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Fabrication of Mini Low-Cost Dual Axis Tracking System Using Arduino

Fabricación Del Mini Sistema De Seguimiento De Eje Dual De Bajo Costo Con Arduino

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ABSTRACT/ A mini dual-axis tracking system has been designed and fabricated in this work. A comparison between the solar cell's power and efficiency of the same solar panel in Tikrit / Iraq has been done for three types of systems: constant solar panel, one-axis tracking system, and dual-axis tracking system which is fabricated here. It is found that the designed dual-axis tracking system is the best for all of the studied factors. The efficiency of the dual-axis tracking system designed here has been increased about (25 – 30 %) more than the efficiency of the constant panel and it is found that it is more active than the constant and one-axis tracking system. From this study; it is found also that the amount of solar radiation in the research's location (Tikrit / Iraq) is suitable for solar cell applications.
Keywords: Dual axis tracking, Photovoltaic cell, Solar tracking, Renewable energy, Solar panel, Solar power, Solar efficiency.
RESUMEN/ Un mini sistema de seguimiento de doble eje ha sido diseñado y fabricado en este trabajo. Se ha realizado una comparación entre la potencia de la célula solar y la eficiencia del mismo panel solar en Tikrit / Iraq para tres tipos de sistemas: panel solar constante, sistema de seguimiento de un eje y sistema de seguimiento de doble eje que se fabrica aquí. Se encuentra que el sistema de seguimiento de doble eje diseñado es el mejor para todos los factores estudiados. La eficiencia del sistema de seguimiento de doble eje diseñado aquí se ha incrementado aproximadamente (25-30%) más que la eficiencia del panel constante y se descubre que es más activo que el sistema de seguimiento constante y de un eje. De este estudio; También se encuentra que la cantidad de radiación solar en la ubicación de la investigación (Tikrit / Iraq) es adecuada para aplicaciones de células solares.
Palabras clave: seguimiento de doble eje, célula fotovoltaica, seguimiento solar, energía renovable, panel solar, energía solar, eficiencia solar.

1. INTRODUCTION:

The future of energy in the world will depend on renewable energy, specifically solar energy, where several research has been completed in the development of equipment to reduce the pollution caused by fossil fuel sources [1-5]. Design and implementation of a solar tracking system for panels, a single-axis solar power tracking device to improve the conversion of solar energy to electricity by directing the photovoltaic (PV) panel correctly according to the reallocation of the sun. The experimental model of the device depends on the DC motor which controlled to moves, the mini PV panel according to the signals received from two simple but effective light sensors. The performance and characteristics of the solar tracking device are analyzed experimentally [6]. The solar tracking system uses four light-sensitive resistors, which are installed on the sides of the solar cell. The solar tracking system becomes more sensitive and allows for a more accurate location of the sun. Shingles & Mangled in 2013 has been made a comparison between the cell itself in the fixed state and the double-tracking system. The results of the system produced 31.3% more energy than the fixed system [7] . Design and manufacture of solar concentrators which is operated by the automatic circuit to move the dishes have been developed. An electromechanical system that tracks the sun on both axes has been designed and implemented and controlled by programmable logic control PLC. The study of the theory and the development of a program in the C language gave the required result for the graphical representation of the recorded radiation. The sun's azimuth was calculated from sunrise to sunset for each day of the year. After the mechanical control of the system began, the performance measurements of the solar panel were carried out. The values obtained from the measurements were compared, and the necessary assessments have been made [8]. The design of the solar tracking system to obtain maximum power generation can be done by adjusting the equipment to obtain the maximum sunlight automatically. This system tracks the maximum intensity of light. When there is a decrease in light intensity, this system automatically changes its direction to get the maximum intensity of light [9]. Fabrication of a dual-axis has been done by using a PIC16F877 microcontroller. The solar panel has been used with a sensors to detect the sun in the sky by using stepper motors, and the system controls the PV panel to get a high solar power throughout the day. The Device programming has been performed using micro basic language. The resulting solar tracking considered as a low cost system with high accuracy, and it is used to assisting rural electrification and reducing the burden on the network supplies [10]. Design of solar tracking system by AT89S52 microcontroller module using light-sensitive resistance (LDR) has been studied by Suman & Soumik in 2016. In such trackers, the data will be read by a microcontroller, and the direction of solar panels will be changed by motors. With this direction, the solar panels attached to the motor spin to get the maximum amount of sunlight. The solar tracking system is designed, applied and tested experimentally [11]. While Oloka in 2015 built the control circuit on ATMega328p controller in Kenya for prototype single axis solar tracking system, and he found that the efficiency will be increases if the tracking system working with two axis, but in Kenya there is no necessary to use complications because Kenya in the equator zone where no big changes will occurred in the sun positions [12]. Bitlal & Malode in 2016 introduced a dual axis solar cell tracker to obtain maximum power using Arduino. This system increases the gain of the solar radiation energy, where it can tracks the sun in fine or bad weather [13]. A single axis sun tracker system have been designed and built by Tegeder in 2007. This system can be automatically directing the solar cell to find the maximum solar radiation angle using a programmed microcontroller to control the solar tracking system [14]. In 2008 Jamludin designed a solar tracking system using a PIC16F877 controller to control the system with light sensors to improve the light intensity [15].

2. THEORETICAL PART:

2.1.SOLAR PANEL:

Solar cell is a device of semiconductor material that works whilst sun radiation falls at the surface of a cell to converts solar radiation into electrical power. This electricity is clean and does not need fuel for its production, so it has accelerated hobby in it and its development to increase its efficiency. Many researchers have labored on growing those additives in phrases of the inner structure, the components of the mobile, the substances that are manufactured, and the approach of manufacturing. Other researchers were worried about the setup of the cells in terms of the angles of the autumn of radiation, cleaning, cooling, and its external elements .The first-class performance while solar radiation falls without delay and perpendicular at the surface [16]. When there is an attitude between the radiation and the surface, the effect of radiation at the surface can be reduced. Consequently we need to preserve the floor of the sun cellular to face sun radiation as long as feasible, notwithstanding the motion of the Earth. Figure (1) illustrates the various angles and other important parameters describing the position of the sun in the sky viewed from an observer O, where. θs is the solar zenithal angle, γs is the solar elevation angle and ψs is the azimuth angle, and N, E, S, and W denote respectively the north, east, south and west.

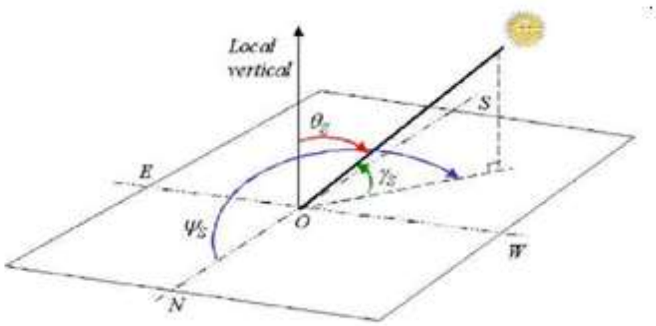

Figure (1): The various angles and other important parameters describing the position of the sun in the sky viewed from an observer O.

Tanvir & Asadur stated that: "The sun travels over 3600 east-west a day, but from the perspective of some fixed place the observable portion is 1800 during a 1/2 day period. Local distance effects lessen this somewhat, making the actual motion about 1500. A solar cell in affixed location between the dawn and sunset limits will see a of 750 on any side, and thus, will loses 75 % of the energy in the A.M. and sunset. Rotating the cell to the east and west can help recall these losses. A tracker rotating in the east-west direction is well-known as a single-axis tracker. Also sun moves through 460 north-south over the period of a year. The same set of panels set at the midpoint between the two local extremes will thus see the sun moves 230 on either side, causing losses of 8.3 %. A tracker that accounts for both the daily and seasonal motions is known as a dual axis tracker".

2.2.EFFICIENC OF SOLAR PANELS:

The performance is the parameter most generally used to compare overall performance of one sun cells to another. It is the ratio of electricity output from the solar panel to enter power from the solar. Further to reflecting at the performance of sun cells, it's going to depend upon the spectrum and depth of the incident sunlight and the temperature of the sun cellular. As a result, situations beneath which performance is to be measured should be managed cautiously to examine overall performance of the various devices. The performance of sun cells is decided as the fraction of incident electricity this is transformed to strength. It is defined as:

$$\eta = \frac{P_{max}}{P_{In}} \quad \text{------------------------------------} \quad (1)$$

$$P_{max} = V_{oc} I_{SC} FF \quad \text{------------------------------} \quad (2)$$

$$P_{In} = A \times I_n \text{------------------------------------} \quad (3)$$

$$\eta = \frac{V_{oc} I_{SC} FF}{P_{In}} \quad \text{---------------------------------} \quad (4)$$

where:

A is " The area of solar panel"

In is "The insulation solar radiation"

FF is "the fill factor"

ISC is "The short-circuit current"

νis "The open-circuit voltage"

η is "The efficiency"

2.3.TYPES OF ACTIVE SOLAR TRACKERS:

The basic types of energetic sun tracker are single-axis and double-axis; as it demonstrated below.

2.3.1. SINGLE AXIS TRACKERS:

The single-axis tracking systems realizes the motion of either elevation or azimuth for a sun energy system figure (2). Which this kind of moves is desired, relies upon on the generation used at the tracker as well as the space that it is set up on. For instance, the parabolic via structures make use of the azimuthally tracking while the many rooftop PV-systems make use of elevation monitoring due to the lack of space. A single-axis tracker can best pivot in a single plane – both horizontally or vertically. This makes it less complex and normally less expensive than a two-axis tracker, but additionally much less powerful at harvesting the full sun electricity available at a domain. Trackers use vehicles and tools trains to direct the tracker as commanded by a controller responding to the solar course. Since the vehicles consume electricity, one wants to use them handiest as important Single axis trackers have one degree of freedom that acts as an axis of rotation. There are numerous commonplace implementations of unmarried axis trackers. These consist of horizontal single axis trackers (HSAT) and vertical single axis trackers (VSAT).

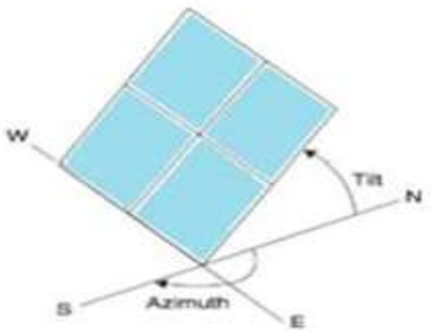

Figure (2) : Single axis sun tracker [18].

2.3.2. DUAL AXIS TRACKERS:

Dual-axis trackers as proven in figure (3) have degrees of freedom that act as axes of rotation. Double-axis sun trackers, as the equal suggest, can rotate simultaneously in horizontal and vertical directions, and so are able to factor precisely on the sun always in any vicinity Dual-axis monitoring systems realize movement both alongside the elevation- and azimuthally axes. These monitoring structures evidently provide exceptional overall performance, given that the additives have excessive sufficient accuracy as nicely.

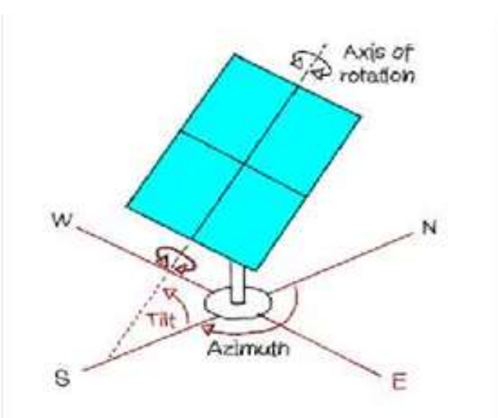

Figure (3): Dual axis geometries [18].

3. EXPEREMINTAL WORK:

This section contains all the electrical and mechanical parts details which have been designed and fabricated with the ways of installations, assemblage, and Arduino programming for tracking process.

3.1.BLOCK DIAGRAM OF THE TRACKING SYSTEM:

The main components of the present work system are illustrated in the block diagram in figure (4) below. It is clear that the hardware of the tracking system contains two main parts; Mechanical structure and Electronic control circuit. Each one includes many parts. The details will be mentioned as it is required in the following sections.

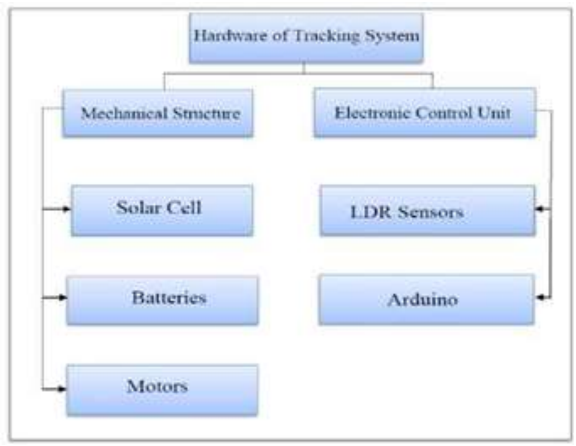

Figure (4): Block diagram of the tracking system.

3.2.SPECIFICATION OF TRACKING SYSTEM IN THIS WORK:

The dual axis solar tracking system under consideration consisting of the solar panel and the components of the tracking system circuit illustrated in the figure (5) below.

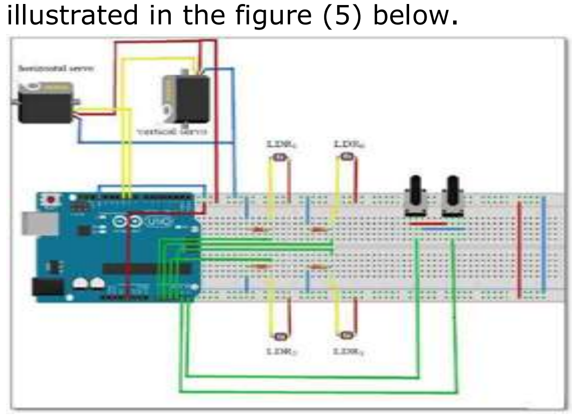

Figure (5): Solar tracking system circuit.

3.2.1. THE SOLAR CELL PANEL:

It is the main part for transforming the light energy to electric energy. In this work a solar cell panel of polycrystalline cells has been used. The panel's dimensions is (17.5 cm x 12.75 cm), and it is shown in figure (6) below. The maximum intensity of the solar radiation is (1000 W/m2) at a temperature of 25 oC. An energy obtained from this solar panel have been stored in a battery of 12 volt. The specifications of the used cell are listed in the table (1) below.

Table (1): The specifications of the used cell in this work.

Company	P_{max} (watt)	V_{pmax} (volt)	I_{pmax} (Amp.)	V_{oc} (volt)	I_{sc} (Amp.)	*FF*	η (%)
Kyocera	3	9	0.34	11.25	0.41	0.66	15.13

3.2.2. THE SENSING UNIT:

This unit composed of four light dependent resistances (LDR) positioning around solar panel as shown in figure (6) below. These resistances used to monitoring the movement of the sun during the day. Each resistance connected to a normal resistance of (10 kΩ) to potential of (5 VDC). The LDR0 & LDR1 are responsible for the right & left of the solar panel movement, while the LDR2 & LDR3 are responsible for the up & down of the solar panel movement.

The light dependent resistances (LDR0, LDR1, LDR2, LDR3) have been connected an analog pins (A0, A1, A2, A3) respectively to the microcontroller at the UNO Arduino board as shown in figure (6) below. These pins represent a data for the microcontroller's later forward orders.

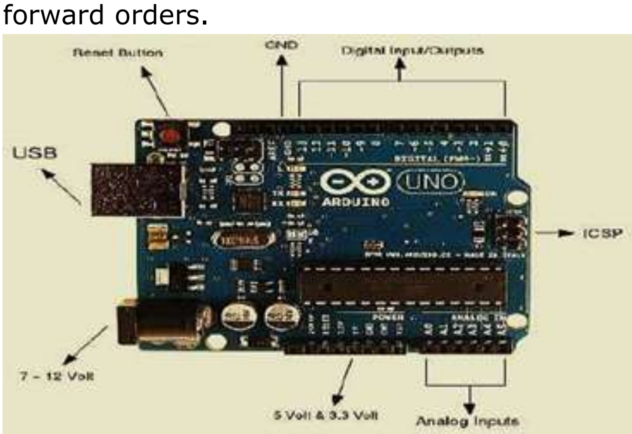

Figure (6): Arduino and its components

3.2.3. MICROCONTROLLER UNIT:

A microcontroller of (ATmega 328) type has been used here. It is responsible for the following procedures:

1. Receives the LDR's signal which is reach to the analog pins.
2. Transforms the analog signal coming from the LDRs' to a digital signal using the "Analog to Digital Converter".
3. Reading the digital data.
4. Sending the microcontroller signal via the digital inputs to allowing the current to operates the Servo Motors.
5. Monitoring the maximum limit of the solar panel rotation and returns it to the default position.

3.2.4. MOTORS GUIDANCE UNIT:

This unit is responsible for moving the solar panel to the direction determined by the microcontroller. This is done by importing the LDR's signals and transforming them to a digital signals, and then sending them to the digital inputs (9 & 11) of the Arduino to do the following procedures:

1. The input (9) is a responsible for moving the Horizontal Servo Motor to the right and left as listed below:

a. When the signal of the LDR0 is higher than the signal of LDR1; this leads to move the solar panel to the right side by the Servo Motor.

b. When the signal of the LDR1 is higher than the signal of LDR0; this leads to move the solar panel to the left side by the Servo Motor.

2. The input (11) is a responsible for moving the Vertical Servo Motor to the up and down as listed below:

a. When the signal of the LDR2 is higher than the signal of LDR3; this leads to move the solar panel to the down side by the Servo Motor.

b. When the signal of the LDR3 is higher than the signal of LDR2; this leads to move the solar panel to the up side by the Servo Motor.

Motors are used for transforming the electric energy to the mechanical energy or vice versa. In the solar tracking systems; many types of motors have been used. One of these types is a Servo Motor; which is a DC motor provided with mechanical speed gearbox to obtain the required momentum for moving. And it includes an electronic circuits for motor's feedback. Two DC Servo Motors have been used here. One of them is for the horizontal axis movement, and the other is for the vertical axis movement. Each motor requires a voltage of (5 volt). A fine tuning resistance of (10 KΩ) has been used with the servo motors to limits the required current passing through it. The used motor and its accessories are shown in the figure (7) below.

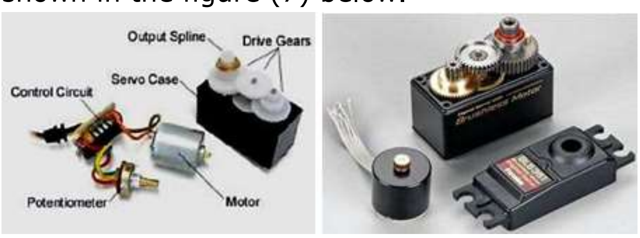

Figure (7): Servo motor used in the present work with its accessories.

4.0.THE SOFTWARE PROGRAMMING:

The microcontroller has been programmed using Arduino programming language, where the Arduino is connected with a computer's MATLAB & MAXMSP programs. The program consists of a set of commands given to the microcontroller to direct the monitor to do series of procedures via outputs beginning of importing inputs data.

4.1.THE SYSTEM ASSEMBLY:

In this work, many components and devices have been used, such as; Arduino UNO board, USB printer cable for connecting the Arduino with the computer, Breadboard to connect the electric and electronic parts easily without needing to use the welding, Resistances of (220 Ω) to limits the required current values of the microcontroller's inputs and outputs, Connection silks to connects the components with each other's ,Solar power meter type (TES1333), Digital Voltmeter & Ammeter; both of them are of type (JYD DT9205A), and Variable resistance fixed at (30 Ω) as a load with the solar panel to compensates any device might be working the panel. The whole design of the dual tracking system built here includes two main parts:

1. The upper part:

This part consists of the solar panel "U shape" wooden holder and the vertical servo motor. The solar panel has been fixed at the middle of the holder using axial road to ease the vertical motion of the solar panel, while the vertical servo motor has been fixed at left side of the panel as illustrated in figure (8.a) below.

2. The lower part:

This part consists of two wooden tablets as shown in figure (8.b) below. The horizontal servo motor has been fixed on the lower tablet, and the upper tablet has been fixed on the upper servo rotated wheel. Three animated axial wheels have been fixed on the lower part of the upper tablet between the two tablets to ease the upper part of the tracker system motion, and also, to reduce the weight of the system on the horizontal servo motor. The upper tablet also has been used to fix the electronic circuits and their connections on it.

Figure (8): (a) The upper part of the fabricated tracking system, (b) The lower part of the fabricated tracking system.

5. RESULTS AND DISCUTION:

A solar power meter has been used to measures the intensity of the solar radiation for the days in which the voltage and current values have been taken in it. The voltage and current measurements have been taken after putting a resistance of (30 Ω) instead of using a device of the same load. After knowing the intensity of the solar radiation, the values of voltage and current, and the area of the solar panel; the efficiency of the solar cell can be found using equation (1) mentioned previously. The efficiency of the same solar panel used here has been calculated and studied by using one axis tracker in addition to a dual axis tracker fabricated here. Then the difference between them have been compared. The details will be illustrated in the next section.

5.1.THE SOLAR RADIATION IN TIKRIT / IRAQ:

The solar radiation of Tikrit, which located on longitude line of (43.670) and latitude line of (34.590) has been studied, where it is the most important factor affecting on the solar cells. From this studies for two days, many thing have been founded:

1. In the 1st day (16/ 3 / 2018); the intensity of solar radiation has been measured at a location time (8:00 – 17:00) as it is seen in figure (9) below, which illustrates the relationship between the solar radiation with the time. It is clear that the solar radiation increased in the period of time from (8:00 – 12:00), and then it has been slightly reduced because of the passage of clouds at that time. After that, it began to increase over time to reach its maximum value at the time (12:00-13:00); i.e. when the sun is almost vertical on the solar panel, then the radiation starts to decrease gradually until sunset. the power of solar panel increasing with increasing the solar radiation

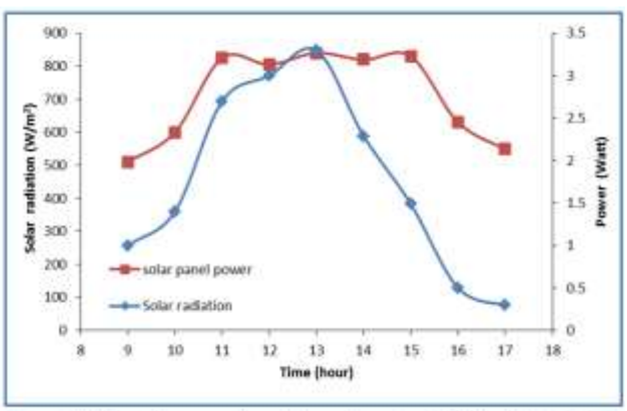

Figure (9): Relation between solar radiation and time for the 1st day (16 / 3 / 2018).

2. In the 2nd day (17 / 3 / 2018); the intensity of solar radiation has been measured at the same above a period of time (8:00 – 17:00). Figure (10) shows the relation between solar radiation and time. The weather was mostly clear. It is clear from this figure (10) that the radiation reaches the peak almost, while the maximum value obtained at the time (14:00) when the sun is vertical on the solar panel. After that, the curve began to reduce gradually.

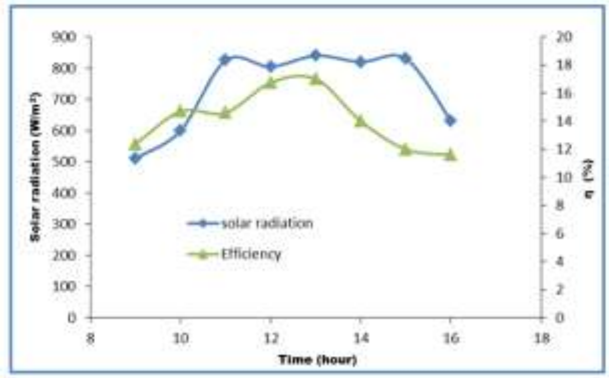

Figure (10): Relation between solar radiation and Efficiency with time.

It is noticed from the previous measurements of the solar radiation that the mean value of the solar radiation in the peak time was around (500 – 800 W/m2).

Also, the power and efficiency with the time between the fixed panel and single and dual tracking have been studied. It is noticed from the figures (11&12) in the fixed panel that the power increasing with increasing of the solar radiation so as the efficiency increased, also in the single-tracking, while the power and efficiency increased because the panel of a single tracking has been exposed to radiation more than that of fixed installation. Also in the dual tracking system; the panel all time directed to the sun, then the power and the efficiency have been increased compared with that of single-tracking and fixed. These outcomes are compatible with outcomes of other researchers [17, 18].

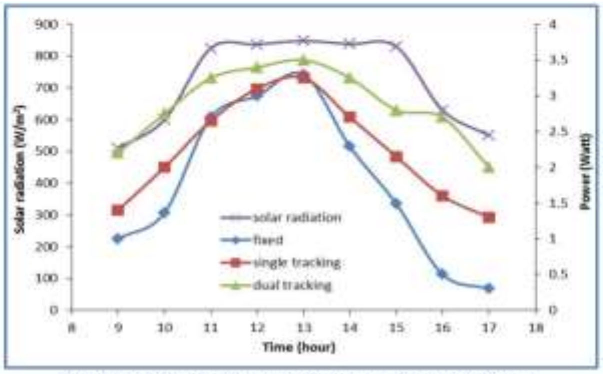

Figure (11): Relation between solar radiation and power with time.

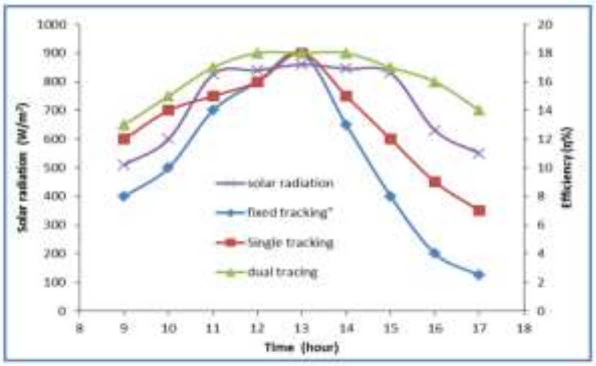

Figure (12): Relation between solar radiation and efficiency power with time.

6. CONCLUSION:

It can be concluded from this research that the dual-axis tracking system designed and fabricated here is the best comparing with constant solar panel and one-axis tracking system, were the range of the peak period has been extended, and the amount of the solar radiation also has been increased. This is due to obtaining the maximum amount of radiation throughout the work period. The fabricated system here is cheap, not complicated, auto-tracking, produces satisfied solar cell power and efficiency for the used panel here, and it can be used for various renewable energy systems that depend on solar radiation. The efficiency of the dual-axis tracking system designed here has been increased about (25 – 30 %) more than the efficiency of the constant panel, and it is more active than both constant and one axis systems. Finally, from this study it clear that the amount of solar radiation in the research location (Tikrit / Iraq) is suitable for solar cell applications.

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