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Design of A 11 KW_p Grid Connected Solar Photovoltaic Power Plant on 100 m^2 available Area in the Birbhum District of West Bengal

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Abstract: The depletion of fossil fuel resources on a worldwide basis has necessitated an urgent search for alternative energy sources to meet present day demands. Solar energy is a clean, inexhaustible and environment-friendly potential renewable energy option. A stand-alone solar photovoltaic cannot provide a continuous supply of energy due to seasonal and periodic variations. Therefore, in order to satisfy load demand, grid connected energy systems are now being implemented that combine solar and conventional conversion units. The objective of this work is to estimate the potential of grid quality solar photovoltaic power in the Birbhum district of West Bengal and develop a system based on the potential energy estimated for an available land area of 100 m^2. Specific equipment specifications are utilized based on the availability of components in India.

KEYWORDS: Diurnal variations; Daily Energy Output; Monthly Energy Output; Grid Connected Photovoltaic (PV) System; PWM Inverters; Solar Radiation; Yearly Energy Output.

1. Introduction

Electricity is obtained from the PV array most efficiently during sunny daytime hours [1-4]. At night or during cloudy periods, independent power systems use storage batteries to supply electricity. With grid interactive systems the grid acts as the battery, supplying electricity when the PV array cannot [5]. Energy storage devices (e.g. batteries) have been avoided in this work, to reduce capital, operation, and maintenance costs. The grid connected PV system is well known in various parts of world, and several technologies are available [6]. This research work focuses on the development of a grid connected pv system. Additionally, there have been efforts to develop the power electronics circuitry involved [7-9] and several types of inverters have been designed [10-15]. Overall, the goal is to measure the potential of a grid connected PV system in the Birbhum district of West Bengal using a solar-meter and to establish a demonstration of this type of system using existing methodologies and available equipment.

2. Materials and Methods

To find the solar PV generation potential in the Birbhum district of West Bengal, solar radiation over nine months (July 2008-April 2009, excluding October 2008) was measured using a solar-meter. The diurnal variations, average monthly output and yearly output have been calculated and the related graphs were plotted to show the seasonal variation [16]. The measured radiation data sheet of Birbhum district for the month of April 2009 has been given as an example. Diurnal variations for different months were plotted then monthly and yearly outputs were calculated.

Observing the peak values, the monthly average peak was calculated, variation of the monthly peak for a year was plotted and the average annual peak was calculated. For calculating output, the efficiency of the PV module was taken as 14.3% [17]. Finally, a grid connected PV system was designed with available technologies for an estimated plant capacity on 100 m^2 of arbitrarily selected land. The total plant capacity was estimated using the solar potential assement data previously determined.

3. Results and Discussions

3.1 Estimation of Solar Potential & Possible Plant Capacity

Solar radiation was measured for the time period July 2008 to April 2009, with the help of solar-meter.

Table 1: Calculation of Average Output April 2009 (Time: 10 AM)

Date	PV Module Efficiency	Solar Radiation (Watt/m^2)	Output (Watt/m^2)	Monthly Output (Watt/m^2)	Average Output (Watt/m^2)
05.04.2009	14.3%	780	111.54		
15.04.2009	14.3%	860	122.98		
26.04.2009	14.3%	890	127.27		
04.2009	14.3%			361.79	120.6

Table 2: Calculation for Diurnal Variations (April 2009)

Time	Average Output (Watt/m^2)	Average Output (Watt/m^2-hr)	Daily Energy Output (Watt/m^2-hr)	Monthly Energy Output (Watt/m^2-hr)
10 AM	120.6	120.6		
11 AM	138.9483	138.9483		
12 NOON	129.653	129.653		
1 PM	115.83	115.83		
2 PM	96.0483	96.0483		
3 PM	69.355	69.355		
4 PM	46.713	46.713		
04.2009			717.1476	21514.428

The results for the month of April 2009 have been shown as a sample (Table 1). Only the average output calculation at 10 AM is shown in this table. Similar results were obtained at 11 AM, 12 NOON, 1 PM, 2 PM, 3 PM and 4 PM. The diurnal variation for the month of April 2009 is also shown (Table 2).

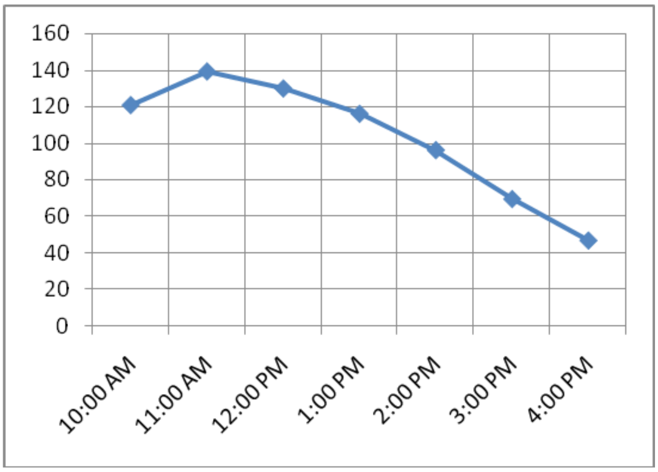
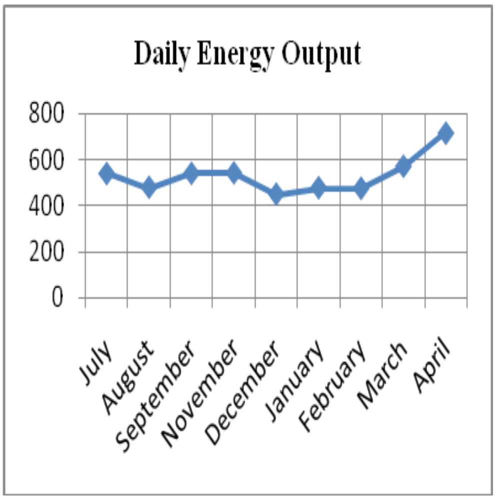


Figure 1: Diurnal Variations April 2009

Table 3: Total Energy Output

Months	Daily Energy Output (Watt/m²-hr)	Monthly Energy Output (Watt/m²-hr)	Average Monthly Energy Output (Watt/m²-hr)	Average Yearly Energy Output (Watt/m²-hr)
July	539.36	16180.8		
August	478.575	14357.25		
September	539.84	16195.2		
November	541.97	16259.1		
December	448.54	13456.2		
January	476.61	14298.3		
February	474.07	14222.1		
March	571.06	17131.8		
April	717.15	21514.5		
			15957.25	191487



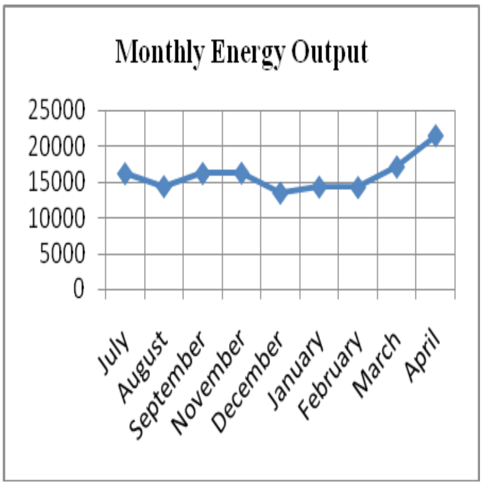


Figure 2: Daily & Monthly Energy Outputs

Table 4: Peak Variation & Possible Plant Rating

Months	Peak Output (Watt/m^2)	Average Peak Output (Watt/m^2)	Average Peak Output for 100 m^2 Area(Watt)	Possible Plant Capacity (KW)
July	126.08			
August	120.84			
September	128.7			
November	120.597			
December	102.245			
January	99.4			
February	102.25			
March	123.22			
April	138.9483			
		118.03	11803	11

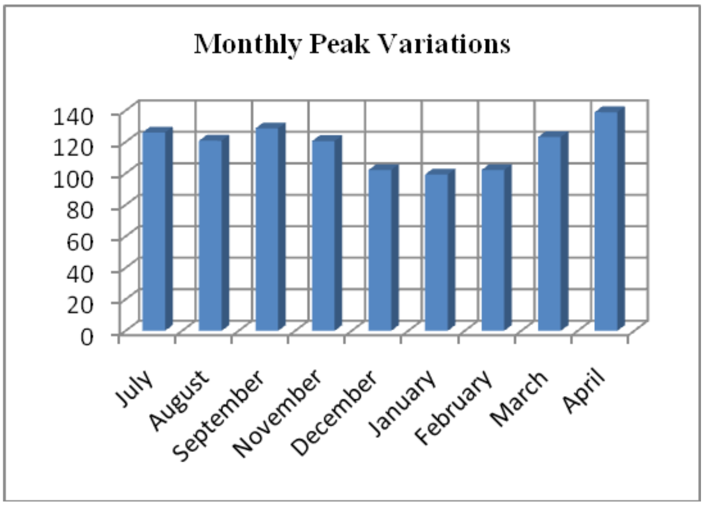


Figure 3: Monthly Peak Variations

Graphs showing diurnal variations of different months (July 2008-April 2009) were drawn. For demonstration purposes, only diurnal variation for the month of April 2009 is shown (Figure 1). Graphs for daily and monthly energy outputs are also shown (Figure 2). Daily, monthly and yearly energy outputs were calculated (Table 3). Using the peak values for the different months the possible plant capacity was estimated (Table 4). Monthly peak variations were also plotted (Figure 3). Readings for the month of October 2008 were not available.

Solar photovoltaic generation potential during the period July 2008-April 2009 was assessed for Birbhum district of West Bengal. It was found that the month of December produced the lowest solar radiation. Due to the rainy season in the month of July and August radiation levels were variable in these months. Monthly and yearly outputs were calculated on the basis of 100 m^2 area. Considering the monthly peaks, the average peak output was calculated and an estimate of the possible plant rating was made.

3.2 System Design

Grid connected PV systems can be designed in various ways: with or without batteries, with or without transformers, etc. Because of short life , large replacement cost and increased installation cost, batteries are not used in this system. However, a transformer is used for boosting AC output voltage and feeding to the grid.

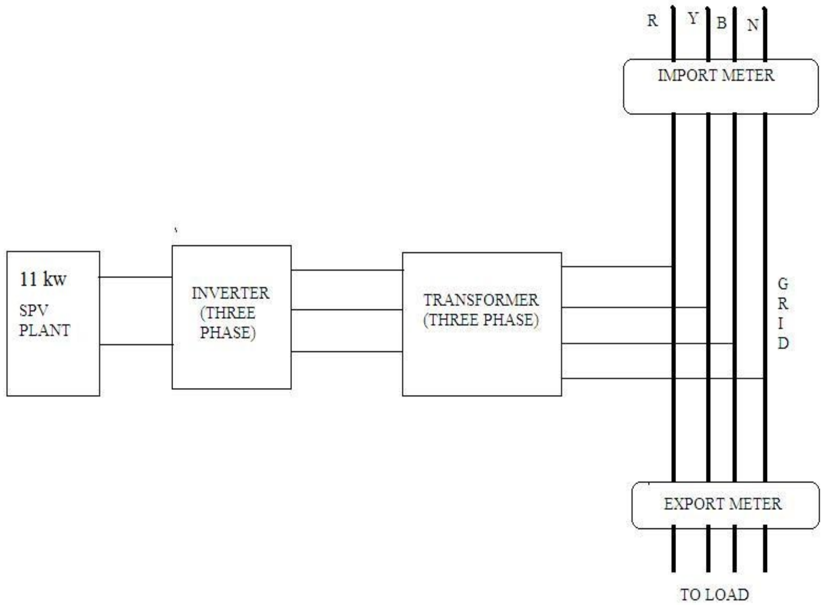


Figure 4: 11 KW_p Grid Connected Solar Photovoltaic Power Plant

There are two meters connected to the system: the import meter and the export meter (Figure 4). The difference between the two meter readings gives the power fed to the grid from the solar PV power plant, making output easy to determine.

From the solar radiation results obtained, a 11 KW_p solar photovoltaic power plant can be developed on a 100 m^2 area. Corresponding system sizing and specifications are provided along with the system design (number of PV modules = 11000/180 = 60). These 60 PV modules can be accommodated within a 100 m^2 area. To ensure appropriate voltage output there are 6 parallel paths of 10 modules each (system voltage = 24 x 10 = 240V). This 240 volt DC output is the input of the 3-phase inverter. After the inverter, a 3-phase transformer boosts the AC voltage and feeds it to the grid. Together, these components make up the complete design layout (Figure 4).

3.3 System Sizing & Specifications

Table 5: The system sizing and specifications for 11 KW_p power plant

Grid Specification	
No. of Phases	Three phase
Voltage rating	400 Volts AC
Frequency	50 Hz.

Solar Photovoltaic Power Plant Specification	
Plant Capacity	11 KW
Voltage Output	240 Volts dc
Current Output	30.24 A dc
No. of Modules	60 nos.
Area	$100m^2$
Inverter Specification	
KVA rating	11.5 - 12 KVA
Input DC voltage	240 Volts DC
Input dc current	30.24 A dc
Output AC voltage	113.136 V ac (phase voltage) 186.96 V ac (line voltage)
No. of Phases	Three
Type	PWM (for suppressing 3^{rd} harmonics)
Efficiency	Almost 90-93%
Total harmonic distortion	< 5%
Transformer Specification	
KVA rating	12 KVA
No of phases	Three
Frequency rating	50 Hz
Primary voltage rating	185 V
Secondary voltage rating	400 V
Primary current rating	45 A + (10-15% extra)
Secondary current rating	58 A + (10-15% extra)
Connections	Primary – delta (for suppressing Secondary – star 3^{rd} harmonics) 10 to 25 taps in secondary
Efficiency	Almost 95 %
Extra features	Air cooled
Solar Panel Specification	
Watt	180 Watt
Voltage	24 Volts
Current	5.04 A
Type	polycrystalline
Efficiency	14.3%
Temperature	25 deg c

Protection	
Protective device	400 Volts under voltage relay
Others: Junction boxes, meters, distribution boxes, wiring, mounting, etc.	

Additioally, PWM inverters are used for suppressing the harmonics produced after DC to AC conversion. The calculation for finding the output voltage of the inverter is:

Phase voltage = $V_{ph} = 0.4714 \times V_{dc} = 0.4714 \times 240 = 113.136 Volts.$

Line voltage = $V_L = 0.779 \times V_{dc} = 0.779 \times 240 = 186.96 Volts.$

4. Conclusions

Solar PV generation potential during the period September 2009-April 2010 was assessed for the Birbhum district of West Bengal. It was found that the month of December produced the lowest solar radiation. Monthly and yearly outputs were calculated on the basis of 100 m^2 area. Considering the monthly peaks, the average peak output was calculated and an estimate of the possible plant rating was made. The methodology adopted seems satisfactory for determining the possible plant capacity for an arbitrarily chosen area. The design described is based on the solar radiation measured. System sizing and specifications are provided based on the design made. Cost analysis of this photovoltaic plant may be performed in the future.

5. Acknowledements

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