International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Issue 06, Volume 6 (June 2019) www.ijirae.com

TECHNO-ECONOMIC ASSESSMENT OF THREE SOLAR PV TRACKING TECHNOLOGIES

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Manuscript History
Number: **IJIRAE/RS/Vol.06/Issue06/JNAE10085**
Received: 04, June 2019
Final Correction: 12, June 2019
Final Accepted: 17, June 2019
Published: **June 2019**
Citation: Sameep, Chaudhari & Pratik (2019). Techno-Economic Assessment of Three Solar PV Tracking Technologies. IJIRAE::International Journal of Innovative Research in Advanced Engineering, Volume VI, 396-400.
doi://10.26562/IJIRAE.2019.JNAE10085
Editor: Dr.A.Arul L.S, Chief Editor, IJIRAE, AM Publications, India

Abstract- Assessment of the viability for different types of solar PV tracking technologies rely on the assessment of whether the annual production of the different tracking technologies is increased enough relative to a benchmark Fixed Tilt system to compensate for the higher installation and operational costs incurred by the tracking systems. To investigate this issue, we use the PVsyst software to simulate electricity production from three representative solar PV systems at Karnataka. In these simulations we use hourly solar irradiance, weather and surface albedo data, technical data relating to both module and inverter characteristics and impacts associated with module soiling and shading.

Keywords- Energy Yield; Irradiation; Levelized cost of electricity; Performance Ratio; PVSyst;

I. INTRODUCTION

Energy is a vital input for the social and economic development of any nation. With increasing agricultural and industrial activities in the country, the demand for energy is also increasing. But the existing sources of energy are fast depleting and in the next few decades, most of them will be depleted. So we need a new source of energy which can supply our future needs. The Renewable energy sources like wind, solar, tidal etc. are considered the future energy sources. But these sources of energy are unreliable and are difficult to handle so they require a lot of technological improvement before they are fully capable of meeting our energy needs.

The Fixed tilt (FT), Single Axis Tracker (SAT) and Dual Axis Tracker (DAT) affects the net solar PV plant yield over a period of time. DAT improves the yield of the plant, but may not be financially viable in the short run. FT on the other hand, will reduce the energy yield of the plant but will reduce the initial investment cost of the plant. This project presents a methodology to select the best method for maximize financial return using an energy estimation software and financial model. The Levelized Cost of Electricity (LCOE) is used as a financial model for checking the feasibility of the tracking technology being selected. The methodology is tested to get the optimum PV tracking technology and applied to a simulation study plant of 2163 kW-DC capacity in Ballari district of Karnataka state modelled in PVSyst software [1].

Basic System Description: Solar Photovoltaic power generator consists of solar modules in series and parallel connections, these convert solar radiations into DC electrical power at the pre-determined range of Voltages whenever sufficient solar radiation is available. The Individual solar cells are connected together in a module (in the series connection), which are hermetically sealed to survive in rugged weather conditions and ensures optimum performance during its long life. In order to achieve a higher system voltage, modules are installed in a series arrangement, called a string. A higher system voltage has the advantage of lesser installation work, higher efficiency of the entire plant and usage of smaller cross section cables. Calculated no. of strings is connected in parallel by cables in Array Junction Boxes. These Array Junction Box outputs are fed to the String inverters/ Power Control Unit (PCU) [2] to invert solar generated DC power into conventional 3 phase AC power. AC power from inverters will be linked to the local LT power distribution box for local use or can be exported to the grid.

The system under consideration is 2163kW DC solar PV plant located at Ballari district of Karnataka state in India. The plant comprises of 6760 numbers of modules having capacity of 320Wp each. These modules inject power into two inverters of 1MW capacity each. The tilt angle provided for FT plant is 15° and all panels are facing true south [3]. SAT system follows the Sun path from east to west with minimum and maximum rotation limits of -45° and +45° respectively. DAT system has minimum and maximum tilt angle of 2° and 24° respectively and is given minimum and maximum azimuth of -90° and +90°. DAT system follows sun path continuously without being affected by seasonal variation [4].

II. LEVELIZED COST OF ELETRICITY

Levelized Cost of Electricity (LCOE) represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle [5]. LCOE is often cited as a convenient summary measure of the overall competitiveness of different generating technologies. Key inputs to calculating LCOE include capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type. The importance of each of these factors varies across the technologies. For technologies with no fuel costs and relatively small variable O&M costs, such as solar and wind electric generating technologies, LCOE changes nearly in proportion to the estimated capital cost of the technology.

$$LCOE = \frac{Sum\ of\ costs\ over\ lifetime}{Sum\ of\ electricity\ produced\ over\ lifetime} \qquad \text{------------------------(1)}$$

III. PERFORMANCE RATIO

The performance ratio is a measure of the quality of a PV plant that is independent of location and it therefore often described as a quality factor. The performance ratio (PR) is stated as a percent and describes the relationship between the actual and theoretical energy outputs of the PV plant. It thus shows the proportion of the energy that is actually available for export to the grid after deduction of energy loss (e.g. due to thermal losses and conduction losses) and of energy consumption for operation [6]. The closer the PR value determined for a PV plant approaches 100 %, the more efficiently the respective PV plant is operating. In real life, a value of 100 % cannot be achieved, as unavoidable losses always arise with the operation of the PV plant. The performance ratio informs as to how energy efficient and reliable PV plant is. With the performance ratio we can compare the energy output of your PV plant with that of other PV plants or monitor the status of PV plant over a prolonged period. The determination of the performance ratio at fixed regular intervals does not provide an absolute comparison. Instead, it provides the operator with the option of checking performance and output: if it is assumed that the PV plant is running optimally on being commissioned, and hence that the initial value for the performance ratio is 100%, then taking of further PR values over time enables the identification of deviations, meaning that appropriate countermeasures can be promptly initiated.

$$PR = \frac{Units\ generated}{Irradiance X Active\ Area X Module\ Efficiency} \qquad \text{-------------------------(2)}$$

IV. METHODOLOGY

The design of a Solar PV plant mainly depends on two things, first type of plant to be designed and second on the type of load to be fed. The cost of Solar PV plant is very high compared to same size plants of different type like thermal or hydro. At present, the cost of the solar plant is around 36000Rs/per kW, which adds to 3.6 Crores for a MW scale plant. So, there is a tremendous need for cost optimization without reducing the system reliability and at the same time increasing the plant yield.The most promising parts of the system which are open to optimize are application of tracking systems and the support structures of the system. Recent research has shown that factors like climatic data and location also play a huge role in their selection rather than just the electrical requirements.

The present work focuses mainly on the selection of best tracking technology for solar PVsyst plant. The goal is to find the optimum PV tracking system for a plant to maximize the financial returns and performance ratio of the plant through its lifetime. The methodology is being developed for Ballari location in Karnataka state, taking into account radiation and other climatic data. Now, to get the optimum tracking system for a plant at Ballari the Levelized Cost of Electricity (LCOE) and Performance Ratio (PR) for different tracking technologies has to be calculated and the one with lowest LCOE is to be selected. For this, first the cost of the solar plant has to be found and the cost of different equipments has to be found in tracking system.

V. RESULTS AND DISCUSSIONS

The Energy yield of all months for the three PV technologies have been obtained from PVsyst System simulation. As compared to the FT, SAT and DAT systems receive 18.02% and 21.5% more effective global irradiation respectively.

Table-1: Irradiation for PV Tracking Technologies

Effective Global Irradiation kWh/m²			
Month	**Fixed Tilt**	**Single Axis**	**Dual Axis**
January	182.1	200.3	228.5
February	175.1	200.4	218.1
March	202.2	243.3	249
April	187.5	235.9	229.6
May	171.1	223.7	238.5
June	140.6	177.5	176.3
July	133.6	163.7	146.8
August	138.5	163.9	160.4
September	157.4	188	187.1
October	174.5	200.1	186.2
November	166.1	180.9	201.3
December	178.4	191.1	217
Average	**167.26**	**197.40**	**203.23**

Energy injected in to grid (E_Grid) increases by 16.67% and 19.38% for the SAT and DAT respectively as inferred from PVSyst.

Table-2: Energy Injected in to Grid

E_Grid in MWh			
Month	**Fixed Tilt**	**Single Axis**	**Dual Axis**
January	328.7	361.9	383.8
February	310.2	353.1	382.1
March	353.2	418.8	427.7
April	326.5	402.4	396.6
May	301.8	387.8	383.9
June	235.9	295.6	313.9
July	241.3	276.5	265.5
August	222.8	294.8	273.9
September	284	334.9	319.5
October	313.6	357.1	331.3
November	299.9	301.6	360.1
December	323.1	347.4	389.4
Average	**295.1**	**344.3**	**352.3**

Performance Ratio for FT system is best followed by DAT system, SAT system shows the lowest performance ratio. The monthly variation of energy injected in to grid can be better deduced from graph shown below.

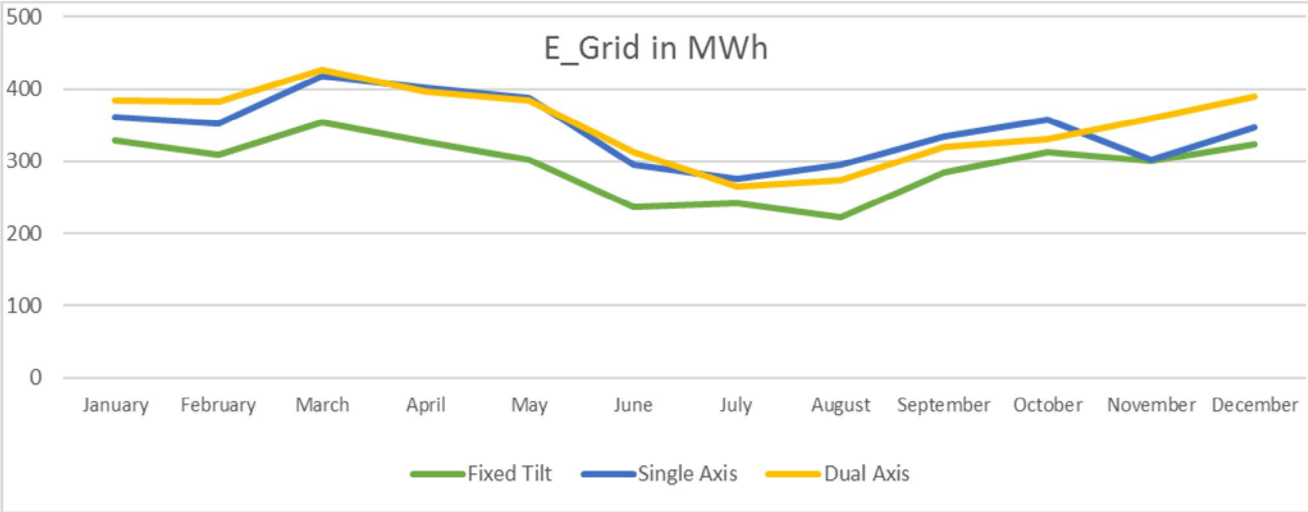

Fig 1. Energy Injected in to Grid- Monthly Variation

Table-3: PR for Each PV Plant

Performance Ratio			
Month	**Fixed Tilt**	**Single Axis**	**Dual Axis**
January	0.782	0.779	0.734
February	0.772	0.763	0.759
March	0.76	0.746	0.744
April	0.755	0.74	0.751
May	0.76	0.747	0.7
June	0.718	0.712	0.773
July	0.773	0.721	0.784
August	0.688	0.766	0.74
September	0.778	0.766	0.741
October	0.779	0.769	0.775
November	0.785	0.719	0.782
December	0.788	0.785	0.787
Average	**0.762**	**0.751**	**0.756**

The cost of mounting structures for FT is given as 7% of the total cost, for the approximate 2MW plant cost of mounting structure comes around Rs.54.5 Lakhs. The cost of mounting structures for SAT is given as 22% of the total cost, for the approximate 2MW plant cost of mounting structure comes around Rs.2.01 crores. The cost of mounting structures for DAT is given as 28% of the total cost, for the approximate 2MW plant cost of mounting structure comes around Rs.2.8 crores. The FT tracking system using energy yield from PVsyst simulation report and costing table gives the LCOE 25 years as Rs.2.46. Similarly, for SAT system the LCOE is Rs.2.70 and DAT system gives LCOE of Rs.2.93 respectively.

The above work provides a methodology to find the optimum tracking system selection for any solar photovoltaic power plant. The methodology was used in a 2163kW DC solar power plant simulated for Ballari, Karnataka. The above methodology helps in finding the optimum tracking system for a power plant at any location. For Ballari, Karnataka to install any solar power plant of MW or sub-MW capacity the best system is Fixed Tilt to get the lowest LCOE. The results also prove that the highest energy output is achieved for Dual Axis Tracker (DAT) and performance ratio of fixed tilt solar plant is highest. So, for locations where the unit price for energy is high, Single

Axis Tracker (SAT) and Dual Axis Tracker can be opted. However, going by this methodology and using computer modeling the most techno-economically feasible tracking system selection for any capacity plant at any location can be found.

VI. CONCLUSION

This report concludes that, the best tracking system selection for a solar plant is dependent on various factors like the solar radiation, the cost of energy and Balance of Systems (BOS) for the plant. The best system selection for locations selected with the same radiation as Ballari, Karnataka is Fixed Tilt Solar PV plant in MW scale.

The Dual Axis Tracking (DAT) configuration for solar power plants provides the best energy yield. The Fixed Tilt solar plant provides the best performance ratio followed by Dual Axis Tracking (DAT) system and Single Axis Tracking (SAT) system gives the least performance ratio. Capex comparison of three technologies is as follows, Capital Expenditure relative to FT for SAT system is +18.87%. Capital Expenditure relative to FT for DAT system is +29.44%. LCOE comparison for Direct purchase with respect to FT, Per unit cost increases by 9.76% for SAT and 19.1% for DAT for 25 years. The dwindling installation cost of solar PV plant and rising per unit grid cost will make the SAT and DAT system economically viable and will result in large scale commercial adoption. For finding the instance at which SAT and DAT will be at par with the FT system financially can be decided using learning curves, which makes use of past installation cost over the years.

ACKNOWLEDGEMENT

This work was partially carried at Chemtrols Solar Pvt Ltd, Mumbai. I thank for the resources and guidance provided that made the project successful.

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