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Design and Compare the Performance of Different Sun Tracker Systems to Produce Maximum Power

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ABSTRACT

In this paper first is expressed the structure and mechanism of the one axis and two axis sun tracker systems. One axis sun tracker systems operates only at 3 different angles (morning, noon and afternoon) and two axis sun tracking systems continuously follow the position of the sun. Two axis sun tracker systems under cloudy conditions, when the sun is not visible, out the dynamic search mode and automatically and routinely follow the sun. After the introduction of these systems based on the done tests, Is compared the performance, efficiency and cost this systems and Is expressed that the present one axis and three position sun tracker PV can perform very close to a dual-axis systems that continuously follow the sun.
KEYWORDS: Axes of motion, Solar Power Generation, Stand-alone solar PV system, sun tracking , The angular position.

1.INTRODUCTION

Due to the high value of solar power and endless this source should provide new ways to increase its efficiency, Increase the efficiency of solar cells can be produced significant amounts of energy **.** If can adjust the angle of the panel's so that angle of the sun is perpendicular , Efficiency is increased.

In this paper, first is expressed the mechanism of the one axis and Three different angular position sun tracking system. This tracker is designed based on Huang's research [2] , These results indicate that Appropriate angle of the panel in morning and afternoon is 50° from the solar noon position. solar cell equipped with a This type of detector can be Increase the amount of electricity generated 35.6% in sunny days and 35.8% in cloudy days.

After investigate the one axis sun tracker, two axis sun tracker systems Has been studied. This type of detector by using a particular type of photo-diode sensors and Calculate the output current of the sensor,can Calculate The angular position of the sun and by using the processor Command to Two small DC motor for change the angle. In this tracker pyrheliometer is used for recognition climate condition. The system operates in a closed loop mode.

Then will be discussed the results of tests done with this detector in Stand-alone same solar PV system. The tests have been carried out by different people and we Citing the Long-term results of tests performed, We express that one axis trackers In addition to lower cost and Easier Construction Design, Efficiencies is very close to two axis tracker.

2. Design of one axis sun tracker system

This tracker system has three different angular position (morning, noon, afternoon) as shown in Fig.1. Analytical results of the Huang researches [2] shows that Appropriate angle in morning and afternoon is $\beta=\mathbf{50}^{\circ}$ from the solar position in noon. The best time to change the pv module position is when the sun angle is half of the stoping angle, i.e. $\mathbf{25}^{\circ}$ **.** These angles are independent of latitude . This analysis also shows that Solar energy absorbed increase 24.5% compared to fixed photovoltaic modules that Latitudes less than 50°.

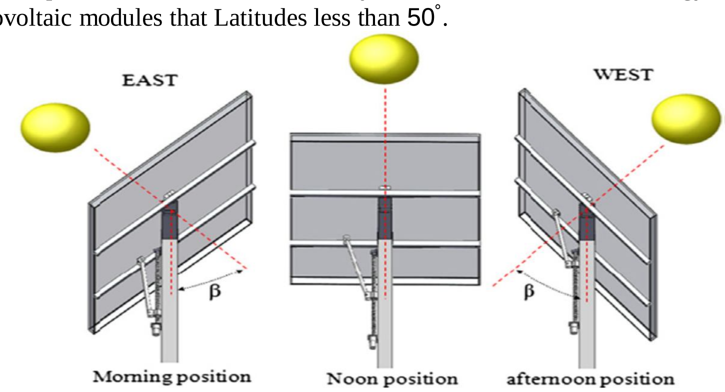

Fig.1. one axis three position sun tracker

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structure of this tracker consists of a three major components: solar cell frame, supporting frame and shifting mechanism as shown in Fig.2.

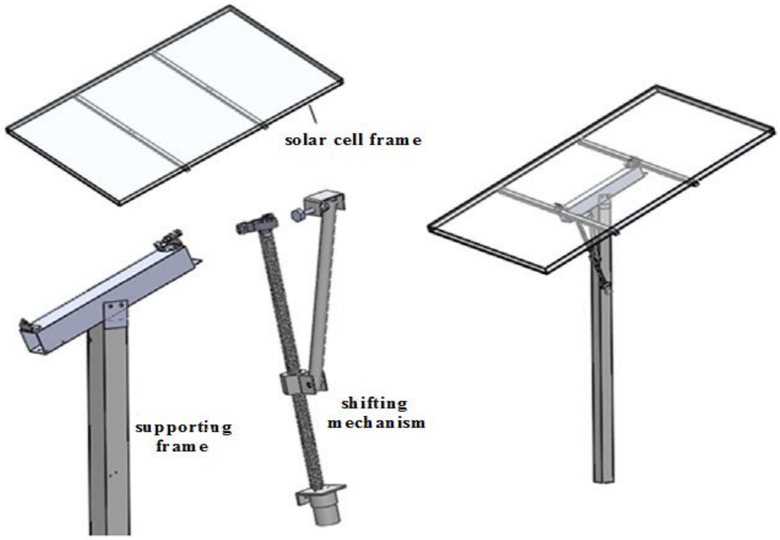

Fig.2. The simple design of a one axis tracker

Control algorithm and Measurement functions for moving pv module, Execute by the processor that can be AVR microcontroller. By using the timer on the determined time Command to DC motor for rotation. the consumable energy has very low for start this engines.

This tracker has a low cost due to its simple structure and is suitable for mass production. This tracker With limited control only for three position which will greatly reduce the tracking malfunctions due to disturbance or noises of environment. According to the Fig.3 easily be installed on walls of buildings and Takes up a little space but for Installing Fixed modules on the roof surface of buildings Need to waterproof and insulate the cause of wind, hurricanes and earthquakes that the cost is very hiegh but whit this structure can be easily installed . also according to done tests in Taipei area can Increase Production of electricity to 23.6% [1]. This increase can be more in the areas with abundant solar resources.

Fig.3. installing tracker system on buildings

3.design of two axis sun tracker system

This system moves on two axis North-South and East-West. as shown in Fig.4 by using a sensor is determined the position of sun.

Fig.4. A typical of the sensor is used

This sensor consists of a four-quadrant photodiode . Fig.5 shows four main zones north-east (NE), north-west (NW),south-west (SW) and south-east (SE). Through an aperture a beam of light illuminates a part of the four zones

(Fig.5). If the sun's position Changes the beam illuminates different positions of each quadrant and consequently produces different currents in the diode. The maximum amount of this currents is when the beam illuminates center of sensor. From output current is determined position of sun .

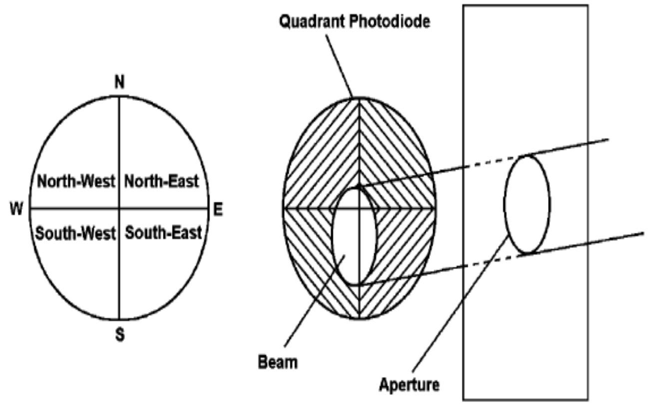

Fig.5. Sensor performance

Tracker system after finds the sun's location, will work In a closed loop. transfer function obtains from The block diagram as shown in Fig.6 [9].

where φ_s is the angle of the sun and φ_m is the angls of the rotation and subscript h is for axis HH (east–west motion) and subscript e is for axis EE(North-South motion).

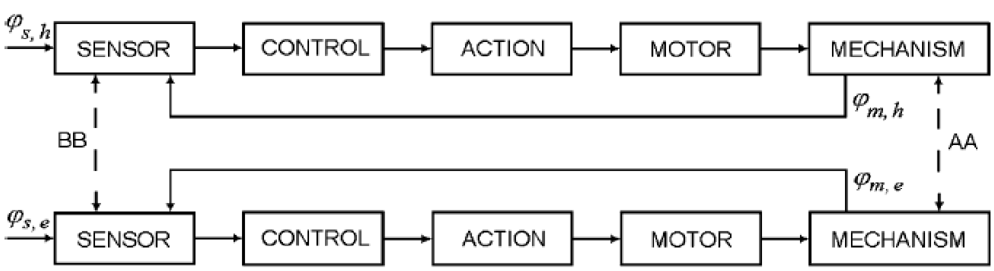

Fig.6. Block diagram of the closed-loop performance two-axis tracker

The control unit is an AVR processor that Checks data's receive from sensor and With command to two dc motor, adjusts moudule direction so that the sun is placed in the center of the sensor. Also a pyrheliomete continuously Measures Vertical radiation that falls on the cell surface. measured radiation is given to a Comparison While The amount of radiation was less than 140 $\frac{w}{m^2}$ (The minimum amount of radiation in sunny conditions) Systems exits the dynamic search mode and automatically follow the sun in this situation EE axis as a pendulum moves between 20° and 100° and HH axis must be moved at about 15°/h (HH axis moves 180° in 12 hour on sunny day) and this axis takes pulses from a Pulse generator or micro processor processor . As soon as the sun appeared The system returns to previous state and Will track the sun's position. Table 1 shows the Actions taken by the tracker.

Table 1. Action of the tracker

Action	Loop	Operation
Return	open	When HH axis reaches the west the mechanism returns to the east.
Dynamic search mode	close	When the sun is visible follows position of the sun.
Automatic mode	open	In cloudy conditions HH Axis moves with constant velocity and EE axis moves like a pendulum until the sun is visible.

According to the done tests by Neville [10] Solar energy absorbed by this system in the middle latitudes Can increase about 41% more than the fixed PV whit appropriate tilt angle. this tracker and Similar trackers that continuously follow the sun are faced with more error than the one axis tracker due to Sensor's error, Malfunctions in signal processing (due to disturbance or noises of environment) , etc.

4. Design of a stand-alone solar PV system for comparative test

Independent Photovoltaic systems (SLED) that are used for comparative tests consist of a photovoltaic module (PV) , a lead-acid battery to store the generated electrical energy at day time and a load (LED that discharge battery). Fig.7 shows a diagram of this SLED system[3] .

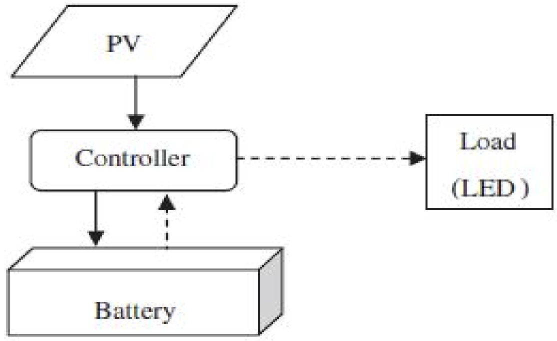

Fig.7. stand-alone solar PV system(SLED)

Pv module Generally for set at a maximum output power can be connected to a MPPT (maximum-power-point-tracking). MPPT calculates Maximum power that available to the module in the specific conditions, In fact finds The maximum power point of the modules for charging the battery and whit converting the output voltage to this point gives to the battery Maximum current. also can make The same conditions for DC consumers that is connected directly to the battery. The voltage which the module can produce maximum power is called maximum power point. maximum power is changed by fluctuation of solar radiation, environment temperature and Solar cell temperature.
In comparative tests conducted by Huang [4] for improve SLED's performance and Increasing Battery life by using pwm Modulation, is reduced Charge current and LED directly Is connected to battery with pwm technique.

4.1.tests results

In this comparative tests Increase the amount of energy generated by the tracker is calculated according to Equation.1.

$$E_{inc} = \frac{\text{power generation of pv equipped with tracker} - \text{power generation of fixed pv}}{\text{power generation of fixed PV}} \quad (1)$$

According to conducted tests by Huang [5] in Taipei area as shown in Fig.8 Amount of electricity produced by a one axis and the three positions tracker is 34.6% more than fixed PV modules also in this area daily Solar radiation on the surface of the module is about HT = 19.9 MJ/m^{2}day.
As is evident, power generated by the pv moudule equipped whit tracker is much higher than the fixed PV during the morning and afternoon. These two systems almost Follow a similar trend in noon.

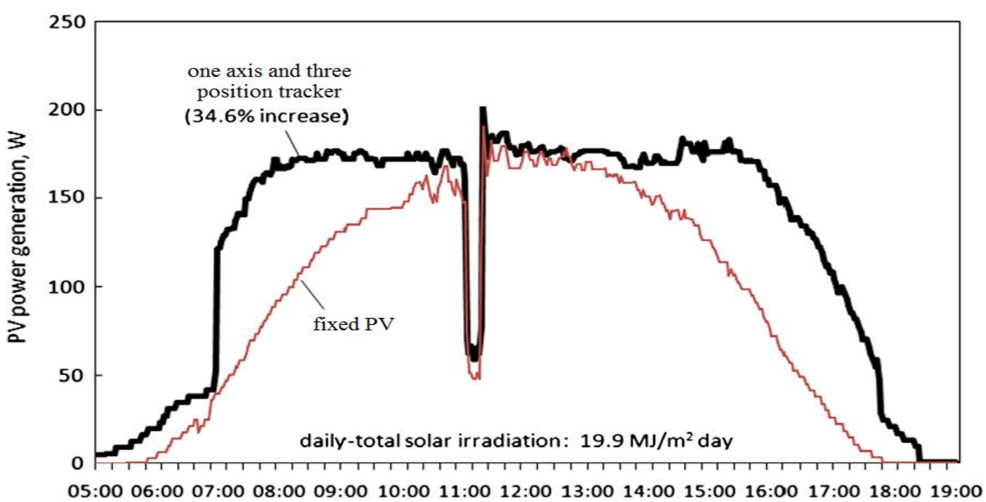

Fig..8 power generation of one axis and three position tracker and fixed PV

Also similar test result on 25 September 2010 suggests the increase of daily power generation is 35.6% whit daily Solar radiation HT = 18.5 MJ/m^{2}day (sunny day). Also on 5 march 2010 whit daily Solar radiation HT = 11.7MJ/m^{2}day (partly Weather cloudy) Increase the amount of power generated by one axis tracker is 35.8% .

For To evaluate long-term performance of one axis and three position tracker systems And the impact of climate change this systems have been examined From 2010 to 2011. However, some information is lost due to malfunctions recorder. The results of this test shows that The most increase in power generation of the tracker has been on 5 March

2010 that The weather is partly cloudy and This increase could be due to the reflection of light from the sky, the clouds and the ground.

Fig.9 and Fig.10 shows daily performance of PV systems Equipped whit one axis tracker and fixed PV in March and September 2010 that respectively represents spring and summer seasons.

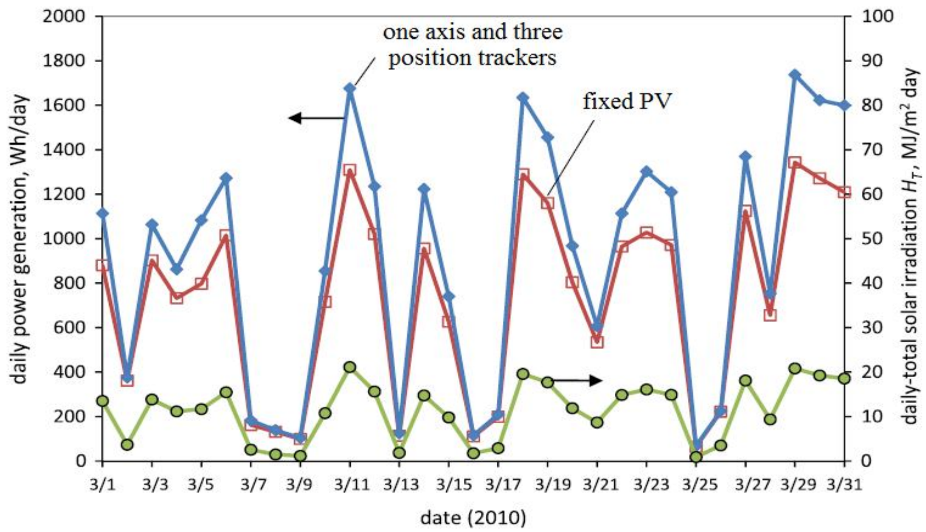

Fig.9. Compare power generation on March

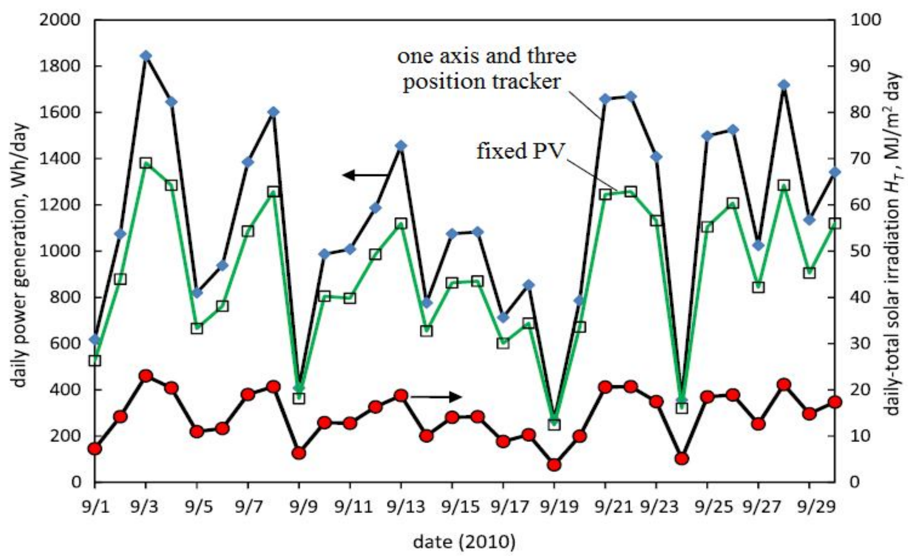

Fig.10. Compare power generation on September

Monthly test results show that increase of monthly power generation is between 18.5% to 28%. The average increase is 23.6% that operates Very close to two axis trackers that (24.5٪) Experiments by Huang and Sun [2].

According to the same tests for two axis tracker Experiments by Kacira in Turkey [6] Is expressed that the gross gain was 29.3% in solar radiation and 34.6% in power generation that operates as shown in Fig.8. So one axis tracker operates is very close to two axis tracker .

Chang [1] carried out a theoretical calculation of yearly gains for a one axis continuous tracking PV in central Taiwan and found that yearly gain is 28.5% that operates Very close to on axis and three position trackers Because in central Taiwan solar radiation is 20% more than taipei.So the single-axis tracker with three angular position operates very close to one axis tracker that continuously follows the sun.

The above results indicate that if one axis and three positions trackers use in areas with abundant solar energy resource that amount of average daily solar radiation is larger than 17MJ/m^{2}day and as regards The average amount of annual solar radiation in the Taipei area is 11MJ/m^{2}day is expected that increase of power production reache to 37.5% ($23.6 \times \frac{17}{10.7}$). This is very close to the dual-axis continuous tracking PV [6] .

Also, according to recent research done by Koussa [8] experimentally has been shown that Two-axis tracking system produces energy little more than single-axis tracker. amount of Mentioned energy towards the construction costs, maintenance costs and Using more elements is negligible.

According to tests conducted by Gibson [7] In cloudy weather Increased energy reaches 50% compared with a two-axis tracker in the same day.

4.2. Survey system performance reliability

Solar cells must have lifespan more than 20 years therefore the reliability of the sun tracking is very important . The reliability problems may arise from the error of timer, malfunction system, impairment in Sensors Identification,controller failure due to disturbances or noises etc.

All one axis and two axis trackers that continuously follow the sun, Have complex structures, expensive and low reliability and Efficiency may be reduced in long-term.

Fig.11 shows that the test has been conducted for 11 months whit solar cell equipped with one axis and three angular position trackers [8] . Error is about 0.6 seconds per day, which equals 30 minutes in every 10 years that this error is acceptable.

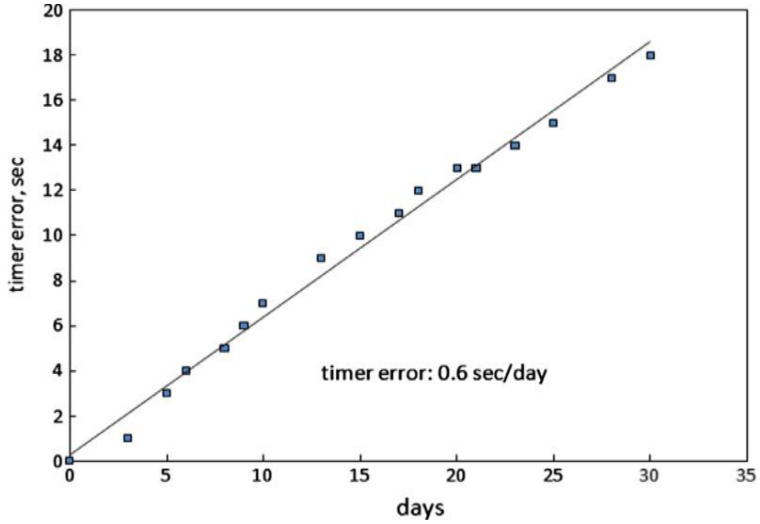

Fig.11. Tracking error in 11 months

In another experiment, one axis and tree positions trackers Have been investigated for 13 months from 1 March to 1 May. as shown in Fig.13 In this period trackers movement Was faultless. However, in September 2010 has been faced a tornado with a maximum wind speed 50 meters per second. But there is no failure in the movements.

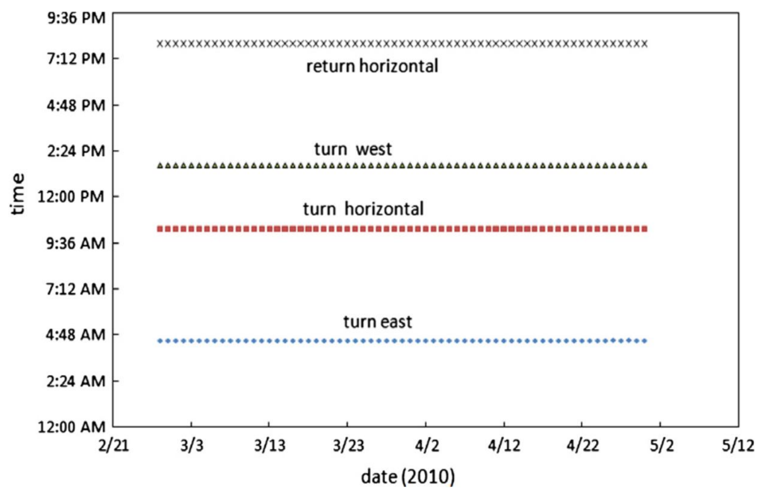

Fig.12. Survey tracker Motions within 13 months

In this experiment, Performance of LED as load is flawless and as shown in Fig.13 LED turns off earlier in midnight from 1 March to 10 March due to poor daily solar radiation.

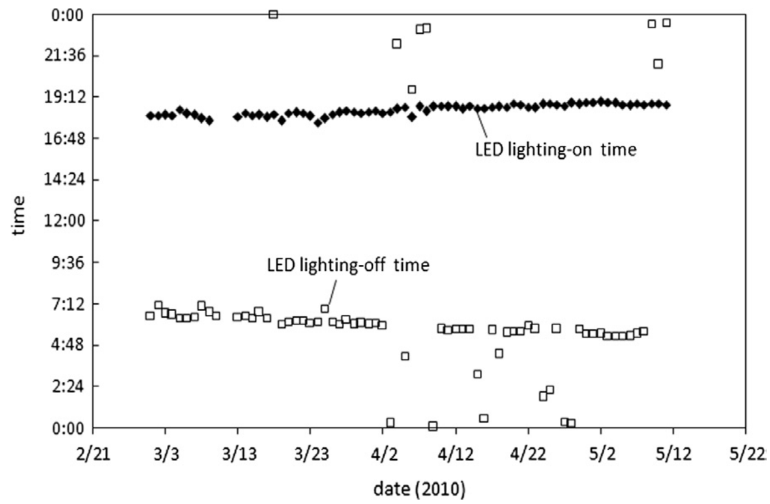

Fig.13. Lighting test of LED (100W) with one axis and three position sun tracking.

Another advantage of using this type of tracker has been shown by Huang [2] and it is stopping angle in the morning and afternoon . that independent of the installation location and theoretically is $\mathbf{50}^{\circ}$. which is relatively steep and can easily swipe off the dust covered on the PV module.

3. Conclusion

Since the theoretical predictions of increased electricity generated by the tracker may be faced with an error due to Unpredictable factors such as Reflecting barriers, speed and direction of wind, dust, falling shadows on the structure, moisture and etc. So it is better we can use the trackers which have less errors. Just as is determined from the results of conducted experiments The tracker that follows the sun continuously have Less reliability. So Single-axis tracker with three different angular positions in the morning, the afternoon and noon operates Very close to two-axis tracker and have acceptable reliability. should be noted that the higher efficiency of the two-axis tracker that continuously follows the sun towards the more cost of constructing and more complex Structures is negligible.

The single axis tracker has a simple design and can be easily mounted so it is suitable for building applications.

If use this one axis and three positions trackers in the areas with abundant solar resources Where the daily radiation is more than 17MJ/m^2day , is expected that long-term increase of the electricity productions can reach to 37.5% and this is very close to two axis tracker efficiencies.

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