Performance Comparison of Fixed and Tracking Type Solar Plants

Devendra Pratap Singh, S. S. Dhami, S. S. Banwait, Deepam Goyal

Abstract: ***Solar energy, which is essential for all on earth, is clean and plentiful and can be transformed into electrical energy using photovoltaic (PV) systems. The generation of energy using different types of PV solar panel mountings viz. fixed, tracking, and adjustable, depends on a variety of factors such as sun intensity, relative humidity, cloud cover, and heat buildup. This paper reviews the various parameters which influence the performance of solar power plants. Further, the performance comparison of fixed and tracking PV systems shows that in comparison to the classical fixed-position PV systems, the tracking type of PV systems capture much more solar energy and thus produce substantially higher output power. Furthermore, consideration is also given to design variables which should be taken into account during the initial stage of engineering of a plant to achieve better performances and outcomes from the generation of a solar power plant.***

Index Terms: ***Cumulative Utilization Factor (CUF), Dual Axis Solar Tracker, Fixed Tilt Solar Plant, Performance Ratio (PR), Photovoltaic Panels, Seasonal Tilt Solar Plant, Single Axis Solar Tracker.***

ABBREVIATIONS

AADAT - Azimuth dual-axis tracker
AI - Artificial intelligence
CUF - Cumulative Utilization Factor
PR – Performance Ratio
PV – Photovoltaic
SAPHT - Solar assist plug-in hybrid electric tractor
TTDAT - Tip–tilt dual-axis tracker

I. INTRODUCTION

Electricity is one of the greatest technological innovations by the human race. It has now become an indispensable part of our daily life. However, a major part of the electrical energy is produced using fossil fuel, which pollutes the environment. Solar energy, which is a free, perpetual, and clean source of energy, was discovered many years back with a piece of shiny metal which can reflect sun rays. It satisfied the basic need for cooking and heating in ancient days. In modern days it is being used in many ways by converting solar energy to electrical energy with a Solar Panel [1].

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The solar panel works by allowing photons, or particles of light, to knock electrons free from atoms, generating a flow of electricity. Solar panels comprise many, smaller units called photovoltaic cells. Photovoltaic effect, which is a physical and chemical phenomenon, is the generation of voltage and electric current in a material upon exposure to light [2]. Many cells linked together make up a solar panel. PV cells can be considered in the form of a sandwich consisting of two slices of semiconducting material, usually silicon. PV cells need to set up an electrical field to operate. An electrical field exists when there is a separation of opposite charges. When the photon of sunlight falls on the upper layer (phosphorus), an electron is set free and this electron is forced out from silicon junction by an electric field. Such electrons are converted in the form of usable power with the help of other components of the cell. Metallic plates, which are conductive and are placed on sides of cells, absorb the electrons and pass them to the wires. At this level, the flow of electrons happens in the same way as any other source of electricity [3].

A. Trajectory of the Sun

The Earth's axis **is** tilted about 23.5 degrees, relative to the plane of Earth's orbit around the Sun. As the Earth orbits the Sun, this creates the 47° declination difference between the solstice sun paths, as well as the hemisphere-specific difference between Summer and Winter. In the Northern Hemisphere, the Winter Sun (November, December, January) rises in the southeast, peaks out at a low angle in the south, and then sets in the southwest. In the Southern Hemisphere, the Winter Sun (May, June, July) rises in the northeast, peaks out at a low angle in the north, and then sets in the northwest. In the Northern Hemisphere, the Summer Sun (May, June, July), rises in the northeast, peaks out slightly south of the overhead point, and then sets in the northwest, whereas in Southern Hemisphere, the Summer Sun (November, December, January), rises in the southeast, peaks out slightly north of the overhead point, and then sets in the southwest. The amount of solar radiation/intensity on the solar PV panel will be highest when the solar PV panel surface is at 90 degrees to the sun's radiation. For achieving this, there is a need to develop a technique, which facilitates to impart movement to the solar panel to follow maximum sunlight [4].

B. Solar Trackers

Solar trackers rotate solar panels during the day in such a way that solar panel follows the direction of the sun to obtain maximum energy from the sun. Solar trackers have been divided into two major categories – Single-axis And Dual-axis, based on their movements.

However, there are some other studies, which have highlighted some unusual complex forms of structures, other than single and dual-axis trackers.

- *Single-Axis Solar Trackers*

A single-axis tracker has one degree of freedom and it rotates about a single axis, Fig. 1. Such a single-axis solar tracker can be horizontal, vertical, tilted, and polar oriented.

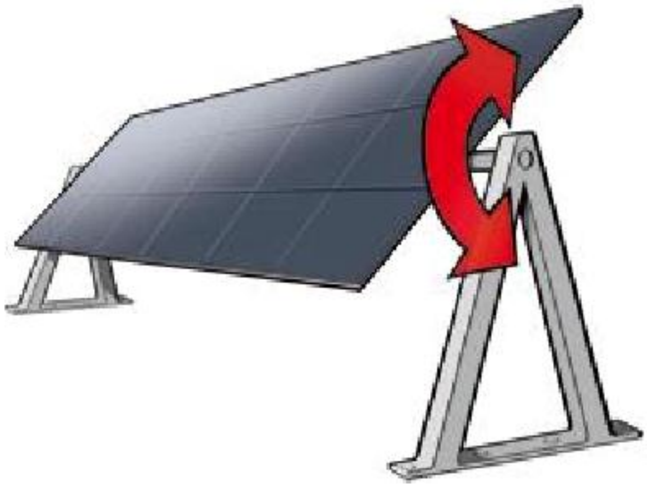

Fig. 1**. Single Axis Solar Tracker System [6]**

- *Dual-Axis Solar Trackers*

Dual-axis trackers are designed in such a way that they are capable of moving in two directions i.e. north-south and east-west so that they continually face the maximum radiation of the sun, Fig. 2. They are further classified into different types, namely tip-tilt and azimuth-altitude. In tip-tilt dual-axis tracker (TTDAT) panel array is affixed on the top of the pole. This array rotates around top of the pole to impart east-west movement. An azimuth dual-axis tracker (AADAT) is designed in such a way that, its primary axis is in the vertical direction to the ground and the secondary axis is perpendicular to the primary axis called elevation axis. These trackers move vertically as well as horizontally with respect to maximum sunlight so that they can help to achieve the highest production of solar energy [5].

Fig. 2. Dual Axis Solar Tracker System [6]

C. Fixed Tilt Solar Plant

In the fixed-tilt solar plant, the solar PV panels are permanently affixed on the roof of the building or the ground using steel frameworks, Fig. 3. For achieving maximum efficiency from solar panels, they must be installed in the direction that receives most of the sunlight. For the northern hemisphere, the solar PV panel must face southward whereas it faces northward in the southern hemisphere to absorb much of the sunlight [7].

Fig. 3. **Fixed Tilt Solar Plant**

D. Seasonal Tilt Solar Plant

A seasonal tilt solar plant is a kind of fixed-tilt solar plant, except in seasonal tilt solar plant, the angle of the solar PV panel is changed seasonally, Fig. 4. Seasonal tilt is favored because it gives a high generation of energy generation and is more efficient than a fixed-tilt solar plant because it has more solar radiation over time.

Fig. 4. Seasonal Tilt Solar Plant

Seasonal tilting is normally achieved in two ways, adjusting the tilt solar panel manually either twice or four times a year, by adjusting bolts and nuts in the slots provided in the structure. In the case of the tilting of solar panels twice a year, the tilting angle of the solar PV modules is changed by dividing one year into two periods. Summer season angle is fixed from mid-March to mid-September and winter season angle is fixed from mid-September to mid-March. Normal practice is that the angles for summer and winter are calculated as follows:

Latitude of the location = L° (say)
Summer tilt angle = L° – 15°
Winter tilt angle = L° + 15°

However, when the solar panel is tilted four times a year, the PV modules are changed four times a year. For doing this, the year is assumed to be divided into four season viz. winter, spring, summer, and autumn. The angles in spring and autumn are fixed as per the value of the latitude value of the location, and the angles in summer and winters shall be calculated as above [8].

E. Performance ratio

Performance ratio (PR) is the ratio of plant output to installed plant capacity in any case with respect to the radiation measured. It can be determined by using Eq. 1 [9].

$$PR = \frac{Measured\ output\ (kW)}{Installed\ plant\ capacity\ (kW)} X \frac{1000\ W/m^2}{Measured\ radiation\ intensity\ (W/m^2)} \quad (1)$$

PR is considered as a basis of solar plant efficiency.

F. Cumulative Utilization Factor

CUF gives a ratio of actual generation of energy by the solar plant in one year to the maximum annual potential capacity of solar plant when measured under ideal conditions. CUF is typically expressed as a percentage and can be determined using Eq. 2 [10].

$$CUF = \frac{Energy\ measured\ (kWH)}{(365X24Xinstalled\ capacity\ of\ tHe\ plant)} \quad (2)$$

II. CURRENT STATUS OF RESEARCH

Many researchers have carried out work on performance analysis extensively and investigated the criteria which affect the efficiency of the solar plant.

Huang and Sun [11] carried out the design analysis of the ‘single-axis three-position sun-tracking PV module’ which was having a low concentration ratio reflector. It has been shown that performance can be optimized with stopping angle (β) of approximately 50°, and selecting switching angle (θ_H) as half the value of stopping angle, i.e. θ_H = β/2, and both of these angles are not linked with latitude. Moreover, there is an enhancement in power generation by nearly 24.5% in comparison to the fixed photovoltaic module for latitudes θ< 50.

Rubio, Ortega, Gordillo, and Martı´nez [12] developed an accurate sun tracker having a feature of easily following the sun and such tracker did not require manual settings for installation. This tracker was in the form of a hybrid system that blended an open-loop system using solar movement models and a closed-loop system employing a dynamic feedback controller. The focus was on energy saving so that motors do not consume extra energy. Simulation, as well as experimental outcomes, indicate that the two-axis solar tracker system with little cost results in low tracking error by using a high concentration of solar arrays.

Abdallah and Badran [13]. described the concept of a computerized sun-tracking device that rotates as per the sun’s movement. Comparative performance analysis between the fixed and sun tracked solar system has been made and the findings exhibit that the energy generation is increased by 22% by using a sun-tracking system. It was inferred that sun tracking is more effective as compared to a fixed solar system and is capable of enhancing energy generation. By using the sun tracker increases the temperature of water while it decreases the thermal capacity of the water. This increases the evaporation rate. Hence the distillation rate of water increases.

Mousazadeh, Keyhani, Javadi, Mobli, Abrinia, and Sharifi [14] discussed the variation of solar radiation intensity on panels because of daily as well as seasonal movements of the earth. The best possible orientation of solar panels with respect to sun direction is achieved by such sun trackers. With the optional use of sun trackers, collected energy can be increased in the range of 10 to 100% depending upon geographical conditions and during various periods. But the use of tracking systems is not preferred for smaller panels as there are high energy losses in driving mechanisms. The tracking device consumes power equivalent to the 2–3% of the increased energy output. **Barsoum & Vasant [15]** programmed a peripheral interface controller to detect the sun’s radiation through the sensors and then give the signal to the motor for positioning so that the maximum quantum of sunlight is received on the surface of the solar PV panel. It has been documented that energy output can be increased by 20% with the use of a single-axis solar tracking system while the increase is 40% for the dual-axis tracking system when compared to a fixed solar system.

Khan, Tanzil, Rahman, and Alam [16] constructed a microcontroller-based prototype for solar panels using photoresistors that can be used in cloudy, hazy or clear sky to track the sun and rotate along with sun movement. A photoresistor is a variable resistor whose resistance varies inversely with the intensity of light. When photons of Sunlight fall on the photoresistors, an electron is set free and this electron is forced out and allowing them to cross the energy gap to the conduction band and then conduct electricity.

Taherbaneh, Rezaie, Ghafoorifard, Rahimi, and Menhaj [17] used the three different types (fuzzy-based maximum power point tracking technique, fuzzy-based sun-tracking technique, and combination of the above two techniques) for maximizing the generated power of a solar panel. It has been found that total power of 23 W (which is nearly 51% of nominal output power) and 11 W (24.5 % of the nominal output power) & 35 W (78% of nominal output power) has been generated with the use of the fuzzy-based maximum power point tracking technique, fuzzy-based sun-tracking technique, and combination of above two techniques, respectively.

Minor and Garcia [18] described the use of the webcam-based exceptional approach for tracking the movement of the sun which eliminated the common issues experienced while using the solar trackers available in the market. The design and fabrication of an electro-mechanism were carried out to ascertain how accurately it can be used for tracking the sun in both inclement as well as conducive weather.

A typical problem that this approach solved was the sensitivity of the various devices like photodiodes/phototransistor to diverse ambient conditions of humidity and temperature. The designed prototype depicted an accuracy of the order of 0.1º and was equally resistant to erratic surges and falls in temperature. Even when the sun was not visible for quite some time it could extrapolate its position as well as relocate it.

Sarker, Pervez, and Beg [19] designed an automatic double-axis solar tracking system to achieve the highest possible power out of the panel. It consists of a sensor, Microcontroller to drive motor with control software, gearbox, bearing arrangements with supports and mountings. It was inferred that sun tracking is more effective as compared to a fixed solar system and enhances energy generation 30-45% at atmospheric conditions.

Mousazadeh, Keyhani, Javadi , Mobli, Abrinia, and Sharifi [20] assembled four light dependent resistive sensors for maximization of the accumulating energy from an onboard PV panel mounted on a solar assist plug-in hybrid electric tractor (SAPHT). Experimental outcomes proved the proposed system to be very effective, robust and collected 30% more energy than that of a horizontally immovable system.

Tudorache Oancea, and Kreindler [21] developed an intelligent drive unit in which the DC motor automatically positions the PV panel as per the sun's movement. It has been demonstrated that 57.55% of excess energy was generated by using a solar tracking panel in comparison to the fixed type of panel on the basis of data of the particular day. Moreover, with the use of higher power PV panels (approx three times more) by the same tracking mechanism, more energy (around 38%) can be produced when compared to the fixed solar system.

Kancevica Navickas, and Ziemelis [22] introduced a sun tracking collector system. Solar collector's surface is tracking the sun's movement during the day and the solar rays are striking it perpendicularly. As a result, the solar radiation losses which are related to the energy reflected from the collector surface will be decreased, and in this case, the efficiency of a solar device will be at its maximum. The result showed that the use of a tracker device generates 1.4 times more energy in comparison to the stationary operating flat-plate collector of similar specifications. **Deb and Roy [23]** designed a stepper motor based single-axis tracker system for converting solar energy to electricity. The motor moves the mini solar panel as per the inputs received from two light sensors. Results exhibited that there was a rise in the energy collection of solar panels, and the obtained results were corroborated by the simulation results. We would be increased the efficiency of solar panels by using the Lab view program. **Rhif [24]** summarized the various experimental works carried out on sliding mode control law based double-axis solar tracking systems. The results exhibit that the automatic sun tracker has led to a 40% increase in power production by the solar PV panels as compared to the fixed solar panel system and also evaluated the efficiency of sliding mode control for the tracking process as well as its durability.

Madhu, Wadekar, Chiragkumar, and Gagan [25] designed the concentrated solar collectors based setup in which single-axis tracker is used to keep track of sun's east to west movement, whereas a double axis tracker additionally tracks sun's seasonal declination motion. It has been noticed that the proposed setup provided an improvement of 26% to 38% in the output power during normal and clear weather as compared to an immovable collector, and also exhibited unpredictable outcomes on bad weather days like improvement of output power is 53% & 61% during rainy days and cloudy days respectively. **Sharma [26]** developed a single axis solar thermal collector and measured its performance. The results demonstrated that an increase of 1 in the mass stream rate substantially enhances the efficiency of the solar collector. Also, the performance was not uniform throughout the year, proficiency was found to be 10% higher in November 2011 when compared with January 2012. The result shows that the proposed thermal collector worked at higher airflow rates of air from 0900 to 1600 hrs for drying of grains to get maximum performance.

Rao and Mahesh [27] proposed a solar tracker method by collecting the input signals using the ARM7TDMI processor as a monitoring controller which is based on the closed-loop algorithm in the embedded system domain. This ARM7TDMI processor does take the input from the sensor and gives the command to the motor for tracking the sun's movement. The result shows that the proposed method leads to maximum current flow and thus to the maximum amount of electric energy being generated.

Pandey and Agrawal [28] demonstrated a small solar PV tracker which was controlled using a programmable system on a chip (PSOC) device. The voltage from the solar panel and a photoresistor is used as input to the PSOC which processes it and the output is given to geared DC motor. A large number of panels can be controlled by using a single microcontroller but this requires accurate data flow across the controller. The result shows that the proposed tracker system has been found to increase efficiency by almost two times. **Okpeki and Otuagoma [29]** constructed a low cost two-directional solar PV tracker system which was used in conjunction with 900V inverter and 100AH battery of 12 volts & 10 Watt solar panel. It has been documented that the three variables, namely, material type and surface area of the panel, intensity/radiation of the incident sun rays, wavelength, are critical in determining the power availability from a PV panel. The result showed that the tracker system uses power for its movement, which was less than the power gain by a tracking system accurately. The most important conclusion of his result that the cost of a 10 Watt solar tracker system is very low, less than $500. This means the system can be mass-produced at a very low cost.

Balabel, Mahfouz, and Salem [30] performed the numerical analysis to design and test the control system for enhancing the effectiveness of solar panels. The design of the suggested tracker system was corroborated on the basis of data calculated for the altitude angle at Taifcity, Saudi Arabia. Results exhibited that the proposed system was accurate yet simple and was applicable in different operational constraints.

Badran and Arafat [31] established a novel tracking methodology of water distillation by utilizing the advantage of the high probable concentration of parabolic trough collectors. In his research, he used an image processing system to catch the movement of the sun and also used an artificial neural network system for tracking the sun's movement in abnormal days like rainy or cloudy or dusty, etc. The result of the image processing system is found accurate & reliable according to the self-monitoring while in Neural network model is reliable according to the obtained low learning errors. The water distillation yield shows a high percentage output of distillate of about 65%. **Ghassoul [32]** constructed and tested a cost-effective sun tracking system using Microchip PIC 18F452 microcontroller to extract maximum solar energy or radiation. The proposed tracker system was established on the basis of two mechanisms viz. pilot and intelligent panels. The pilot panel was used for locating the position of the sun, and an intelligent panel was used to align itself with the pilot mechanism when there is a possibility of extracting maximum energy. The result shows that the pilot mechanism is to locate the best position for maximum energy extraction while an intelligent panel mechanism is rotated to the position when energy extraction is optimal. **Li, Liu, and Tang [33]** contrasted the optical performance of a single axis vertical positioned solar panel with the fixed and dual-axis solar tracker. On the basis of monthly horizontal radiation, a mathematical procedure was also suggested for computing yearly receivable radiation on fixed as well as tracked panels. It has been shown that the annual optimum tilt angle for the vertical single-axis solar panel to optimize the yearly energy collection had an almost linear relationship with site latitude. Moreover, the highest yearly receivable radiation in the single-axis vertical positioned solar panel was nearly 96 percent of the radiation annually accumulated by a two-axis solar tracker. The amount of receivable radiation produced by using single-axis vertical positioned solar panel got enhanced by 28 percent in those zones where solar resources were abundant and by 16 percent in those zones where solar resources were scarce when the comparison was done with the conventional south-facing fixed solar panel positioned at an optimum tilt angle.

Jamil, Kirmani1, and Rizwan [34] explained the different types of solar tracking system designs and evaluated these designs on the basis of techno-economic and performance analysis. It has been found that Conventional sizing methods are used when all the metrological data is available for a particular site however where these data are not available then conventional sizing methods could not be used then we have to use artificial intelligence techniques.

Goura [35] carried out an on-field performance analysis of a 1 MW grid-tied PV system. In this study, various parameters (i.e. the effect of temperature on PR values, temperature effect on the PV cells and efficiency, the performance of the inverters, environment and other factors that affect the performance of the PV Park, and energy injected into the grid) were taken into account for evaluating the performance of the plant. The result shows that the annual performance ratio in the range was 0.74 to 0.79 when the analysis was performed over a period of time.

Tarigan, Djuwaria, and Purbab [36] conducted a simulation study by modeling for performance assessment of PV installation using solar GIS- PV planner in Surabaya. The global horizontal irradiation in Surabaya is found at about 5.54 kWh/m2 per day. The optimum orientation of the panel for the fixed mounted type of solar tracker system was noted with an inclination of 13 ° and an azimuth of 45°. In the above-said condition, the unit cost of electricity was 0.34– 0.61 USD/kWh while the price of electricity from the national grid (PLN) in Surabaya is 0.08 USD/kWh at that time. The simulation results showed that it was not economically feasible to use a solar PV system for domestic electrification or household electrification in Surabaya. **Chokmaviroj, Wattanapongb, and Suchart [37]** checked the efficiency of the 500 kW grid-connected PV systems. In his study, various parameters (i.e. temperature, energy drop, environment, and inverter efficiency) are taken into account for evaluating the performance of the plant. The solar system consists of 1680 modules (in which 140 strings, 12 modules/string; 300 W/module), power conditioning units, and battery converter system. The efficiency of the PV array system was 9 to 12% and the power conditioning unit was 92 to 98%. Approximately, 1695.9 kWh of electricity generation was done per day, and the PR within the range of 0.7 to 0.9.

Cucumo, Rosa, Ferraro, Kaliakatsos, and Marinelli [38] 3 KW grid-connected PV systems were projected and built at the Building Energy Laboratory of the University of Calabria for checking average electricity generation. In his study, he validates the model with the use of experimental data and simulates it and determined the performance of the overall plant. The result shows that the PV plant had a maximum power of 2.7 kW and the average generation of electricity per day was 9.1 kWh.

Makrides et al. [39] summarized the potential of 13 different PV systems that were installed parallel at a single location in Cyprus. By compiling the data related to the efficiency of all types of PV systems throughout the year, it clearly shows that different types of PV system have a major impact on future energy. On a seasonal basis, PV systems with thin-film technologies had more stable efficiency than PV systems with crystalline silicon technology. **Drif et al. [40]** 200 KW grid-connected PV systems were projected and built at the Jae´n University buildings for checking average electricity generation. In his study, the PV system is bifurcated into four subsystem i.e. system 1 & 3 – 70 KW, system 2 – 20 KW, and system 4 – 40 KW. The result shows that the average electricity generation was 168.12 MWh which was 6.40% of the total consumption of Jae´n University.

Ueda et al. [41] explored the performance and loss computation for different system configurations on grid-connected domestic PV systems. The results of the study indicate that the south-facing arrays produce 11-22 percent excess electricity in comparison to other array configurations but differences in PR originated due to various causes, such as the module supplier and the DC-DC converter with specific string voltages.

Ubertini and Desideri [42] A 15 KW rooftop solar PV project built on a school Italy. The system consists of 220 modules i.e. 22 arrays that are connected to an inverter and then connected to an appliance. In his study, establish a simulation model and validate it with the measurement of electricity generation of a large PV roof. The result shows that the overall predicted energy production is 18.9 MWh/year against 18.2 MWh/year which was generated.

Ayompe, Duff, McCormack, and Conlon [43] considered a 1.72 kW grid-connected PV system installed on a flat roof of a 12 m high building in Dublin, Ireland (latitude 53.4N and longitude 6.3E). The result shows that the average generation of electricity per annum was 885.1 kWh, and also PR and capacity factors observed were 81.5% and 10.1% respectively. **Sharma & Chandel [44]** carried out the analysis on a 190 KW rooftop grid-connected PV system installed at Khatkar-Kalan, India. The result shows that the average generation of electricity per annum was 812.76 kWh while it was simulated to be 823 KWh by using PVsyst software. The estimated average generation of electricity is close to predicted value but it is less than the predicted value due to system losses like irradiance, temperature, module quality, array mismatch, ohmic wiring, and inverter. Furthermore, PR and capacity factors to be 74% and 9.27% respectively.

Kymakis, Kalykakis, and Papazoglou [45] took a 171.36 kW grid-connected photovoltaic park on the island of Crete. Performance ratio and the various power losses (like temperature, soiling, internal, network, power electronics, grid availability, and interconnection) of the park are calculated after the monitoring of one year of the park. The result shows that the average generation of electricity per annum was 1336.4 kWh whereas PR and capacity factor was 67.36% and 15.26% respectively. **Kumar and Sudhakar [46]** calculated the performance of the 1 MW grid-connected PV system at Ramgundam, India. In this study, considered the various power losses (like temperature, soiling, internal, network, power electronics, grid availability, and interconnection) while designing in PVsyst & PV-GIS software. The result shows that the average generation of electricity per annum was 15798.192 MWh whereas PR and CUF were 86.12% and 17.68% respectively. **Mitavachan et al. [47]** calculated the performance of the 3 MW grid-connected PV system (Yalesandra Power Plant) at Karnataka, India, running effectively for about 4085 h during the entire year. The result shows that the average generation of electricity per day was 6655 kWh, and plant efficiency was between 10% and 15% in favorable conditions i.e. clear sky, and no grid or inverter problems. The total electrical energy generated by this plant was 3.34 million KWh while by Belgaum power plant, having the same capacity**,** generated 3.90 million KWh in the same year. The tripping of inverters was found to be the main cause of lesser electricity generation in Yalesandra Power Plant. **Decker and Jahn [48]** carried out the performance analysis on 170 KW scale grid-connected PV in Germany. In his study, he considered the various power losses (like temperature, soiling, internal, network, power electronics, grid availability, and interconnection) while designing it. The result shows that the average PR of 47.5% – 81% (range) was observed. This measured PR is compared with standardized PR. So, we may identify the performance of the plant without a doubt with respect to the standardized PR.

Cardona and Lopez [49] used a 2.0 KWp grid-connected PV system installed at the University of Ma´laga, Spain. The power output of arrays was estimated by using measured I–V curves for the installed modules. In his study, he considered the threshold-inverter and coupling losses of the inverter to the grid, while designing it. On low irradiation, the inverter is not able to make the connection with the grid, which is called threshold-inverter loss. The result shows that the average performance ratio and the average electricity generation (per annum) were found to be 0.645 and 2648 kWh respectively. **Pavlovic et al. [50]** presented the quantum of electricity generation of PV solar plants using different types of solar systems i.e. fixed type, single & dual-axis solar systems. The annual electricity generation per annum based on the climate conditions by the fixed type were least of all and in range of 1050 MWh - 1260 MWh, while single-axis PV system generated 1330 MWh - 1650 MWh Maximum generation was found in case of two-axis system and range of 1360 MWh to 1680 MWh marginally higher than a maximum generation.

Besarati, Padilla, Goswami and Stefanakos [51] presented the scope of harnessing solar radiation generated by different types of solar PV plants in Iran. The survey results revealed that the southern and central areas of Iran had higher potential whereas cities near to the Caspian Sea had a low value of CUF due to a large number of cloudy and rainy days and also to the high level of relative humidity, in which the maximum CUF of 26.1% was noticed in Bushehr, while the lowest value of 16.5%was observed in Anzali. **Dolara et al. [52]** calculated the performance of 800 KW grid-connected single-axis solar tracker system in Italy. In this study, considered Accuracy of Monitoring System and Uncertainty Assessment for Performance Ratio and Transposition Factor, Irradiation, and Transposition Factor. The result shows that the annual PR of the plant is 81%. **Vieira, Guerra, Vale, and Araújo [53]** presented the comparative analysis of the performance of the 25W single-axis solar tracker system & fixed solar system in Brazil. This study considered various parameters like current and voltage, panel temperature, and solar radiation. The result shows that the power generation per day was around 163 Wh i.e increased by 11% as compared to the fixed system while motor consumption was not considered.

Othman, Manan, and Jumid [54] presented the comparative analysis of the performance of 150W dual-axis solar tracker system & fixed solar system in Malaysia. In this study, considered current, voltage, and power and observed it for two days. The result shows that dual-axis solar tracker system better than the fixed solar panel in terms of current, voltage, and power because the dual axis solar system captured more solar radiation than the fixed system. **Hussain, Islam, Hasan, and Fariha [55]** presented the comparative analysis of the Performance of Single and Dual Axis Sun Tracking System. In this study, considered solar irradiance and incident energy for fixed, single-axis & dual axis over the year. The result shows that dual-axis system generated 3.17 MWh while single axis generated 3.04 MWh and fixed solar system generated 2.25 MWh i.e Single-axis produced about 35.30.% more energy compared to the fixed axis and dual-axis tracker produced about 41.07% more energy than the fixed axis for the same plant.

Table 1: Comparative performance analysis of various PV systems

Authors	Location	PV Technology	Type of PV Plant	System Size	Grid Connection	Measured Parameter	Test Duration	Electricity generation	PR	Capacity factor
Goura[35]	India	mono-crystalline silicon	Fixed Axis	1 MW	Yes	Effect of temperature on PR values, Temperature effect on the PV cells and efficiency, Performance of the inverters, Environment, and other factors that affect the performance of the PV Park.	12 Months	-	0.8	-
Chokmaviroj et al. [37]	Thailand	ASE-300-DG-FT modules	Fixed Axis	500 kW	Yes	Analysis of the performance of PV array, Analysis of the performance of power conditioning units (PCU), Analysis of the performance of the entire PV system.	8 Months	1695.9 kWh per day	0.7 – 0.9	-
Cucumo et al. [38]	Italy	polycrystalline silicon	Fixed Axis	3 kW	Yes	cell temperature and solar radiation	2 Months	9.1 kWh per day	-	-
Drif et al. [40]	Spain	polycrystalline silicon	Fixed Axis	200 kW	Yes	global irradiation and the ambient temperature, yields & energy losses	12 Months	168.12 MWh per annum	-	-
Ayompe et al. [43]	Ireland	mono-crystalline silicon	Fixed Axis	1.72 kW	Yes	final yield, reference yield, array yield, system losses, array capture losses, cell temperature losses, PV module efficiency, system efficiency, inverter efficiency, performance ratio, and capacity factor.	11 Months	885.1 kWh per annum	0.8	10.1
Sharma & Chandel [44]	India	polycrystalline silicon	Fixed Axis	190 kW	Yes	The final yield, reference yield, performance ratio, and system losses due to irradiance, temperature, module quality, array mismatch, ohmic wiring, and inverter.	12 Months	812.76 kWh per annum	0.7	9.27
Kymakis et al. [45]	Greece	polycrystalline silicon	Fixed Axis	171.36 kW	Yes	performance ratio and the various power losses (temperature, soiling, internal, network, power electronics, grid availability, and interconnection)	12 Months	1336.4 kWh per annum	0.7	15.26
Kumar and Sudhakar [46]	India	-	Fixed Axis	1 MW	Yes	Average solar radiation, average temperature & various system losses internal network, power electronics, grid-connected, etc and performance ratio.	12 Months	15798.192 MWh per annum	0.9	17.68
Dolara et al [52]	Italy	polycrystalline silicon	Single Axis	800 KW	Yes	Accuracy of Monitoring System and Uncertainty Assessment for Performance Ratio and Transposition Factor, Irradiation, and Transposition Factor.	12 Months	-	0.8	-
Vieira et al [53]	Brazil	mono-crystalline silicon	Single Axis	25 W	No	Current and voltage, panel temperature, and solar radiation.	8 days	163 Wh per day	-	-
Othman et al [54]	Malaysia	mono-crystalline silicon	Dual Axis	150 W	No	current and voltage, and power	2 Days	1.24 W peak power in a day.	-	-
Hussain et al [55]	Bangladesh	-	Fixed Axis	-	-	Solar irradiance & Incident energy	12 Months	2.25 MWh per annum	-	-
			Single Axis	-	-	Solar irradiance & Incident energy	12 Months	3.04 MWh per annum	-	-
			Dual Axis	-	-	Solar irradiance & Incident energy	12 Months	3.17 MWh per annum	-	-

III. CONCLUSION

Solar energy has enormous potential as a source of renewable energy for meeting the strong and ever-growing energy demand in the world. In the last three decades, significant development has taken place in various solar energy systems for exploring their use as a source of renewable energy. Such systems have been successfully utilized for diverse domestic and industrial applications. This paper provides a state-of-the-art review of possible performance variables for the analysis of performance comparison of fixed and tracker type solar plants. The solar-powered electricity generation system is solar photovoltaics (PV) and concentrated solar power or a combination of two. It has been found that the parameters affecting the solar plants are land undulation, solar radiation, solar PV panel's temperature, degradation of solar cell efficiency, inverter efficiency, the shadow on solar PV panel, design of plant (ac and dc losses), conduction losses, grid failure, rust and dust, cleaning of a solar module on a regular interval, weather like wind, snow, etc. The different categories of solar PV systems are fixed and tracking type of systems. In comparison to the classical fixed-position predecessors, solar systems that track the sun's trajectory over the course of the day capture much more solar energy and thus produce substantially higher output power. Further**,** dual-axis solar systems are observed to be more efficient in comparison to single-axis solar systems as they are capable of consuming more radiation during the day. Nonetheless, due to their higher cost, a single axis tracker system is usually favored. The choice of a fixed or tracker system- single or dual-axis depends on the variety of variables, including cost and size of the projects. A variety of commercially available modeling and simulation tools, such as PV-Syst & PV-GIS, are used for performance comparison of fixed, single and double -axis tracking systems for assisting the users in selecting the optimal type of system under a given condition. However, there is scope for developing computer based applications for designing of Photovoltaic solar plants using scientific application software like LabView and MATLAB.

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