A Review Paper on Energy Flow Study of Existing 2kw Solar Power Plant Along With Simulation of Tilt Angle to Enhance Efficiency

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Abstract - The Energy efficiency is achieved when energy intensity in a specific product, process or area of production or consumption is reduced without affecting output, consumption or comfort levels. Promotion of energy efficiency will contribute to energy conservation and therefore integral part of energy conservation promotional policies. It provides additional economic value by preserving the resource base and reducing pollution. Although, energy efficiency has been in practice ever since long back, it has today assumed even more important because of being the most cost effective and reliable means of mitigating the global climatic change. So in order to have maximized annual average incident solar energy on the surface of PV system, it is required to determine optimal tilt angle. Optimization of tilt angle ensures the maximum energy generation, thereby reducing the cost of power generation. The estimation of optimal tilt angle by simulation, using various simulation softwares, like RETSCREEN, PVSYST and NREL SAM. The simulated result shows that the majority of average solar radiation is above 5KWh/m^2/d and falls in the range of 5.5-7KWh/m^2/d. The yearly optimal angle obtained are having variation of -2^o to -1^o from the latitude of the location and also efficiency increased by 21%.

Keywords: Tilt angle, PV system, Solar Photovoltaic, Solar radiation.

I. INTRODUCTION

India is a country where, there is a huge difference in demand and supply of electricity and rising electricity prices have forced us to look for cheaper and cleaner alternative. Our objective can be met by the use Renewable Energy. In the 21st century where India aims to become a world super power, we still lack in the energy sector. We have only 0.3% of world's oil resources, only 0.7% of gas resources and about 6.5% other resources. All our conventional sources of energy are imported at very high unpredictable costs. Also important point to notice that large coal storage transporting in foreign countries is being spent on importing energy resources. On broader perspective this also has impact on energy security of the country.

Environmental concerns as well as rise in demand for cleaner energy are the main motives for research in various renewable resources like wind, tidal, geothermal and solar. Solar is an ancient source of energy among all these resources of energy which is the origin of all fossil fuel and renewable energy like biomass, wind, etc. High density energy consumption urban areas are considered to be one of the most reasonable locations for installation of renewable energy technologies due to the recent shortage of fossil fuel. The quantity of solar radiation captured by a solar collector is mainly affected by the orientation and tilt angles of PV panel. This is because both of these factors influences the angle of incidence of the solar radiation upon the solar panel and can change the amount of solar radiation arriving at the earth's surface. Explicit data of solar radiation reception by a solar surface at different tilt angles along with cognizance of the optimum tilt angle are of great importance for experts and designers related to solar energy field. Generally speaking, the optimal orientation is due south for the India as it lays in the northern hemisphere. It is also immensely important to calculate the optimum tilt angle for each particular location because it depends upon climatic condition, latitude, solar system utilization span as well as solar radiation characteristics of that particular spot.In order to ensure energy security and match the electricity supply and demand gap this is the perfect moment to acknowledge the fact that solar energy is the solution to our energy problems.

In current scenario, the solar energy based power generating systems can play an important part in fulfilment of the energy requirements of the industrial sector.India most importantly needs to meet its energy demands in a sustainable, responsible and eco-friendly manner, in the right way and at the right time. Due to all these aspects, it is required to replace non-renewable sources with renewable ones, especially solar energy, for fulfilling the electricity or power needs. In India about 5×109 GWh solar radiation energy is incident per year with most parts receiving solar irradiance of 4-7 kWh/m^2/d. Hence, solar energy has a vast potential to satisfy the increased demands of energy.

In all the solar PV technology, the most significant parameter is input, which is solar radiation. Solar radiation input is required for performance evaluation of PV as well as for optimization of solar thermal and solar PV. While having maximized incident solar radiation, we require optimal tilt inclination of PV module [6]. Photovoltaic (PV) panels convert solar energy into electrical energy with the peak efficiencies in the range of 5–20%, depending on the type of PV cells. The National Action Plan on Climate Change (NAPCC) is the main key plan for the development of solar energy technologies in India. The Government of India approved "Jawaharlal Nehru National Solar Mission" (JNNSM), in November 2009. The Mission mainly focuses on deployment and development of solar energy technologies in the country to achieve parity with grid power tariff by 2022.

Although the optimum inclination angle is normally close to the latitude of the location, but definite value can rarely be on optimum tilt angles. There are different optimization techniques to obtain optimal tilt angle such as using experimental analysis, solar tracking method and simulation or modelling. In spite of many practical and modelling based investigations on optimization of solar systems inclination, there are several inconsistencies in the presented results. In Indian scenario where solar radiation intensity is 1000KW/m2 ,the optimal tilt angle variation from latitude of the location is not much and has good opportunity to collect maximum solar radiation.. In this study, PV simulation software RETSCREEN, PVSYST and NREL SAM are used to determine the optimal tilt angle for Sehore and different Smart cities of India lying in different regions (northern, southern, eastern, western and central region) i.e, Ahmedabad(Latitude23.0300°N, 72.5800°E), Delhi(Latitude 28.6139° N,77.2090°E),Kolkata(Latitude22.5667°N,88.3667°E),Bhopal(Latitude23.2500°N,77.4167°E),Mumbai(Latitude 18.9750° N, 72.8258° E) and Chennai(Latitude 13.0827° N, 80.2707° E). These six cities comes under Smart cities programme running by Indian Government. Determination of optimal tilt for PV installation will be useful aspect for Smart cities programme.

1.1 Solar Energy Centre, MNRE Data

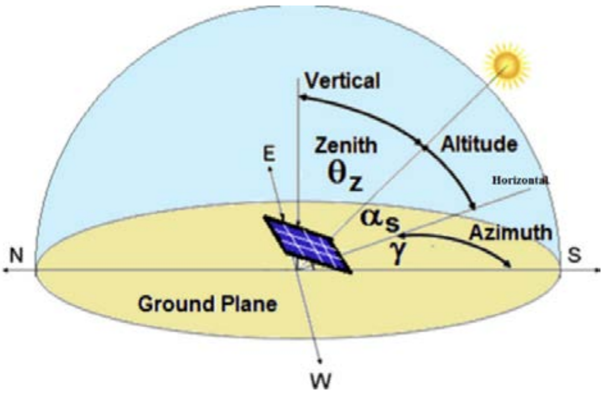
The average solar radiation data for the location of Sehore as monitored by Solar Energy Centre (SEC), MNRE (currently known as National Institute of Solar Energy-NISE) during period 1986-2000 is given in Table 1.The solar irradiation data of Sehore in the form of Global HRZ and Global POA is given below in Table 1. The 'Global HRZ' is the global radiation on horizontal surface and the 'Global POA' is the global radiation on the Plane of Array (POA) facing south at a tilt of approximately 23.21 degrees to horizontal.

Solar irradiation data of Sehore, MNRE data (Latitude 23.21°N, Longitude 77.12°E).

Table-1

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Average.
Global HRZ (KWh/m^2/day)	**4.36**	**5.21**	**6.00**	**6.46**	**6.49**	**5.43**	**4.09**	**3.62**	**4.70**	**5.10**	**4.60**	**4.08**	**5.01**
Global POA (KWh/m^2/day)	**5.58**	**6.21**	**6.50**	**6.41**	**5.99**	**4.96**	**3.83**	**3.50**	**4.83**	**5.84**	**5.85**	**5.34**	**5.39**

1.2. Angle position:



II. LITERATURE REVIEW

On the optimum tilt angle of the solar system, several studies have come into the field of vision in the literature.

Hamid Moghadam and Saeed Moghadam Deymeh,et al[1]Determined the optimum location and optimum tilt angle of solar collectors placed on the roof, in respect of the shadow of adjacent buildings. Their result suggests that for northern hemisphere of the earth solar collectors should be installed on the southern verge of the roof as far as possible away from the bigger adjacent building. They found that optimum location direct solar radiation collected energy could be increased furthermore the 15%. In addition to this, shade has little effects on the optimum tilt angle for the parts of the roof near to the taller adjacent building.

Hamdy K. Elminir, et al [2]Examines the theoretical features of tilt angle selection for the solar flat-plate collectors used in Egypt. They performed a statistical comparison of three specific anisotropic models (Tamps Coulson, Perez and Bugler) to get the most accurate solar radiation estimating model. That most accurate model used to determine optimum collector slope. Their study showed that the Perez’s model is the best one, followed by the Tamps-Coulson then Bugler models in respect of overall calculated performance of all these three models.

Adnan Shariah, et al [3] Used the annual solar fraction of the system as an indicator to obtain optimum tilt angles for a thermosyphon solar water heater installed in northern and southern parts of Jordan. The powerful computer program TRNSYS (Transient System Simulation) used by them for calculation of the system operated with a daily hot water load of 150L at 55°C flowing during the day as per the widely used Rand consumption profile. The results reveal that the optimum tilt angle for the maximum solar fraction is about $\phi + (0\rightarrow10°)$ for the northern region and about $\phi + (0\rightarrow20°)$ for the southern region. These values are about 5 to 8° more than those for maximum solar radiation.

Lave and Kleissl, et al [4]Calculated the optimal tilt and azimuth angles of solar PV panels in the continental United States. They compared the annual global radiation incident on a panel at various optimum orientations with that of a flat horizontal panel and a 2-axis tracking panel. They found that solar irradiation at optimum fixed tilted PV panel increases from 10% to 25% with increment in latitude. Also, solar irradiation reception on a 2-axis tracking panel was between 25% and 45% more than irradiation on the panel at optimum fixed orientation.

Ekadewi A. Handoyo, et al [5] Done the research to find the optimal angle of installing a solar collector for helping the farmers. They used mathematical equation and done experiments to determine the optimum tilt angle for Surabaya location of Indonesia. The result shows that for a collector installed in Surabaya, the optimal tilt angle during March 12 – September 30 is varied between 0 – 40˚ (face to the North) and during October 1 – March 11 is between 0 – 30˚ (face to the South). Another option is installing two collectors with one facing to the East to be used in the morning session and one to the West in the afternoon session of the day. The optimal tilt angle obtained for these orientations is 36˚ – 39.4.

Milan Despotovic and Vladimir Nedic, et al [6] Examined the optimum tilt angle of solar collectors for Belgrade, which is situated at the latitude of 44^{o}47’N. They found yearly, biannual, seasonal, monthly, fortnightly, and daily optimum tilt angles by looking for the values for which the solar radiation on the collector surface is maximized. They observed that, by installing the PV panels at yearly, seasonal and monthly optimum tilt angles, yield increases amount of collected solar energy by a factor of 5.98%, 13.55%, and 15.42% respectively compared to PV panels at current roofs’ surface angles.

III. METHODOLOGY

Solar energy incident on solar PV surface is sum of beam and diffuse radiation. For maximized output from a PV system, it is necessary to understand the nature of dependence of solar radiation and inclination angle of PV system. Over the past few years, many simulation, modelling and experiment have been done to estimate the solar radiation on inclined surface. All these investigation and experiment have specific technique and measurement. Some of these are limited in their scope for determining the optimal tilt angle. In this study, PV simulation software are used to determine annual average solar radiation on various tilt. Finally maximum annual average solar radiation on different tilted surfaces was obtained to estimate optimum tilt angle.Solar PV based technology is prime, an ideal choice for power generation. In all these solar based application, the amount of solar radiation plays an important role which is mainly affected by tilt and azimuth angle of location. The Simulation is the technique performed on computer to change the various alternate values of input and observe intricately whether output value is productive, and then only according to that simulated change is applied practically.As all permotation and combination of possible input change is not economical.

Images of rooftop Solar PV Power Plants of 2KW installed in Department of Mechanical Engineering, School of Engineering, SSSUTMS, Sehore, M.P, India.

3.1 Simulation tilt angles

PVsyst is a suitable software tool for grid-connected, stand-alone, pumping and DC-grid systems. It is a windows based software package and has similar meteorological data requirements as RETScreen. This can be used for PV system analysis of any location that has long term measured meteonorm solar radiation data to calculate all the PV parameters. The latest version of PVsyst is 6.4.3 (April, 2016), which facilitates a multi-language interface (English, German, French, Italian and Spanish). In this study the PVsyst 6.3.9 is used. PVsyst gives several choices to the PV system designer for project design as it has three different steps.The optimal tilt angle of solar PV using various simulation software.

3.2. PVsyst (PhotoVoltaic systems)

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3.3. RETSCREEN software

RETScreen is a clean energy management software technology for energy efficiency analysis. It designed with the contribution of numerous experts from government, industry, and academia. This software has an entry of monthly global solar radiation on horizontal surface, ambient temperature and wind speed. The latest version of RETScreen is version 4. It consist of two separate program one is RETScreen 4 and another one is RETScreen plus. RETScreen 4 is excell based software tool that can be utilized in the area of technical as well as financial visibility of renewable potential, energy, efficiency, analysis and cogeneration energy projects. Here, RETScreen 4 has been utilized to simulate optimal tilt angle . This software can be used worldwide to evaluate the energy generation and savings, total installation and operation and maintenance costs, CO2 emission reductions, economical viability and risk analysis for various types of Renewable-energy and Energy- efficient Technologies(RETs). RETScreen (Renewable Energy Technologies Screen).

3.4 National Renewable Energy Laboratory Solar Advisor Model (NREL SAM).

The System Advisor Model (SAM) is a free simulation software developed by the US department of the National Renewable Energy Laboratory that prognosticates hourly energy production for renewable energy systems. It is a performance and the financial model software tool. The purpose of this model is to make a quick decision for people related to various areas of renewable energy. It is a software for planning, monitoring and visualizing energy systems. For all this purpose NREL SAM provides state-ofthe-art functions in the form of blocks that can be linked to a concrete solution, for e.g. in simulating meteorological data, electrical and thermal energy components, etc. SAM utilizes a system-driven approach (SDA) and Solar Energy Technologies Program (SETP).Latest version of SAM is 2015.6.30.

3.5 Simulation softwares

Simulation Software	Manufacturer	Cost	Website/Link	Versin Utilizd
RET-Screen	Natural Resources Canada	Free of Charge	www.retscreen.net	4
PVsyst	Institute of Environme ntal Sciences (ISE),University of Geneva, Switzerland	900CHF for one machine license; 150CHF for additional machines	http://www.pvsyst.com /5.2/index.php	6.3.9
NREL SAM	National Renewable Energy Laboratory, Washington	Free	https://www.nrel.gov/analysis/s am/ba ckground.html	2015.6 .30

IV. CALCULATION

The Roof top Solar PV Power Plant of 2KW in SOE of SSSUTMS installed during 1st June -15th June 2018

4.1.1

2KW ELECTRICITY WITH BATTERY BACK UP OF 6 HOURS GIVES US

2KW X 6 HOURS = 12 KW HOURS

= 12 Units of Electricity (@ of Rs. 10 per unit)

= Rs. 120 per Day …………………………………….(1)

4.1.2

Solar Radiation available for 300 days in the roof of Mechanical Engineering Department.

Thus Saving in 300 days = Rs. 120 per Day x 300 days

= Rs.36,000 per year ………………………….(2)

4.1.3

Life of 2 KW SOLAR POWER PLANT INSTALLATION is 25 Years.

Thus Total Saving = Rs. 36,000 per year x 25 Years.

= Rs. 9, 00,000……………………………………(3)

4.1.4

Preventive Maintenance and Maintenance cost for next 25 Years

Only cleaning with wet and dry cloths daily (Only duty of Peon)

Thus negligible maintenance cost. The toughen glass of Solar Module can withstand any blow of even small stone up to 500 gram, rain, ice balls, and permanent clamping firmly of Solar Modules can withstand wind blowing up to 60 KM/Hour.

Finally: Negligible Maintenance Cost ………………………………………..(4)

4.1.5

Initial 2 KW SOLAR POWER PLANT INSTALLATION AND COMMISSIONING ON THE ROOF OF MECHANICAL ENGINEERING DEPARTRMENT, cost involved is

= Rs. 2, 00,000 ……………………………………………….(5)

4.1.6

NET our Project Contribution in future for at least 25 of years to the National Grid, with Simple Pay Back Period, electricity saving, how much tube lights and fans are glowing for 6 hours.(Equation (3) - Equation (5).

= Rs. 9, 00,000 - Rs. 2, 00,000

=Rs.7, 00,000 per 25 year

= Rs.7, 00,000 / 25 year

= Rs.28, 000 / year

= Rs.28, 000/ 12 month

= Rs.2333/ Month

= Rs.2333/ 30 days

= Rs.77.8 / day

4.1.7

Simple Pay Back Period

SPB = Investment Amount / Rs.7, 00,000 per 25 year

SPB = Rs. 2, 00,000 / Rs.7, 00,000 per 25 year

SPB = 2 x 25 year / 7

= 7.14 year

= 7 + .14 x 12 months = 7 years and 1 month +.68 months

= 7 years and 1month +.68 x 30 days

= 7years and 1month 2 days

4.1.8

Connected Load from Solar PV Modules this present work of 2 KW PV Solar power plant on Roof Top with battery back up of 6 hours to enlighten.

7 Tube Lights (40 W), 6 Fans (120 W), 3Computers (300 W), 3 charging points (300 W).

- 7 Tube Lights Load = 7 x 40W = 280 W
- 6 Fans = 6x120 W = 720W
- 3 Computers = 3x300W = 900 W
- 3 Charging Point = 3x 100W = 100W

Total = 2000 W

4.1.9

The Proposed Energy Audited way to exactaly double the present use of 2 Kw power by using energy efficient electrical appliances as per BEE are:

a) 14TubeLights = 14 X 20 W = 280 W

b) 12 Fans = 12 X60 W = 720 W

c) 3 Computers = 3 X 300 W = 900 W

d) 3 Charging Point = 3 X 33.33W = 100 W

Total = 2 KW

4.2 Initial investment

4.2.1

Investment for this present power utilization capacity is by utilizing Bureau of Energy Efficiency contribution of improved LED Tube Lights and Fans:

14 Tube Lights (20 W) Cost @Rs.500 = Rs. 7,000

12 Fans (60 W) Cost @Rs.1500 = Rs.18,000

Total = Rs.25,000

4.2.1

Extra Energy saving by this present power utilization capacity is to be doubled by utilizing Bureau of Energy Efficiency contribution of improved LED Tube Lights and Fans:

- 14 Tube Lights X 20 W = 280 W
- 12 Fans X 60 W = 720W

Total = 1000 W

4.2.2

This 1000 W is net extra contribution as perutilizing Bureau of Energy Efficiency of improved LED Tube Lights and Fans and is available with battery back up of 6 hours:

Extra Energy available = 1000 W X 6 Hr

= 6 KWh

= 6Units of Electricity (@Rs10/unit)

= Rs. 60 per day

As sun light is available for 300 days in a year = Rs. 60 per day X 300 days

Total Extra Energy available = Rs. 18000 per year

This present work of 2 KW PV Solar Power Plant on Roof Top with battery backup of 6 hours to enlighten at least for 25 years.

Grand Total Extra Energy available in guaranteed period= Rs. 18000 per year X 25 year

= Rs. 4, 50,000

Total probable energy cost recovered in entire span of 25 years by our efforts of upgrading present power utilization capacity (doubled by utilizing Bureau of Energy Efficiency contribution of improved LED Tube Lights and Fans)

Thus, Total Energy Cost Recovered

= Rs. 4, 50,000 - Rs. 25,000

= Rs. 4, 25,000 in 25 year

= Rs. 17,000 in a year

4.2.3 Simple Pay Back Period

SPB = Investment Amount / Rs.4, 25,000 per 25 year

Rs. 25, 00,000

SPB = ---------------------------------
Rs.4, 25,000 per 25 year

25 year
SPB = ------------------
17
= 1 years 5 months and 19 days

Thus ,total probable energy cost recovered is Rs.17,000 in a year by our efforts of upgrading present power utilization capacity (doubled by utilizing Bureau of Energy Efficiency contribution of improved LED Tube Lights and Fans)

V. RESULT ANDDISCUSSION AFTER SIMULATION

5.1 Solar radiation

Solar radiation energy for PV system placed at horizontal surface are simulated using three different simulation software . All receive maximum solar radiation on horizontal surface from the month of Feb to June which ranges from 5.5 to 7 KWh/m^2/d. While during the rest of the month the solar radiation ranges between 4 and 5.5 KWh/m^2/d.Annual average solar radiation is more than 5 KWh/m^2/d .

Solar radiation energy (KWh/m^2/d) simulation at horizontal surface using RETScreen/ PVsyst/ NRELSAM:-

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Solar radiation (KWh/m^2/d)	**4.46**	**5.56**	**6.55**	**6.86**	**7.00**	**6.63**	**5.55**	**4.82**	**5.19**	**5.55**	**5.14**	**4.48**	**6.34**

5.2 Optimal tilt angles

Now by varying the tilt angle of PV panel through simulation software ±3^o from latitude of location in India, solar radiation for these tilt angles are obtained. Wherever the enormous solar radiation is harvested by PV module, it is concluded as the optimal tilt angle of the location. The optimal tilt angles for Sehore varying between -2^o to -1^o. Optimal tilt obtained is close to the latitude of the location.

Optimum tilt angles for Sehore:-

S.N	City	LATITUDE (in degree)	0PTIMAL TILT ANGLE(in dgree)		
			RET Screen	PVsyst	NREL SAM
1	Sehore M.P INDIA	23.21˚N	**21.6˚ N**	**21.5 N**	**21.45˚ N**
			AVERAGE = 21.5N		

VI. CONCLUSION

6.1.

Roof Top Solar PV Power Plants of 2 KW capacity during 1st-15th June-2018.

The Simple Pay Back Period of 7 years and 1month 2 days

The Profit = Rs 77.8 per day

We are producing electricity is of only Rs. 120 but we will receive benefit of Rs 77.8 per day, because of Simple Pay Back Period is 7 years and 1month 2 days and electricity is entirely free for the rest guaranteed period of 17 year 11 month and 28 days.

Total benefit = Rs77.8 per day X 365 DAY X25 YEAR= Rs 70,99,25 (25 YEAR)…………..(1)

6.2

The Learned ways of Energy Flow study in National Workshop Cum Industrial Training Programme on Solar and other Renewable Energy Sources during 25th-30th June-2018 and apply learned principles for energy auditing.

The Initially Connected Load from Solar PV Modules were:

a) 7TubeLights = 7 X 40 W = 280 W

b) 6 Fans = 6 X120 W = 720 W

c) 3 Computers = 3 X 300 W = 900 W

d) 3 Charging Point = 3 X 33.33W = 100 W

Total = 2 K W

6.3

Proposed Energy Audited way to exactly double the present use of 2 KW power by using energy efficient electrical appliances as per BEE are:

a) 14TubeLights = 14 X 20 W = 280 W

b) 12 Fans = 12 X60 W = 720 W

c) 3 Computers = 3 X 300 W = 900 W

d) 3 Charging Point = 3 X 33.33W = 100 W

Total = 2 K W

The SimplePay Back Period of 1 years 5 months and 19 days

The Profit = Rs 60 per day

Total BENEFIT = Rs 60 per day X 300 DAY X25 YEAR= Rs 4,50,000 (25 YEAR)…………(2)

The additional cost of replaced tube lights and fans = 12,000 (APPX.) ……………………..... (3)

AND are to be reused at remote places of less consumption.

Grand Total Benefit=(1) +(2)+(3) = Rs 70,99,250

Rs 4,50,000

\+ Rs 12,000

Grand Total Benefit = Rs. 11,71,925

By Simple installing Roof Top Solar PV Power Plants of 2 KW capacity and applies energy audited suggestions.

Energy generation using solar PV technologies can be enhanced by setting the PV system inclination to the optimum tilt angle for the entire year. In this study, we have preferred the PV simulation software to calculate optimal tilt angle. Optimum tilt angle of Solar PV system in India are determined by varying the tilt angle from ±3° from its latitude. The conclusions obtained are summarised as follows:

(i) This study reveals that the annual optimal tilt is close to value of the location latitude in most cases.

(ii) For location Sehore, the optimal tilt angles obtained were varied **-2° to -1°** from its latitude.

(iii) We observed that annual average solar radiation for Sehore is **6.34 KWh/m2/day** at optimal tilt angle.

(iv) There is solar radiation energy increment of **0.8KWh/m2/d** to **1.5KWh/m2/d** at optimal tilt compared to solar radiation energy at zero tilt or horizontal surface of PV or at latitude.

(v) And also efficiency increased by **21%.**

6.4 Performance Comparison:

Sl.No	At Latitude	Tilt angle of existing solar array at SSSUTMS	Proposed Simulation (Tilt angle)	Remarks
PVSolar Position from surface (Deg.)	23.21˚N	23 N	21.5˚ N	Difference -1.71˚N
Solar radiation (kWh/m2/d)	5.01	5.10	6.34	Increased Efficiency 21%
SSSUTMS Power generation	-	2KW	2.42KW	21%

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