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RESEARCH ARTICLE

EXPERIMENTAL MONITORING AND COMPARISON OF ENERGY PRODUCTION ON SOLAR TRACKING SYSTEMS AND FIXED SUPPORT

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Abstract

The major objectives of researchers and industrialists in the solar field are to improve the efficiency and reduce the costs of cells, modules, and photovoltaic systems in order to make them as competitive as possible. There are two ways to maximize the useful energy rate by optimizing the conversion and degree of absorption, and by increasing the incident radiation rate by using mechanical steering systems. These systems, also known as solar trackers, allow the modules to be oriented throughout the day.The solar tracker, also called solar tracker, is a motorized arm that allows photovoltaic panels to follow the sun. Throughout the day, the arm rotates to capture as much sunlight as possible.For this work, we compared the production of panels mounted on fixed supports and trackers.The measurements were obtained on a year to make it possible to estimate the energy gain due to the orientation which is around 25%, thus confirming the economic importance of this systemProduction on tracker supports ramps up in the morning while production on fixed support gradually increases to its maximum at solar noon. The difference measured greatly exceeds at the beginning and end of the day; the average is 44.5% for this sunny day. The greater the sunshine in the place considered, the greater the difference in favor of the tracker. On an annual average, the optimum gain of a 1-axis solar tracker varies by approximately 25% and 40% for 2-axis trackers compared to a fixed photovoltaic plant.

Introduction:-

Solar energy has the potential to largely cover our energy needs, provided it can be converted efficiently and at low cost. This is what is at stake in the current development of solar energy. The voluntarist approach of the first years has since given way to a more rigorous approach introducing new concepts, new clean technologies favorable to the protection of the environment [1].In the photovoltaic sector, the design, optimization and implementation of PV systems are current issues for a better exploitation of solar energy.

A solar panel captures the sun's radiation to convert it into electricity. The energy produced is then intended to meet, totally or partially, energy needs.

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The control strategy of a tracker is basically to generate the trajectory of the tracker in order to perfectly pursue the sun in order to maximize the production. Inindeed, the control of the actuators of the trackers is generally considered to be mastered and is therefore not addressed. This control strategy may have other objectives and other constraints such as minimizing the energy consumed, adapting to variations in meteorological conditions.

When a photovoltaic panel is fixed in relation to the ground and oriented towards the south (installation in the northern hemisphere), its energy yield is not constant during the day: at the start and end of the day, the wrong angle of illumination of the panel reduces the efficiency of electrical production. The orientation system is based on programming the movement of the solar panel atpredefined time intervals according to the path of the sun, so as to keep the active surface of the photovoltaic module perpendicular to the radiationsolar. It is one of the many photovoltaic systems that can be used for self-consumption. The purpose of this tracker is very simple: it improves the performance of your photovoltaic installation. This depends on the orientation and inclination of the panels.

By using a solar tracker, these two elements are optimized throughout the day.

An experimental comparison between a fixed panel and a single-axis tracking system is presented.

Solar tracking system classification: 1-axis and 2-axis tracker: literary review

There are two systems: 1-axis trackers and 2-axis trackers. The first follows the course of the sun (the azimuth) from east to west. It optimizes the orientation of the panels throughout the day. The second also takes into account the incidence of the sun's rays by modifying the height of the panels. It optimizes both orientation and inclination. They are therefore more efficient.

The programming of solar trackers takes into account the time of day, the season, as well as the latitude at which the installation is located on Earth.

The use of a solar tracker allows:-

To obtain a better yield on a photovoltaic installation. With a 1-axis solar tracker, the efficiency is 25% to 30% higher than with a classic south-facing installation. For 2-axis trackers, the efficiency is 40% higher.

Mono axial trackers:-

A single axis tracking system has one degree of freedom that acts as the axis of rotation. [2]. The single axis tracking system is the simplest tracker, they generally use less power and have complexities than a multi-axis system [3]. The plane of this type of tracker is inclined at a location latitude angle directed due south and the tracking angle equal to the hour angle [4].

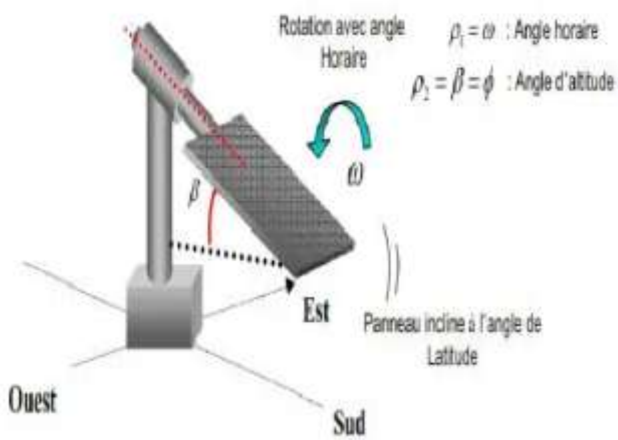


Figure 1:- Mono axial trackers.

Khalid et al. [5] have built an automatic single-axis solar tracking system and demonstrated a new method that will automatically track the position of the sun and accordingly change the direction of the solar panel to obtain the maximum output from the solar cell using LM339N IC, Sensor (LDR) and DC gear motor.

Nowshad A et al. [6] develop a low-cost, single-axis automated sunlight tracker design for higher PV power yield. Accordingly, for LDRs which are separated by a short distance, the solar panel can be rotated through the three difference angles such as 55° (left LDR), 52° (middle of the panel) and 47° (right LDR) for the solar panel to trace the light source but the panel is unable to accurately face towards the light source. The acquisition of minimum cost of components for the design of the tracker structure is achieved by using programming codes instead of mechanical switches for the mechanical safety control of the tracker. The unique design and positioning of only two LDR sensors realizes the single axis sunlight tracker for photovoltaic applications. This tracker is made in the price range of about 1/50 (one fiftieth) of its kind as a remarkable achievement.

Guiha Li, Runsheng Tang, HaoZhong [7] studied single-axis horizontal tracked solar panels. They achieved results because tracking the east-west axis was poor at improving energy while tracking the sun to the south-north was the best. The increased efficiency for the east-west axis was less than 8%, while for the south-north axis it increased by 10-24%.

Chaiko and Rizk [8] have developed a tracking system that effectively uses solar panels. They designed a simple single-axis tracking system using a stepper motor and a light sensor. They observed that this system extends the efficiency of energy harvesting by holding a solar panel perpendicular to the sun's rays. And they also found that the power gain was increased by 30% compared to the static photovoltaic system.

In 2011, Ponniran et al., [9] develop an automatic solar tracking system that will keep solar panels aligned with the sun to maximize solar energy harvest. The system tracks the maximum light intensity. When the intensity of the light decreases, this system automatically changes direction toobtain maximum light intensity. The LDR light detector is used to plot the coordinates of the sun. While to rotate the appropriate position of the panel, a DC gear motor was used. The system was controlled by two relays as the driver and a microcontroller as the main processor. Figure 4 shows the design of a single-axis sun tracking solar system.

In 2012, Deb et al. proposed a solar tracking system with two sensors to measure the temperature in the east and west. Using the LABVIEW, the authors calculate the light intensity with the collected temperature data. The direction of movement of the solar tracking system through a stepper motor directly has been determined when there is a difference between one direction of light intensity in the other direction [10]. Kamala et al. designed a single-axis solar tracker driven by a PIC microcontroller to maximize energy harvest. The two PV panels are arranged in the shape of a triangle facing each other. Two threshold levels are implemented to drive the movement of the PV array. The first threshold is designed to enable tracking and indicate the availability of solar power. Meanwhile, the second threshold is used to turn off devices during cloudy or rainy weather conditions for a long time. The authors designed the economic system but faced the problem when the system stops working after sunset. This is because the PV panel needs to be repositioned to the east side for the next monitoring day [11].

Biaxial trackers:-

They have two degrees of freedom thanks to which the axis perpendicular to the photovoltaic panels is aligned perfectly and in real time with the rays of the sun, to the detriment on the other hand of a greater complexity of construction [4]

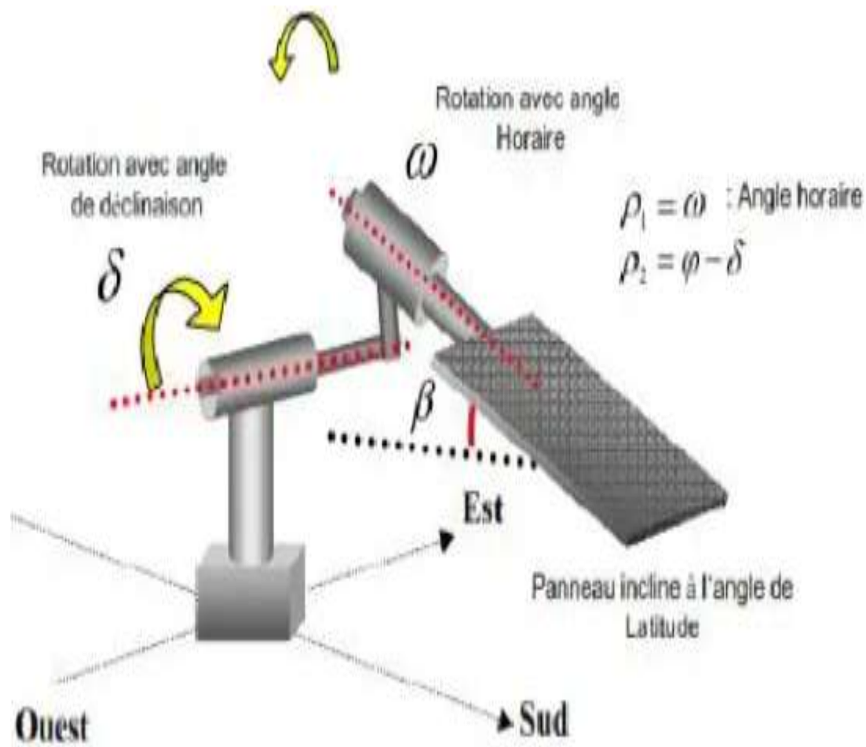


Figure 2:- Biaxial trackers:

In 1992, Agarwal [12] presented a two-axis tracking system consisting of worm drives and four bar-type kinematic linkages to facilitate precise focusing of reflectors in a solar concentrator system.

Park and Kang [13] designed and implemented a two-axis sun tracking system for the Korean-built parabolic concentrator. The sun tracking mechanism is composed of a 1/30000 (3-stage) gear reducer and a 400W AC servo motor for each axis. The nominal tracking speed of each axis is ±0.6o/sec and the system has driving ranges of 340o and 135o in the azimuth and elevation tracking axis respectively. Sun tracking control system consists of sun tracking sensor, environmental and working condition measuring system, AC servo motor control system and PC as controller major.

The sun tracking sensor detects the sun within ±50° measured from the normal direction of the sun tracking sensor. The PC calculates the position of the sun, sunrise and sunset times. It also decides whether the system should track the sun or not based on information gathered from the sun tracking sensor, environmental and working condition measurement system.

In 2004, Abdallah and Nijmeh [14] developed a two-axis electromechanical tracking system in which the movement of the sun-tracking surface was controlled by an open-loop control algorithm implemented using a PLC unit. The proposed system had two separate tracking motors, namely one motor to rotate the sun tracking surface around the horizontal north-south axis, i.e. to adjust the slope of the surface and the another to rotate the sun tracking surface around the vertical axis, i.e. to adjust the azimuth angle of the surface. Experimental results indicated that the dual-axis tracking system increased total daily energy collection by approximately 41.34% over that obtained from

V Sundara Siva Kumar and S Suryanarayana [15] proposed a dual axis tracking system to implement and develop a simple and efficient control scheme with a single tracking engine. Their main purpose is to improve power gain through precise tracking of the sun. In this article, they have successfully designed, built and tested a dual-axis sun tracking system and achieved the best result. They concluded by saying that this tracking technology is very simple in design, accurate in tracking and low expense.

In 2010, M.Serhan and L. El-Chaar [16] designed a two-axis sun tracking system. The system autonomously tracks the sun in altitude and azimuth. Two AC motors move and an 80 watt panel is mounted on the mechanical structure. It requires no human interface where four connected sensors continuously update a PIC microcontroller which in turn controls the rotations of the motors. The horizontal axis rotates the panel from east to west and the vertical axis from south to north, so the system has two degrees of freedom. The hinges facilitate the revolution of the axes. The frame is designed to hold the desired solar panel and the base supports the entire rigid body.

Shrishti [17] developed a dual axis automatic solar tracking system is a design and implementation of a single axis polar solar panel tracker. It has a fixed vertical axis and an adjustable horizontal motorized axis. This configuration is similar to an office swivel chair. The tracker actively tracks the sun and changes its position accordingly to maximize power output. To avoid wasting energy by running the motor continuously, the tracker corrects its position after 2-3 degrees of misalignment. The sensors compare the light intensities on each side and move the panels until the tracker detects equal light on both sides. In addition, it prevents rapid changes in direction that could be caused by reflections, like passing cars. A rear sensor circuit is also incorporated to help reposition the solar panels for the next sunrise. The gearmotor has reversing triggers to prevent the panel from rotating 360° and tangling the wires. The motor control and sensing circuit runs on batteries charged by the solar panel. This system uses three small 10W solar panels approximately 15 inches by 10 inches to model larger panels used in industries. The motor control and sensing circuit runs on batteries charged by the solar panel. This system uses three small 10W solar panels approximately 15 inches by 10 inches to model larger panels used in industries. The motor control and sensing circuit runs on batteries charged by the solar panel. This system uses three small 10W solar panels approximately 15 inches by 10 inches to model larger panels used in industries.

In 2017, ChaitaliMedhane, TejasGaidhani [18] implemented a two-axis model based on a microcontroller activated on a solar panel. Using this model, they observed that the solar panel extracts maximum power if the solar panel is aligned with the intensity of light received from the sun. It improves the power output and also the necessary precaution of the system against rain and wind.

MidriemMirdanies, Roni PermanaSaputra [19] proposed a two-axis system with a combined method of an astronomical algorithm and camera-based processing to locate and track light intensity to increase efficiency in the production of electrical energy. They also devised a compound algorithm method to merge sun approximation data acquired from astronomical and visual emissions. After simulation, it resulted that the squared errors of the sum of azimuth and elevation of the proposed algorithm are 0.3688 and0.3874 degrees, and the astronomical algorithm is 1.0997 and 1,2877 degrees.

Ozturk et al. [20] present an experimental comparison of the performance of a 2-axis tracking system with a fixed panel in a renewable solar energy system was carried out in Duzce, Turkey. The comparison provides quantitative analysis to calculate the time to payback if a tracking module is used instead of a fixed module. It was found that under the same conditions, the tracking module harvests 35% more solar energy than the stationary module, and the tracking system pays for itself in 16 years.

Presentation of the Measurement site:-

The Malicounda solar park has an installed capacity of 22 MWp, i.e. 86,400 monocrystalline photovoltaic solar panels with a unit power of 255 and 260 Wp on fixed supports.

Figure 3:- Malicounda solar power plant (fixed panel support).

For this work, we tracked 144 solar panels mounted on fixed supports and 144 on trackers.The orientation system is based on programming the movement of the solar panel at predefined time intervals according to the trajectory of the sun, so as to keep the active surface of the photovoltaic module perpendicular to the solar radiation.

An experimental comparison between a fixed panel and a single-axis tracking system is presented.

Figure 4:- Experimental trackers in the Malicounda solar park.

The monitoring was done using the monitoring software of the Malicounda plant: Esolar.

Presentation of the Esolar interface: monitoring system for photovoltaic installations
ESolar is a local or remote maintenance monitoring and management system for photovoltaic systems. ESolar integrates a home automation engine, using the KNX communication protocol, the only open global standard for home and building automation in accordance with CEI EN 50090 and ISO/IEC 1454 standards.

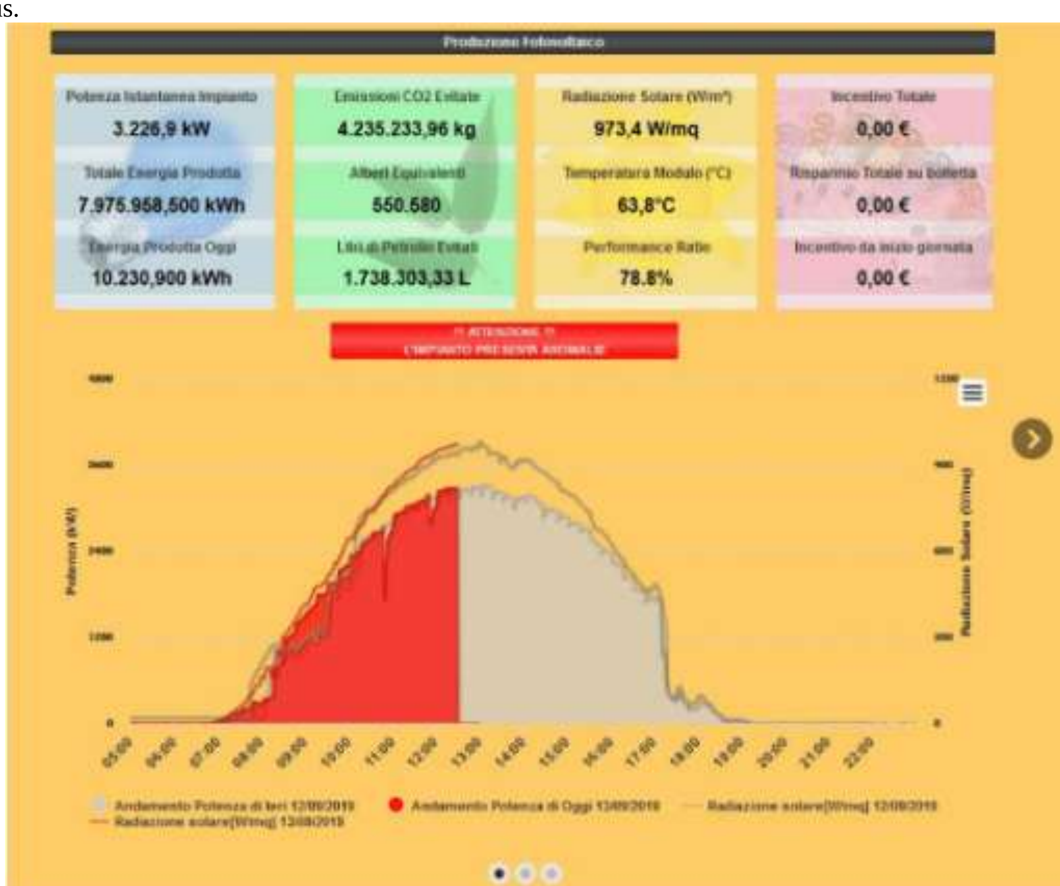
ESolar is able to communicate with most photovoltaic inverters, energy meters, string controllers on the market via RS232 / RS485 and

Figure 5:- Esolar.

Interfaces ETHERNET and pulse output, and it is able to get measurement quantities.

It can also manage groups of inverters to allow detailed examination of each part of the plant, if different photovoltaic technologies have been used.

ESolar collects, stores and allows viewing of log file graphs or graphs every 15 minutes, daily, monthly and annually for 10 years. Esolar is able to obtain quantities from different types of sensors and make actuations via the KNX bus.



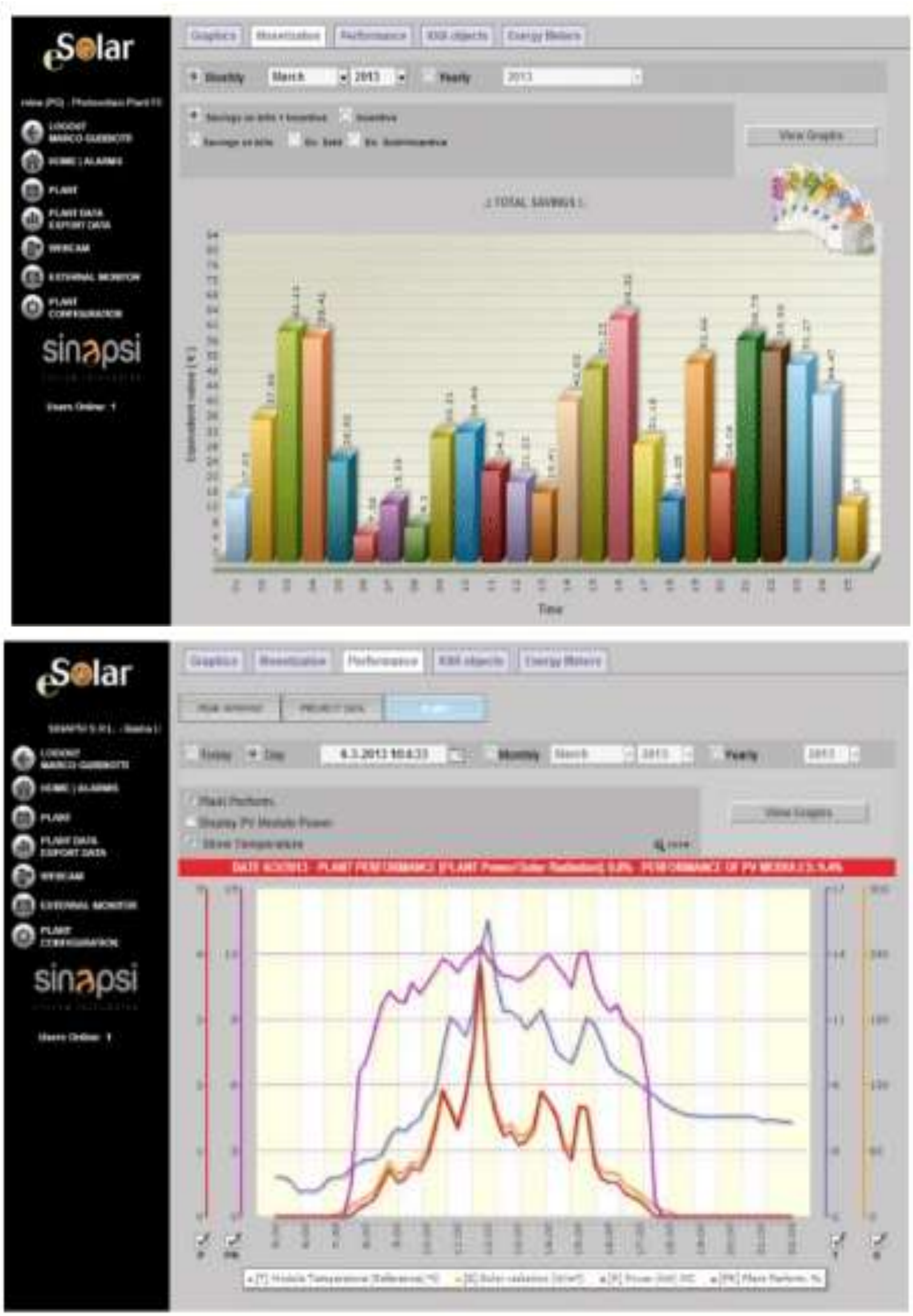


Figure 6:-Esolar interface.

Results And Discussions:-

In the diagram below, the Production comparison between trackers and fixed supports:

Sunny day analysis

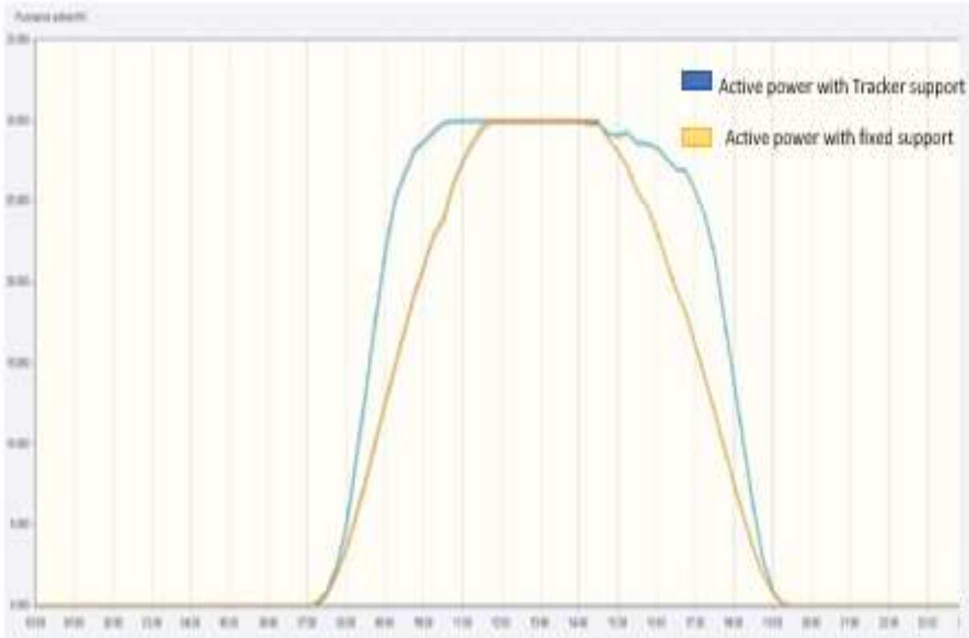


Figure 7:- Comparison of Tracker bracket and fixed bracket on a bright sunny day.

The measurements were obtained on a year to make it possible to estimate the energy gain due to the orientation which is around 25%, thus confirming the economic importance of this system

The blue curve of the tracker increases in power in the morning while the yellow curve of the fixed support gradually increases to its maximum at solar noon. The difference measured greatly exceeds at the beginning and end of the day; the average is 44.5% for this sunny day.

Analysis of a moderately sunny day

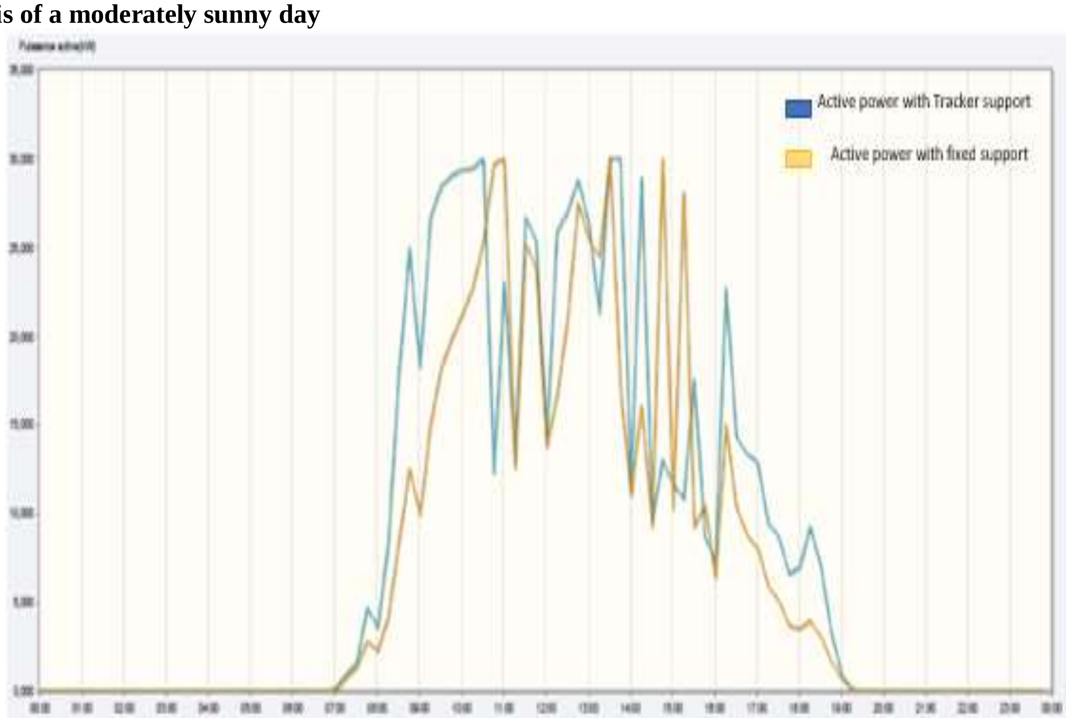


Figure 8:-Comparison of Tracker support and fixed support during a less sunny day.

Direct radiation becomes largely a minority under a cloudy sky; on this day the veil dissipated at the end of the afternoon; the gain for the day is still 22.2%.

The greater the sunshine in the place considered, the greater the difference in favor of the tracker. On an annual average, the optimum gain of a tracker varies by approximately 25% from a fixed photovoltaic plant facing due south and inclined at 30° identically to the tracker.

Conclusion:-

The energy gain of trackers on a single axis obtained over one year compared to the fixed support is around 25%, confirming the economic importance of this system. Solar photovoltaic systems are simple to develop, but they produce less power and less energy without tracking mechanisms. In this article, we reviewed the active tracking system either on one (single) axis or on two (dual) axes. For the work carried out, the existing system on Malicounda is a mono-axial tracker. The result revealed that the tracking solar system is more efficient compared to this fixed solar system. Besides, the dual-axis tracking system is also more efficient than the single-axis tracking system. Concretely, the 2-axis solar tracker makes it possible to produce almost 40% more solar energy compared to a fixed solar installation. The 2-axis motor follows the path of the sun and adjusts the inclination of the panel perpendicular to the radiation for optimal capture.

Another considerable advantage is that of the natural ventilation of the solar panels by a stronger wind resistance which acts as a natural cooling system. This has the effect that the wear is slowed down and the service life is extended.

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