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Research Article

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Design and Construction of a Tracking Device for Solar Electrical Systems

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Abstract Renewable energies such as solar or wind power have been used as a permanent source of energy over the past two or three decades, and are now widely used in many countries of the world as small units for domestic use or state-level units as energy farms. To improve the operation of these systems, solar tracking is used. A solar tracker is device that keeps a solar panel face toward the sun. Tracker devices are used to reduce the angle of incidence between the incoming sunlight direction and a solar panel surface. This thing acts to increases the capacity of energy which can produced from solar radiation on the same solar panels.

The generation ability of a solar power plant is largely dependent on the intensity of the sun radiation, so the changing of sun position during the day causes a variable shining intensity, therefore solar tacking systems can be consider as an essential part of solar power system. This paper presents the design and constructs a simple and economical single and double axis solar tracking system. The effect of single and dual axis solar tracker system are examined at Baghdad city in four selected days of four seasons at 2016. The influence of each case on solar energy systems were, the single axis tracker system tends to 35% improvement of power generated relative to fix panel, while double axis tracker system tends to 38% rise in output power.

Keywords solar tracking system, single axis tracker, double axis tracker, converter

1. Introduction

The rising population and the consequent rise in energy and transport requirements cast a shadow over much of the world. Fuel used to produce energy and operate vehicles and trucks is fossil fuels that are non-environmentally friendly and polluting [1]. So, there is a challenge for most societies to move to renewable energies. These energies are clean, environmentally friendly, and renewable [2]. Of these energies: solar energy, wind energy, geothermal energy, energy and energy, and wave energy. They are available for free and their consumption is renewed forever [3]. Over the past 25 years, the renewable energy market has grown dramatically, such as solar and wind power, in electricity production [3]. Projects from power plants and wind farms have also increased worldwide. In the last decade, the use of solar power plants began at high levels. But, most of these stations were expensive to build because of the necessary tools and additional devices, which reflected on the cost of energy produced from these stations [4, 5].

Solar cells are used in many applications. They supply electricity to remote areas and can be used for irrigation through their operation of pumps [6]. The productivity of these panels has increased and the price has become more popular. These panels are affected by the climatic conditions of the area from the intensity of solar radiation, temperature, relative humidity and wind speed [7]. Also, the shade and shadow coming from dust, clouds, and neighboring buildings affect the PV panels' performance highly as it reduce the incoming radiation [8, 9]. Although it requires high radiation intensity to generate the maximum electrical power, but the panels use fraction of the radiation and the rest stored inside it, causing the temperature of these panels to rise [9]. PV modules performance decrease due to the increased of its temperature. In recent times, there has been increasing interest in the use of PV systems, which combine the production of heat and electricity in one system [10]. Hence, solar radiation does not adversely affect these systems [11].

Solar systems rely on direct sunlight to generate energy, so the tracking system that directs these panels toward the sun is very useful for the solar panels to achieve maximum performance [12, 13].
Solar radiation can be divided into two main parts: the direct beam, which represents about 90% of the solar power, and the diffuse sunlight that carries the remaining energy [14]. The scattered radiation is the one who gives the sky a blue color on a clear day. In days covered by clouds the scattered radiation increases [15]. Since most of the energy is in the direct beam, increasing the direct beam is done by making the sun visible to the panels by tracking the sun by the panels [16]. Figure 1 shows a significant reduction in direct radiation energy with a cosine the angle between the direction of light and the solar panel. [17]

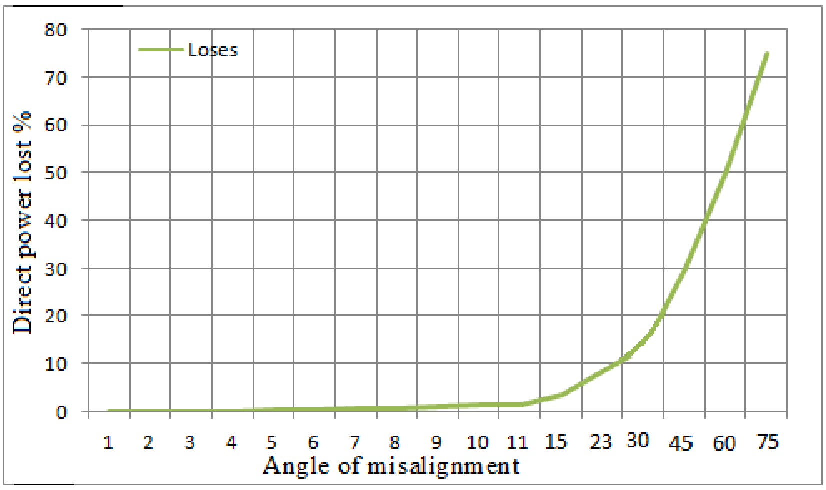

Figure 1: Direct power lost % due to Angle of misalignment

Lost=1-cos (Angle)

The researchers observed that if the solar panel face (using the tracking system) is directed to the sun with an error rate of ± 5°, in this case, the PV panels can achieve a ratio of 99.6% of the direct solar beam energy with 100% of indirect beam energy [18, 19].

1.1. Daily motion of the Sun

The Sun move through 360^o from east to west per day, but for any fixed location on the earth surface the visible sky is 180^o during an average half day period, more in summer and less in winter. For a fixed solar panel between the sunrise and sundown, it will see a motion of sun about 110^o to either side as show in fig.(2) [20]. The curve in the figure shows that the photovoltaic cell loses more than 70% of the energy during its daily work morning and evening. Tracking the photovoltaic cell of the sun from east to west contributes greatly to reducing these losses. The single-axis tracking device and the East-West movement are called a single-axis tracker [21].

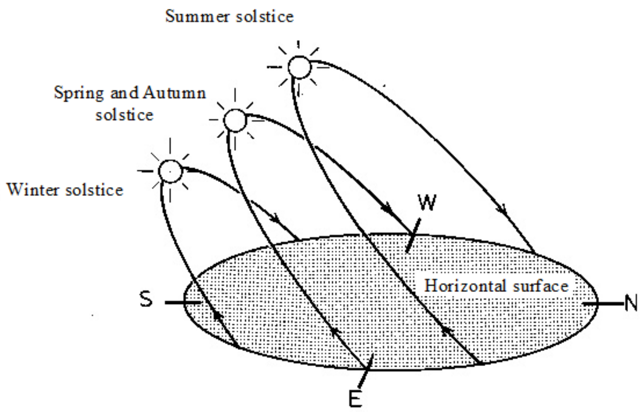

Figure 2: The path of sun during the different seasons

The Sun moves northward and the current is about 36 degrees because of the tendency of the Earth's axis and this is done during the seasons change over a whole year. In the case of stationary panels, these panels will fall midway between the two local sides and will see the sun move about 18 degrees on either side. Therefore, the single-axle tracking system will lose up to 7% of energy during the summer and winter and as an average will lose about 3% throughout the year [22, 23]. However, this loss will increase when the position of solar system moves away from the equator, where the loss at the 60 ° latitude will be greater than 40% of the sun's energy. This leads to the fact that whenever the solar system is far from the equator, it is necessary to use a two-axis solar tracker system, and for solar system position near to the equator a single axis is enough, where the loss is relatively low [24, 25].

There are many facts that must take in account. First the price of a solar tracking device construction relatively high and complex, also the dual-axis tracking system is more expensive and complexity [26]. Second there are other important factors affect on the values of panel angle inclination as dust accumulation heat dispersion etc. So, solar tracker system should not be used unless it is absolutely needed [27]. Therefore fixed systems without tracker system can be used for places near the equator and also for small systems [28]. A single-axis tracking system can be used for place with latitudes less than 35° and for medium power intensity. For Large systems with latitudes greater than 35 degrees, it is necessary to use the two-axis solar tracker [29].

1.2. Effect of the dust density on the inclination of solar panel

In general the Iraqi climate is desert weather: dry, hot and dusty at summer, and moderate temperature, little rain, and dusty at winter and maybe dusty along the year [3]. It is known that the accumulation of dust on the solar panels leads to hide the sun radiation from photovoltaic cells, thus tend to decrease the performance of the system [30]. In order to maintain the operation of the system in optimum level, the dust should be cleaned from time to other, the cleaning process can be carried out easily for small systems, but for the large system it will be too difficult process [31].

The best way to limit this problem, solar panels should fixed with a little inclination, at this position wind and rain can help to remove the most amount of the accumulated dust. According to the above explanation, it recommends to place the solar panels at an inclination angle of about 30^o to eliminate the effect of this problem.

1.3. Temperature Effect on solar panel

Temperature has a significant bad effect on the physical properties of silicon photovoltaic cells in terms of instantaneous energy production, and permanent effect. The permanent effect is the reduction of the solar panel service life, where practical experience have shown a decrease in the energy performance of solar panels by 8% after the first year of operation in Iraqi weather, where the cells expose to more than 100 °C. The instantaneous effect have too much reduction of solar panel performance with temperature rise. It is known that the efficiency of photovoltaic cells decreases with the increase of temperature by about 0.4%/°C [32], at the summer the efficiency of the solar panels reduced significantly to 60% of the design capacity, this amount of redaction is always shown on panel label [10].

Therefore, in Iraq weather at summer days the productivity of solar panels is less than panels productivity at winter, until as know that the intensity of light at summer is greater than at winter, causing a high PV temperature effect.

1.4. Solar energy systems

The absorption of solar energy in the photovoltaic cell causes the p-n junction to produce electricity from the DC. The voltage of a single photovoltaic cell is 0.5 volts with low output power, so connecting a number of these cells together will be a system of solar panels of 12 volts or 24 volts. Figure 3 shows the relationship between the electrical voltage and the capacity of the PV panels. There is a peak point in the PV panels called Maximum Power Point (MMP). Connects a controller to the panels and adjusts the voltage and current in a way that achieves the highest performance of the system [33, 34]. There is also a DC-AC adapter that adjusts current and output voltage so that they are within that point. The adapter is called the MPPT, and it is its duty to modify the output voltage of the PV panels. The structure is called the MPPT, which is attached to a series of sub-plates

[35]. The photovoltaic system is connected to the national grid using the inverter. The energy generated by the solar cells is known to depend on the amount of solar radiation the panels receive. As mentioned above, the angle of solar radiation falling varies with days and seasons. Therefore, many power plants are using solar-tracking devices and adjusting the PV panels to always be perpendicular to the falling solar radiation [36].

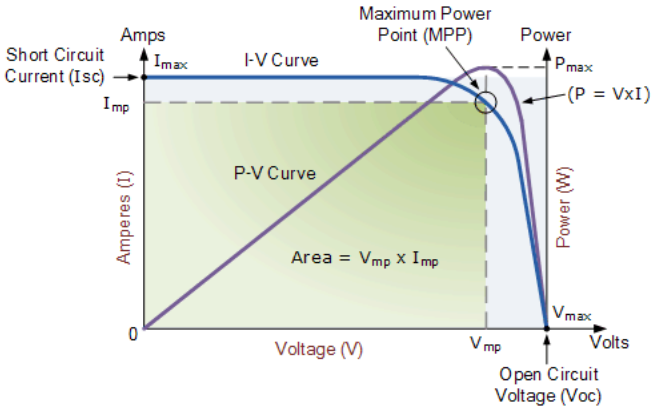

Figure 3: Current – voltage characteristic of a typical solar panel

The above curves shows the current-voltage (I-V) characteristics of a typical silicon solar panel cell. The power delivered by a solar cell is (I x V). This curve shows a maximum power point at I_{max} and V_{max}.

1.5. Types of photovoltaic systems

There are three types of photovoltaic systems witch actually applied namely as:
fixed panel system, single axis tracker system and double axis tracker system.[7].

A. Fixed solar Panel Systems:

In this system, PV modules are fixed at tilt angle from the earth towards the south in the event that the system is installed in the northern hemisphere. In this type of systems, its position cannot be change during the day but it can change the angle of inclination with the changing seasons to achieve the best performance.

B. Single Axis solar Tracker:

In this system, it is easy to guide the PV module in one path from east to west because the sun moves during the day from east to west. From here, the movement of the panels was done in a way that suits the movement of the sun. It is the duty of the tracker here to try to keep the solar panels perpendicular to the solar radiation throughout the day and for each year. In PV systems that use a single-axis tracking device located in the north of the equator, the PV module is routed to the south at an angle of 20 to 30°.

C. Double Axis solar Tracker:

In this system, the solar panel moves two horizontal directions from east to west and vertical from north to south, making the board always perpendicular to the direction of the sun and in this case will receive the maximum radiation falling. In this system does not require a manual intervention to modify trends, but is controlled by the tracker.

2. Design of the Solar Tracking System

2.1. Tracker system composition and who it work

Some of the tracking devices are set by a pair of optical sensors. If the radiation is not absorbed on the board, the steering of the control unit is disrupted so that the system is directed to rotate the board in a direction that makes the imbalance equal to zero. Planetary relationships and parameters are used in some other tracking systems, during which the sun's angle is determined each time during the year by feeding this information to a microcontroller. The tracker always has to direct the panel to the desired angle.

The solar tracking system is a mechanical system made from steel structure to withstand the wind and weight of panels; It carries the solar panels and moves them towards the solar disk direction. The structure movement is controlled by a small low power DC electric motor, through a self-action electrical circuit, it work automatically by comparison the light density between two photocell resistors as shown in Fig. (4).

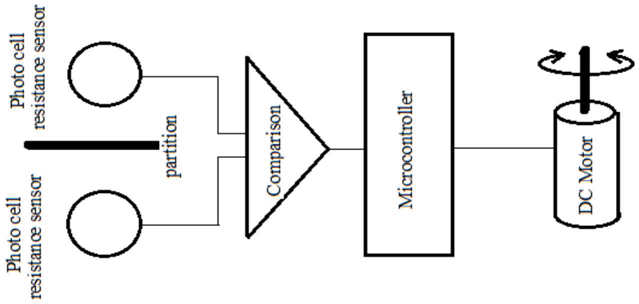

Figure 4: Diagram represents the component of tracker device

These sensors are positioned near one another as, and have a divider, a tilted mount at a defined angle and Collimator, as shown in fig(5).

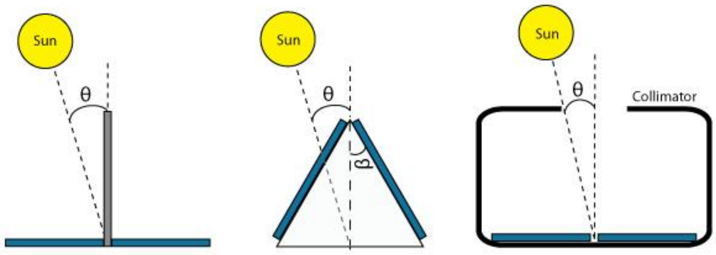

Figure 5: Tracker Sensor Setups from Left to Right: Divider, Tilted Mount, and Collimator

In the solar cell system, a combination of resistors, amplifiers, diodes, capacitors, PNP and NPN transistors are used to form a comparator circuit and an operating circuit. The ICD outputs operate the steering circuit, which in turn turns on the engine and changes its direction according to the sensor, which works to receive a greater amount of illumination and thus directs the PV to be perpendicular to solar radiation [37].

2.2. Photocell resistance sensor Array

The main essential component in this circuit are two or four photo resistance sensors depending on type of solar tracker as shown in fig.(7), for this electrical circuit are two photocell resistors, each with a measured dark resistance of about 1.36 MΩ.

Figure 6: Four photocell resistance

These sensors are mounted vertically on the light source as shown in figure (7). This method of preparation provides acceptable accuracy, allowing the possibility of adjusting the angle of inclination of the system used in this study.

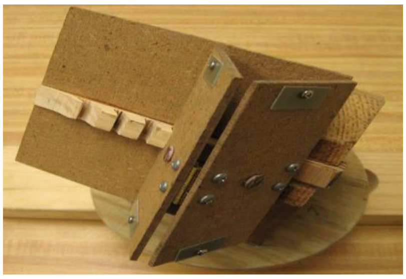

Figure 7: Two photocell resistance fixed on adjustable mountain structure

2.3. Basic H-bridge Circuit:

This circuit uses a couple of mosfet (type of transistor) working together to provide the current of the motor in a certain direction. The BD mosfet (139) is PNP while the BD mosfet (140) is NPN. PNP devices are used when no voltage multiplier is used to obtain sufficient voltage to operate the device. When a PNP allows mosfet to pass through it and NPN mosfet is also tilted, the tracking engine rotates one way [38]. If the engine needs to be rotated in reverse, both are turned off and the other two columns are running, as shown in the diagram in Figure 8.

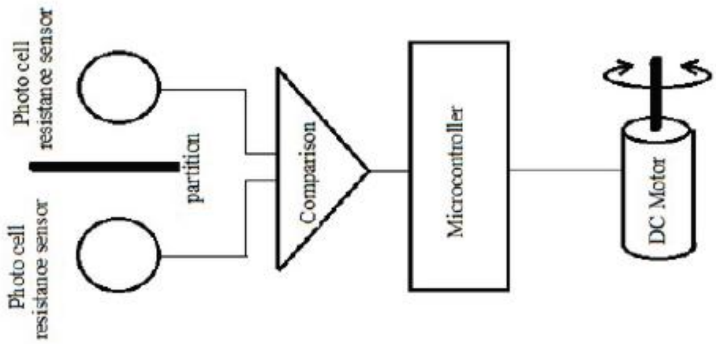

Figure 8: The schematic diagram of tracker electrical circuit

2.4. Motor Drive System

As described previously the use of DC motor can rotate in both directions depend on the direction of the current supplied. the specification of the required drive motor were: input voltage DC 12V, the required power was 20W, output shift revolution 20 rpm, so the DC motor prepared with high speed ratio gear, and high output rated torque. Since the greatest interest in the design of the tracker focuses on the direction of the engine role, therefore, the speed of the engine is not considered the most important variables in design. This issue can be addressed across the driver's circle [39]. Fig. (9) shows 12v DC motor.

Figure 9: The small 12V, DC motor

3. Practical Work

The main objective of this research is to study the possibility of increasing the performance of the solar system by maintaining the sun's rays perpendicular to the surface of solar panels, along the daytime and maybe along the year, this can be achieved as main head line.

Measuring the electrical energy produced by a solar panel, first without sun tracker, measuring the electrical energy produced by a solar panel equipped with a single-axis tracker, and finally measuring the electrical energy produced by a solar panel equipped with a dual-axis solar tracker. After collecting all the data, compares the capacity of the electric power generation from each case, this will lead us to identify the impact of each case. Also, it is taking into account the total cost of the system.

In order to simplify the relatively complex practical aspect, the following steps should be followed: This work requires three solar panels of the same origin and the same technical specifications as 120 watts 12V.

First solar panel is fixed without any solar tracking device, this panel must be connected to a 12V-150Ah lead acid battery, through a charging controller unit, for this work (Steca) type is used, the panel was mounted on ground at 30^o inclination. Its directed to the south as shown in fig.(10).

Figure 10: Solar panel fixed on building roof with 30^o inclination, without tracker system

The second solar panel of 120 watts 12V was equipped with a single-axis solar tracker, it is also connected to the same storage battery, through a second charging control of type (Steca), and the panel was mounted at inclination about 30^o to the building roof. So the panel can move to sun direction according to the single axis tracker device. As shown in fig(11).

Figure 11: Solar panel equipped with a single axis tracker

The third solar panel of 120 watts 12V was equipped with a double-axis solar tracker; it connected to the same storage battery by a third charging control device type (Steca), as shown in fig. (12).

Figure 12: Solar panel equipped with a double axis tracker

The three solar panels are placed on the roof of a building as described previously; the three systems were run from sunrise morning till sunset at evening continually. During this time current was measured for each case, and also during the time the battery was loaded with 300-watt electric to discharge the panel's power.

The test was carry carried out during 2016, at selected represented different seasons of the year. These dates were 1/1/2016, 1/3/2016, 1/7/2016 and 1/9/2016.

The charging controller has been special selected of (Steca) type, for its advanced facility, represented as saving data of battery voltage, current of battery charging and discharging and the total amount of solar power produced during the day, as shown in fig.(13).

Figure 13: Steca type charging control device

Practical Results

The solar tracker system was tested practically on the three solar energy systems, for four specific periods as explained previously, each test refer to three output panels energy for one season. A comparison is then carried out to verify the effectiveness of each case. The results illustrated in the following charts as shown in fig.(14).

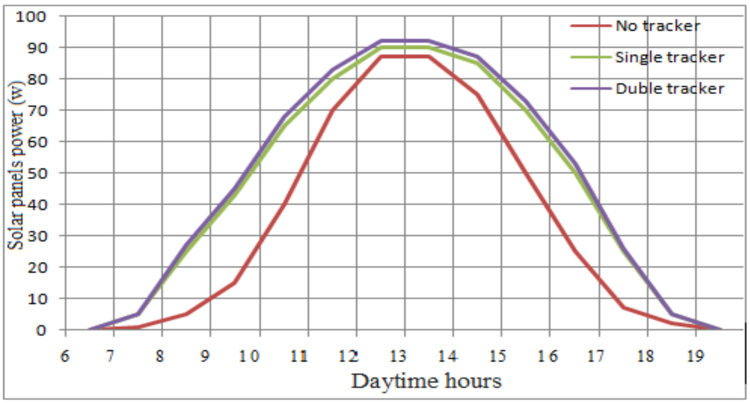

Figure 14: Power of solar panels at spring season

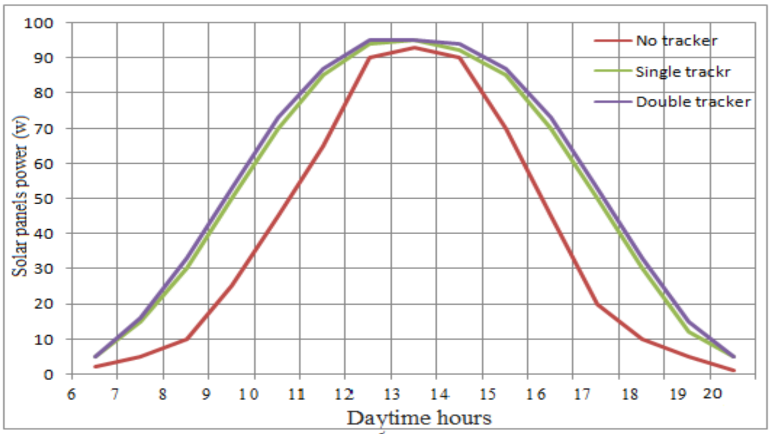

Figure 15: Power of solar panels at summer season

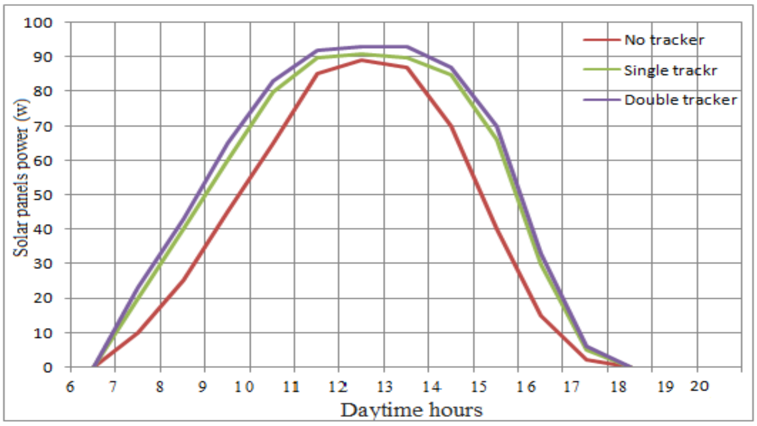

Figure 16: Power of the solar panels at autumn season

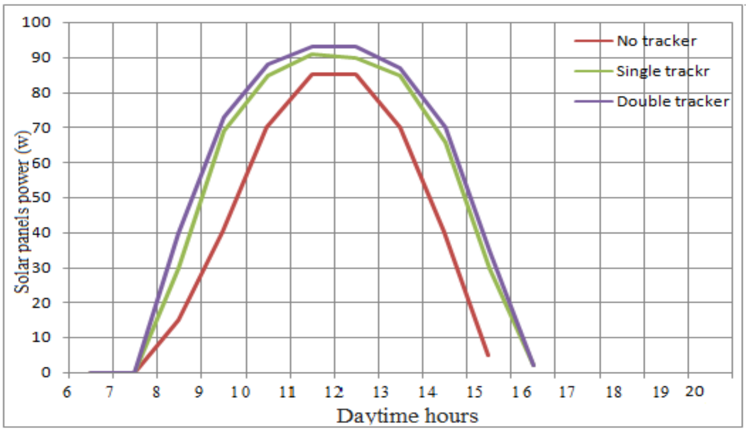

Figure 17: Power of solar panels at winter season

Charts show helpful results of this work, the amount of the energy production, can represent the amount of received radiation for referred days at winter, spring, summer, and autumn.

The results showed that the single-axis tracking device could significantly increase the solar radiation received by the photovoltaic cell by up to 35% compared to what is received by a fixed PV panel. The results of the study also showed that the double-axis tracker did not increase the received solar radiation except by very narrow limits, as a limited increase of only 3% was gained when compared to the single-axis tracker.

4. Conclusion

This paper included a practical work o compare the performance of different photovoltaic systems, the solar tracker system was installed in Baghdad-IRAQ to measure the solar radiation received. The impact of the use of single axis and double axis trackers and compared this influence to fixed solar panel, a solar tracker had been constructed, the three system were tested and got a logical knowledge.

The influence of each device on solar energy systems were, the single axis tracker system tends to 35% improvement of power generated relative to the fixed solar panel, while double axis tracker system tends to 38% rise compare to the fixed solar panel.

There are many other facts that must take in account. First the price of a solar tracking device construction relatively high and complex, also the dual-axis tracking system is more expensive and complexity. Second there are other important factors affect on the values of panel inclination angle, as dust accumulation heat dispersion etc. So, solar tracker system should not be used unless it is absolutely needed. Therefore fixed systems without tracker system can be used for places near the equator and also for small systems. A single-axis tracking system can be used for place with latitudes less than 35° and for medium power intensity. For Large systems with latitudes greater than 35°, it is necessary to use the two-axis solar tracker.

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