as 150,433 kWh.
- Total energy injected into the grid was obtained as 147,610 kWh. The lowest energy injected into the grid was observed in July as 9,194 kWh and the maximum in March as 15,158 kWh.
- The efficiency of the PV modules was found as 22.79% at the standard testing condition (STC).

This 100 kWp simulation model represents the geographical details, details of system design, simulated results. Considering all the important parameters discussed above, this model can be considered as profitable. Analyzing different types of PV modules in different climate conditions is yet to be done. In future work, those comparison analyses will be done to get more detailed ideas.

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