Research Article

ASSESSMENT OF SOLAR PHOTOVOLTAIC GENERATION POTENTIAL & ESTIMATION OF POSSIBLE PLANT CAPACITY FOR 100 M^2 AVAILABLE AREA IN KOLKATA

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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 up the present day demands. Solar energy is clean, inexhaustible, environment friendly and a potential resource among the various renewable energy options. Solar radiation is the key factor determining electricity produced by photovoltaic (PV) systems. This paper reports a novel method to measure the potential of solar photovoltaic generation in Kolkata, the state capital of West Bengal measured with the help of solar-meter. Further, possible plant capacity is estimated for 100 m^2 available area.

KEYWORDS Diurnal variation, Daily Energy Output, Monthly Energy Output, Photovoltaic (PV) System, Solar Radiation, Yearly Energy Output.

INTRODUCTION

It is anticipated that photovoltaic (PV) systems will experience an enormous increase in the decades to come. However, a successful integration of solar energy technologies into the existing energy structure depends also on a detailed knowledge of the solar resource. Therefore solar radiation is a key factor determining electricity produced by photovoltaic (PV) systems which is usually obtained using Geographical Information System (GIS). A case study of solar radiation database was prepared in Europe as was reported in [1]. Using Photovoltaic Geographic Information System (PVGIS) another study was made in the 25 European Union member states and 5 candidate countries. The calculation of electricity generation potential by contemporary PV technology is a basic step in analyzing scenarios for the future energy supply and for a rational implementation of legal and financial frameworks to support the developing industrial production of PV. Three aspects were explored - the expected average annual electricity generation of a 'standard' 1 kW$_p$ grid-connected PV system, the theoretical potential of PV electricity generation and determination of required installed capacity for each country to supply 1% of the national electricity consumption from PV. The analysis shows that PV can already provide a significant contribution to a mixed renewable energy portfolio in the present and future European Union [2]. In [3], a GIS based analysis of the theoretical PV potential to be installed on noise barriers along Italian national roads has been carried out. [4] It presents a methodology for the assessment of photovoltaic potential in urban areas using open-source solar radiation tools and a 3-D city model implemented in a geographic information system (GIS). The solar radiation tools are represented by the *r.sun* solar radiation model and PVGIS estimation utility. The applicability of the methodology has been demonstrated on a selected urban area of a small city in Eastern Slovakia. In [5] the potential of different PV systems in countries with high solar irradiation was explored and their performances were compared through the assessment of thirteen different types of PV systems that had been installed side by side in Nicosia, Cyprus and Stuttgart, Germany. Finally useful insight into the performance of the PV systems as a function of the meteorological conditions and location was highlighted. A GIS database of solar radiation was presented in [6] and photovoltaic (PV) potential estimations of 10 European Union Candidate Countries were created to support that data. The database was integrated with a web application to provide access also to the public at large. An application was developed to browse and query GIS maps and to do a simple calculation for any location within that region. The objective of the work carried in [7] was to examine the performance as well as the economic feasibility of grid-connected PV systems in the Kuwaiti climate. A program was written to evaluate the performance as well as the economic feasibility of such systems in Kuwait. The input to the program was the weather data for Kuwait, time dependent building loads, as well as the utility rates for Kuwait. Weather data generator subroutine included in TRANSYS (Transient Simulation) program was used to generate hourly weather conditions from the monthly average values of daily radiation on horizontal surface, and ambient temperature available for Kuwait. The five-parameter PV model was then used to determine the performance of the solar modules used in that study [8] utilizes ENERGY-10, a design tool used to model and simulate the performance of PV systems that is integrated with the building [9] discusses the recorded Global Solar Radiation, received in the Kathmandu valley by three different, Si-mono-crystalline, Si-poly-crystalline and Si-amorphous calibrated solar cells and proposes the best-suited solar PV module technology for roof top solar PV systems inside the Kathmandu valley. Thus we find that most of the previous literatures involve the use of GIS systems to obtain the solar photovoltaic potential estimation. The method described in this paper suggests a unique method to measure the PV potential and estimate the possible plant capacity based on the available area, chosen as 100 m^2 for this work.

METHODOLOGY

To find out the solar photovoltaic generation potential, the solar radiation over 10 months (July 2008-April 2009) is measured in Kolkata with the help of solar meter following the methods discussed in [10-11]. Then the diurnal variations, average monthly output, yearly output have been found out and related graphs are plotted for showing the variation in different seasons and time. Also observing the peak value in different days, the monthly average peak is calculated and variation of the monthly peak is plotted for a year and the average annual peak is also calculated. For calculating the output the efficiency of the PV module is taken as 14.3% [12]. Chosen area for the estimated plant capacity is considered as 100 m^2 as per availability.

RESULTS & DISCUSSIONS

The solar radiation data are given from 10 A.M. to 4 P.M. for few specific dates of the month of July 2008 as shown in Tables 1-5. The respective outputs are calculated considering the PV module efficiency as 14.3%. Finally the average output is calculated for every hour of the day. The results for the month of July 2008 have been shown in Tables 6-12. The diurnal variation for that month is then shown in Table 13. Graphs showing the diurnal variations of the different months (July 2008-April 2009) are then drawn as shown in Fig. 1. Daily, monthly and yearly energy outputs are calculated as shown in Table 14. Graphs for daily and monthly energy outputs are obtained as shown in Fig. 2.

Table 1: Solar Radiation for July 2008 (Date: 02.07.2008)

Time	Solar Radiation (Watt/m^2)
10 AM	580
11 AM	685
12 NOON	690
1 PM	535
2 PM	465
3 PM	230
4 PM	110

Table 2: Solar Radiation for July 2008 (Date: 10.07.2008)

Time	Solar Radiation (Watt/m^2)
10 AM	540
11 AM	700
12 NOON	580
1 PM	490
2 PM	470
3 PM	255
4 PM	100

Table 3: Solar Radiation for July 2008 (Date: 16.07.2008)

Time	Solar Radiation (Watt/m^2)
10 AM	590
11 AM	690
12 NOON	530
1 PM	420
2 PM	510
3 PM	210
4 PM	90

Table 4: Solar Radiation for July 2008 (Date: 24.07.2008)

Time	Solar Radiation (Watt/m^2)
10 AM	625
11 AM	730
12 NOON	695
1 PM	580
2 PM	425
3 PM	175
4 PM	85

Table 5: Solar Radiation for July 2008 (Date: 30.07.2008)

Time	Solar Radiation (Watt/m^2)
10 AM	645
11 AM	730
12 NOON	690
1 PM	655
2 PM	545
3 PM	165
4 PM	90

Table 6: Calculation of Average Output July 2008 (Time: 10 AM)

Date	PV Module Efficiency	Solar Radiation (Watt/m^2)	Output (Watt/m^2)	Total Output (Watt/m^2)	Average Output (Watt/m^2)
02.07.2008		580	82.94		
10.07.2008		540	77.22		
16.07.2008	14.3%	590	84.37	426.14	85.228
24.07.2008		625	89.375		
30.07.2008		645	92.235		

Table 7: Calculation of Average Output July 2008 (Time 11 AM)

Date	PV Module Efficiency	Solar Radiation (Watt/m^2)	Output (Watt/m^2)	Total Output (Watt/m^2)	Average Output (Watt/m^2)
02.07.2008		685	97.955		
10.07.2008		700	100.1		
16.07.2008	14.3%	690	98.67	505.505	101.101
24.07.2008		730	104.39		
30.07.2008		730	104.39		

Table 8: Calculation of Average Output July 2008 (Time 12 NOON)

Date	PV Module Efficiency	Solar Radiation	Output (Watt/m^2)	Total Output (Watt/m^2)	Average Output

		(Watt/m^2)			(Watt/m^2)
02.07.2008		690	98.67		
10.07.2008		580	82.94		
16.07.2008	14.3%	530	75.79	455.455	91.091
24.07.2008		695	99.385		
30.07.2008		690	98.67		

Table 9: Calculation of Average Output July 2008 (Time 1 PM)

Date	PV Module Efficiency	Solar Radiation (Watt/m^2)	Output (Watt/m^2)	Total Output (Watt/m^2)	Average Output (Watt/m^2)
02.07.2008		535	76.505		
10.07.2008		490	70.07		
16.07.2008	14.3%	420	60.06	383.24	76.648
24.07.2008		580	82.94		
30.07.2008		655	93.665		

Table 10: Calculation of Average Output July 2008 (Time 2 PM)

Date	PV Module Efficiency	Solar Radiation (Watt/m^2)	Output (Watt/m^2)	Total Output (Watt/m^2)	Average Output (Watt/m^2)
02.07.2008		465	66.495		
10.07.2008		470	67.21		
16.07.2008	14.3%	510	72.93	345.345	69.069
24.07.2008		425	60.775		
30.07.2008		545	77.935		

Table 11: Calculation of Average Output July 2008 (Time 3 PM)

Date	PV Module Efficiency	Solar Radiation (Watt/m^2)	Output (Watt/m^2)	Total Output (Watt/m^2)	Average Output (Watt/m^2)
02.07.2008		230	32.89		
10.07.2008		255	36.465		
16.07.2008	14.3%	210	30.03	148.005	29.601
24.07.2008		175	25.025		
30.07.2008		165	23.595		

Table 12: Calculation of Average Output July 2008 (4 PM)

Date	PV Module Efficiency	Solar Radiation (Watt/m^2)	Output (Watt/m^2)	Total Output (Watt/m^2)	Average Output (Watt/m^2)
02.07.2008		110	15.73		
10.07.2008		100	14.3		
16.07.2008	14.3%	90	12.87	67.925	13.585
24.07.2008		85	12.155		
30.07.2008		90	12.87		

Table 13: Calculation for Diurnal Variations (July 2008)

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	85.228	85.228		
11 AM	101.101	101.101		
12 NOON	91.091	91.091	466.323	13989.69
1 PM	76.648	76.648		
2 PM	69.069	69.069		
3 PM	29.601	29.601		
4 PM	13.585	13.585		

Table 14: Total Energy Output

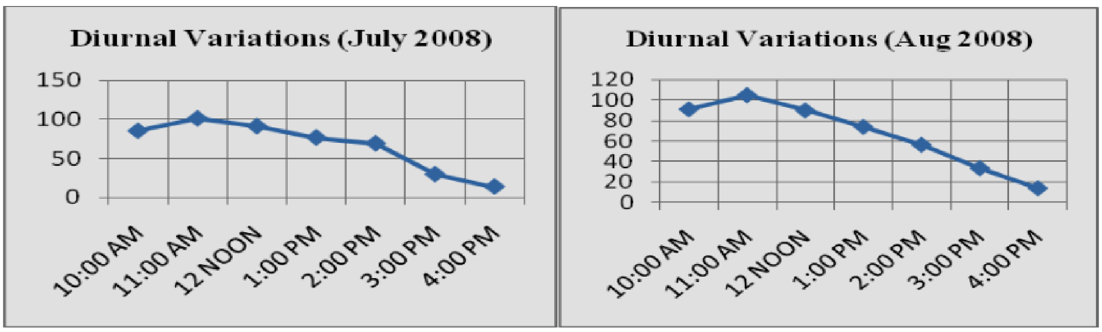
Months	Daily Energy Output (Watt/m^2-hr)	Monthly Energy Output (Watt/m^2-hr)	Average Monthly Energy Output (Watt/m^2-hr)	Average Yearly Energy Output (Watt/m^2-hr)
July	466.323	13989.69		
August	465.179	13955.37		
September	40712.1	12213.63		
October	467.467	14024.01		
November	514.657	15439.71	15046.908	180562.896
December	341.627	10248.81		
January	470.899	14126.97		
February	533.104	15993.12		
March	632.06	18961.8		
April	717.199	21515.97		

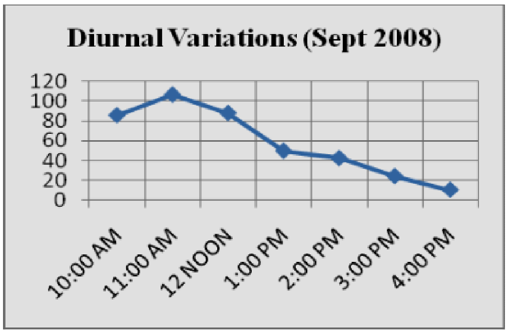
Table 15: Peak Variation & Possible Plant Rating

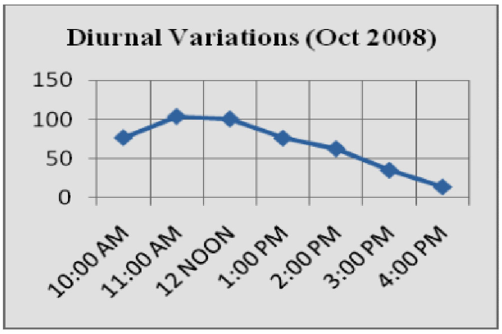
Months	Peak Output (Watt/m^2)	Average Peak Output (Watt/m^2)	Average Peak Output for 100 m^2 Area(Watt)	Possible Plant Capacity (KW)
July	101.101			
August	104.962			
September	106.678			
October	103.961			
November	106.678	108.0079	10800.79	10
December	80.652			
January	102.531			
February	106.535			
March	129.987			
April	136.994			

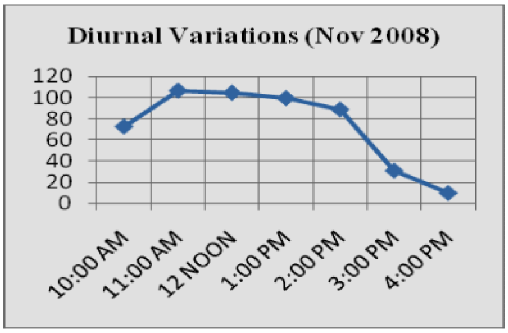
Using the peak values for the different months the possible plant capacity is estimated as shown in Table 15. Monthly peak variations are also plotted as shown in Fig. 3. Solar photovoltaic generation potential during the period July 2008-April 2009 is assessed for Kolkata. It is found that the month of December produced the lowest solar radiation. Due to the rainy season in the month of July and August radiation level was 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 is calculated from where as estimate of the possible plant rating is made. The methodology adopted seems satisfactory for determining the possible plant capacity for an arbitrarily chosen area.

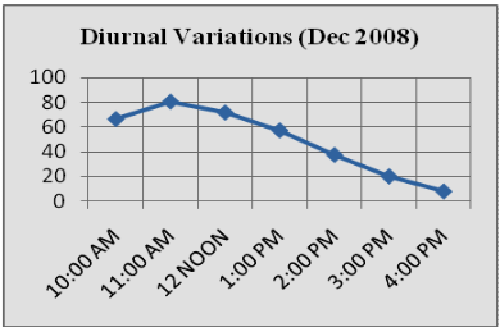
Figure 1: Graphs for Diurnal Variations (July 2008-April 2009)

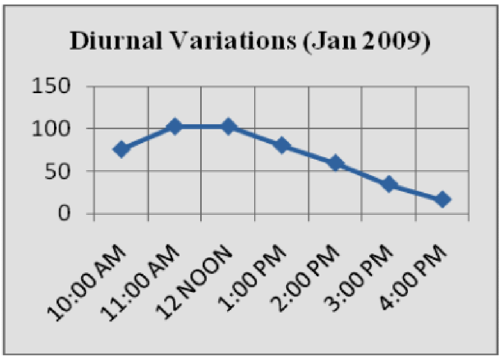


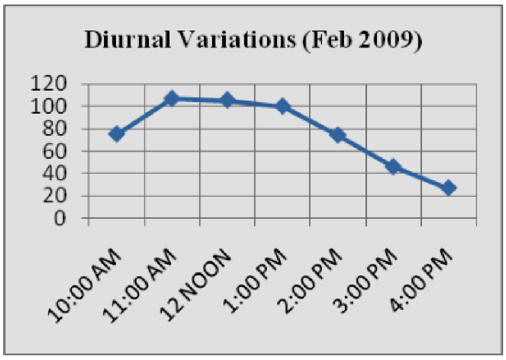

Diurnal Variations (Sept 2008)
120
100
80
60
40
20
0
10:00 AM
11:00 AM
12 NOON
1:00 PM
2:00 PM
3:00 PM
4:00 PM

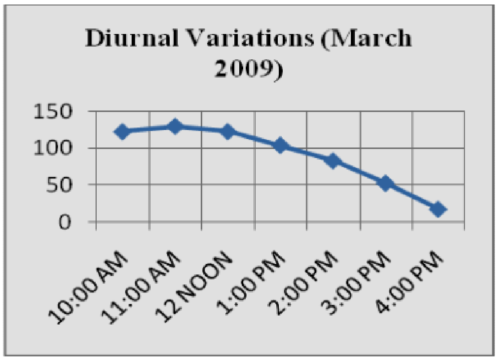

Diurnal Variations (Oct 2008)
150
100
50
0
10:00 AM
11:00 AM
12 NOON
1:00 PM
2:00 PM
3:00 PM
4:00 PM


Diurnal Variations (Nov 2008)
120
100
80
60
40
20
0
10:00 AM
11:00 AM
12 NOON
1:00 PM
2:00 PM
3:00 PM
4:00 PM


Diurnal Variations (Dec 2008)
100
80
60
40
20
0
10:00 AM
11:00 AM
12 NOON
1:00 PM
2:00 PM
3:00 PM
4:00 PM


Diurnal Variations (Jan 2009)
150
100
50
0
10:00 AM
11:00 AM
12 NOON
1:00 PM
2:00 PM
3:00 PM
4:00 PM


Diurnal Variations (Feb 2009)
120
100
80
60
40
20
0
10:00 AM
11:00 AM
12 NOON
1:00 PM
2:00 PM
3:00 PM
4:00 PM


Diurnal Variations (March 2009)
150
100
50
0
10:00 AM
11:00 AM
12 NOON
1:00 PM
2:00 PM
3:00 PM
4:00 PM

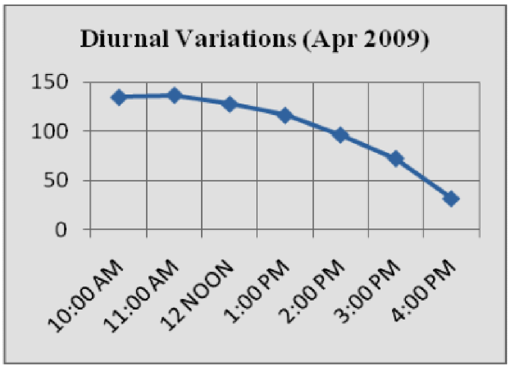
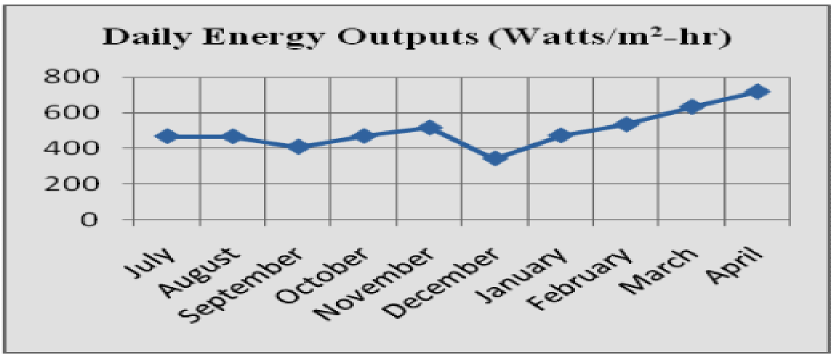

Diurnal Variations (Apr 2009)
150
100
50
0
10:00 AM
11:00 AM
12 NOON
1:00 PM
2:00 PM
3:00 PM
4:00 PM

Figure 2: Daily & Monthly Energy Outputs (Watt/m^2-hr)



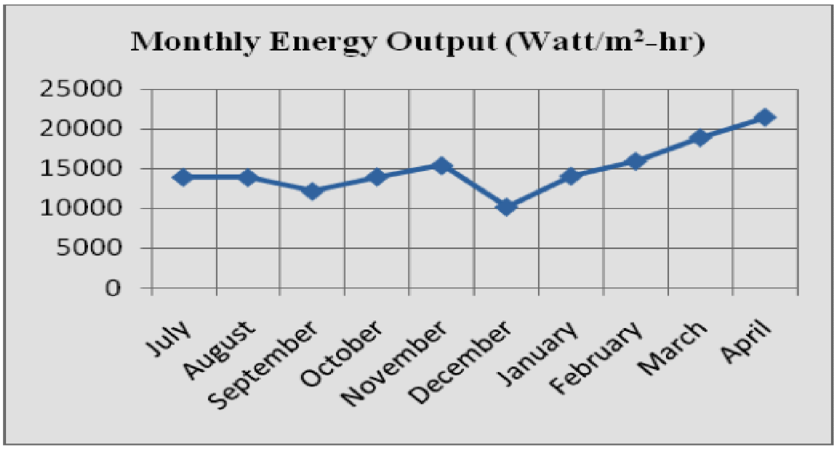
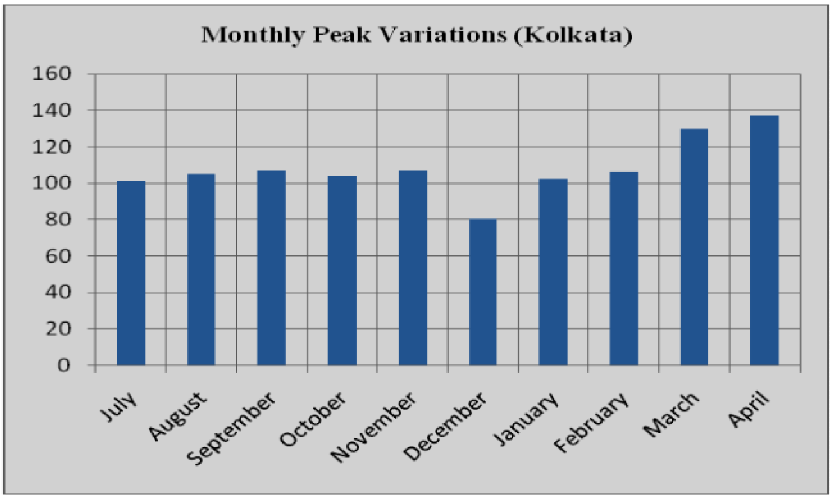


Figure 3: Monthly Peak Variations in Kolkata



CONCLUSIONS

Available area for the calculation shown has been considered to be 100 m^2. With greater available area higher capacity plant can be set up. Moreover, the possible plant capacity has been estimated from the peak output results available from the solar radiation readings of each month. No optimised approach has been carried out which can be taken up as a future scope of work. Had calculations been available for the months of May and June which offers the highest solar radiation, the result would have been far more accurate and yielded higher capacity plant. Designing of this solar photovoltaic power plant now need to be done once the capacity is estimated which can be carried out in future publications.

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