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.

Key words: 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. Government's target of installation of 100,000 MW of solar power by 2022 is good indication of this. Solar PV technology is increasingly seen as viable option for our current and future energy supply.

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.

II. LITRETURE 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 $\phi + (0 \rightarrow 10°)$ for the northern region and about $\phi + (0 \rightarrow 20°)$ 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 $0 – 40^{\circ}$ (face to the North) and during October 1 – March 11 is between $0 – 30^{\circ}$ (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 $36^{\circ} – 39.4$.

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°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, Sehor, 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 softwares.

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) [22].Latest version of SAM is 2015.6.30.

3.5. Simulation softwares

Simulation Software	Manufacturer	Cost	Website/Link	Version Utilized
RET-Screen	Natural Resources Canada	Free of Charge	www.retscreen.net	4
PVsyst	Institute of Environmental Sciences (ISE), University of Geneva, Switzerland	900CHF for one machin e license; 150CHFfor additio nal machin es	http://www.pvsyst.com /5.2/index.php	6.3.9
NREL SAM	National Renewable Energy Laboratory, Washington	Free	https://www.nrel.gov/analysis/sam/ba ckground.html	2015.6 .30

IV. CONCLUSION

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 $\pm 3^{o}$ 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**^{o}from its latitude.

(iii) We observed that annual average solar radiation for Sehore is **6.34kWh/m^2/day** at optimal tilt angle.

There is solar radiation energy increment of **0.8kWh/m^2/d** to **1.5kWh/m^2/d** at optimal tilt compared to solar radiation energy at zero tilt or horizontal surface of PV or at latitude.

V. REFERENCES

[1] Zhao Chaohui. " Emerging Technology: Photo-Voltage Generation Status and Trends". Journal of Shanghai Dianji University, 2008, 11(1): 104-109.

[2] Peter Wurfel " Basic principles of solar cells and the possible impact of nano-structures" IEEE Cat.No. 03CH37497 3rd World Conference on Phofovoltaic Energy Conversion May 11-18, 2003 Osab. Japan, Page 2672 - 2675 Vol.

[3] Matt Boreland and Darren Bagnall, "Current and future photovoltaics",Foresight-HorizonScanningReport,5th July2006.

[4] Tim Bruton, et al, "Towards 20% Efficient Silicon Solar Cells Manufactured at 60 MWp Per Annum", Proceedings of the 3rd World Conference on Photovoltaic Energy Conversion, 2003, Vol.1, pt. 1, pp. 899-902.

[5] W. Xiao, W. G. Dunford, and A. Capel, "A novel modeling method for photovoltaic cells", in Proc. IEEE 35th Annu. Power Electron. Spec. Conf. (PESC), 2004, vol. 3, pp. 1950–1956.

[6] P G Nikhil and D Subhakar "An Improved Simulation Model for Photovoltaic Cell" IEEE 978-1-4244-8165-1/11 2011.

[7] J. A. Gow, C. D. Manning "Development of a photovoltaic array model for use in power electronics simulation studies", IEE Proceedings on Electric Power Applications, vol. 146, no. 2, pp. 193-200, March 1999.Datasheet Vikram Solar ELDORA 40-P

[8] Muhammad H. Rashid "Power Electronics: Circuits, Devices & Applications" TextBook.

[9] A.Roman, R.Alonso,P.Ibanez, S.Elorduizapatarietxe and D.Goitia, "Intelligent PV module for grid-connected PV systems," IEEE Trans. on Ind.Electron., Vol. 53, No. 4, Aug. 2006.

[10] W. Xiao, N. Ozog and W. G. Dunford, "Topology Study of Photovoltaic Interface for Maximum Power Point Tracking," IEEE Transactions on Industrial Electronics, vol. 54, no. 3, June 2007.

[11] L. Zhang, W. G. Hurley and W. Wolfle, "A New Approach to Achieve Maximum Power Point Tracking for PV System with a Variable Inductor," 2nd IEEE International Symposium on Power Electronics for Distributed Generation System.

[12] V. Agarwal H. Patel. Maximum power point tracking scheme for pv systems operating under partially shaded conditions. IEEE Trans.Ind. Electron., 55:1689{1698, 2008.

[13] Thesis"Maximum Power Point Tracking:Algorithm and Software Development" Delft University of Technology Faculty of EEMCS June 27, 2012.

[14] Datasheet Arduino Development Board Kit " http://www.arduino.cc.

[15] BidyadharSubudhi, Senior Member, IEEE, and RaseswariPradhan "A Comparative Study on Maximum Power Point Tracking Techniques for Photovoltaic Power Systems" IEEE Trans. On Sustainable Energy, VOL. 4, NO. 1, JANUARY 2013.

[16] D. Hohm and M. Ropp, "Comparative Study of Maximum Power Point Tracking algorithms," Progress in Photovoltaics: Research and Applications, pp. 47-62, 2002.

[17] TrishanEsram and Patrick L. Chapman "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques" IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 22, NO. 2, JUNE 2007.

[18] M. E. Ropp D. P. Hohm. Comparative study of maximum power point tracking algorithms. Prog.Photovolt: Res. Appl., 11:47{62, 2003}.

[19] Md. Rabiul Islam, Youguang Guo, JiansGuo Zhu, M.G Rabbani, "Simulation of PV Array Characteristics & Fabrication of Microcontroller Based MPPT", 6th International Conference on Electrical and Computer Engineering ICECE 2010, 18-20 December 2010, Dhaka, Bangladesh.

[20] Karel Castex, Julio Lara, David Wade, and Jing Zou "Integrated Renewable Power System (IRPS)" Orlando, Florida, 32816-2450.

[21] Inverter circuit available at "http://danyk.cz/menic230_en.html".