JAUES

Journal of Al-Azhar University Engineering Sector

Vol.16, No,60 , July 2021 , 678 - 691

SMART FABRICATION OF DUAL AXIS SOLAR TRACKER

Fathy M. Mustafa[1], Michael Ernest[2], N. M. Hussein[2] and Rania Ahmed Abul Seoud[2]
[1]Electrical Engineering Department, Faculty of Engineering, Beni-Suef University, Beni-Suef, Egypt.
[2] Electrical Engineering Department, Faculty of Engineering, Fayoum University, Fayoum, Egypt.
*Corresponding Author's E-mail: eng.michaelernest@yahoo.com

Received: 07 March 2021 Accepted: 05 June 2021

ABSTRACT

Currently, the most renewable energy production is produced depending on wind and solar energy are widely used in developed countries and some developing countries; Lately, the means of producing electricity using renewable energy sources have become commonplace, and there are many countries that have put in place plans to increase the percentage of their production of renewable energy so that they cover their energy needs by 20% of their consumption in 2020. Photovoltaic panels are used to convert solar energy into electrical energy. When photovoltaic panels are fixed at a particular angle, limited power can be generated. This disadvantage can be decreased by designing a solar tracker system which changes its position automatically in accordance with the sun's movement. Dual axis solar tracker can continuously track the position of the sun in vertical and horizontal directions. This paper aims to implement the most accurate control application of dual-axis solar tracker which can rotate in horizontal and vertical direction that grantee the photovoltaic panel remains perpendicular always facing the sun. The fabricated tracker achieves higher efficiency so the solar panel remains a sun-oriented position at all times using two linear DC motors, an Arduino UNO controller and some auxiliary components to improve the energy generated from PV panels up to 36%.

KEYWORDS: Single-axis solar tracker, Dual-axis solar tracker, Solar Energy, Photovoltaic Panel, Light Dependent resistor.

الابتكار الذكي لمتعقب الطاقة الشمسية ثنائي المحور

فتحي محمد مصطفي[١]، مايكل ارنست[٢]، نشأت محمد حسين[٢]، رانيا أحمد أبو السعود[٢]
[١]قسم الهندسة الكهربية، كلية الهندسة، جامعة بني سويف، بني سويف، مصر
[٢] قسم الهندسة الكهربية، كلية الهندسة، جامعة الفيوم، الفيوم، مصر
*البريد الاليكتروني للباحث الرئيسي: eng.michaelernest@yahoo.com

ملخص البحث:

حاليًا، يتم إنتاج معظم الطاقة المتجددة اعتمادًا على طاقة الرياح والطاقة الشمسية المستخدمة على نطاق واسع في البلدان المتقدمة وبعض البلدان النامية ؛ في الآونة الأخيرة ، أصبحت وسائل إنتاج الكهرباء باستخدام مصادر الطاقة المتجددة شائعة ، وهناك العديد من الدول التي وضعت خططًا لزيادة نسبة إنتاجها من الطاقة المتجددة بحيث تغطي احتياجاتها من الطاقة بنسبة ٢٠٪ من استهلاكها في ٢٠٢٠. تستخدم الألواح الكهروضوئية لتحويل الطاقة الشمسية إلى طاقة كهربائية.

عندما يتم تثبيت الألواح الكهروضوئية بزاوية معينة ، يمكن توليد طاقة محدودة. ولكن يمكن تقليل هذا العيب من خلال تصميم نظام تعقب شمسي يغير موضعه تلقائيًا وفقًا لحركة الشمس. يمكن لمتعقب الطاقة الشمسية ثنائي المحور تتبع موضع الشمس باستمرار في اتجاهات رأسية وأفقية. تهدف هذه الورقة إلى تنفيذ أدق تطبيق للتحكم في جهاز تعقب الطاقة الشمسية ثنائي المحور والذي يمكن أن يدور في الاتجاه الأفقي والرأسي بحيث تظل اللوحة الكهروضوئية متعامدة دائمًا في مواجهة الشمس. يحقق جهاز التعقب المُصنَّع كفاءة أعلى ، لذا تظل اللوحة الشمسية في وضع موجه للشمس في جميع الأوقات باستخدام محركين خطيين للتيار المستمر ، ووحدة تحكم اردينو اونو وبعض المكونات الإضافية لتحسين الطاقة المتولدة من الألواح الكهروضوئية تصل حتى ٣٦٪.

الكلمات المفتاحية :
تعقب الطاقة الشمسية فى اتجاه محور واحد، تعقب الطاقة الشمسية المزدوج المحور، الطاقة الشمسية، اللوح الضوئي، المقاومة المعتمدة على الضوء.

1. INTRODUCTION

Non-renewable energy has many uses today, as it is used in all areas of life, industrial and agricultural for electricity, water and cars. But it has many disadvantages for that all scientists advise to replace non-renewable energy with renewable energy sources as possible, as non-renewable energy causes many harmful phenomena to the environment and society, including “air pollution - acid rain - acid cold - acid mist” [1-2], however the many advantages and features of non-renewable energy, its disadvantages are more and the world always has to avoid using it as much as possible.

Solar energy is one of the most important resources of renewable, plentiful and endless source of energy, offering not only alternative energy resources; but also minimizes global warming as well [3-4].Solar trackers are the device used to guide the photovoltaic panels. The position of the sun changes throughout the year and according to the different seasons.

When the sunlight is perpendicular on the PV panel more power can be generated, so the main propose from the dual tracker is to track the sun in all position through the year. Passive, active and chronological tracking techniques are the most popular techniques for the solar energy tracking system [5-7]. Passive tracking structure use some types of the compressed gas fluid that is driven to one side or the other using the heat of the sun to cause the tracker to move in response to an imbalance.

Active tracking structure use different types of sensors to follow the position of the sun and control the motors of the solar panel. Chronological tracking structure is a timer based tracking system where the solar panel rotates in a fixed rate throughout the day [8-10].

Warm countries should use solar energy as main renewable energy resource. In the Middle East region has a relatively long sunny day all over the year [11-12]. This makes these countries, particularly on the South side of the desert, very rich in solar energy. The main problem appears in the usage of solar energy is the generated power efficiency is not to high , so researchers all over the last decade try to raise the power efficiency generated to a new levels [13-14].

Recently, there have been researches on dual axis tracking methods using different ways [15], Deepthi.S, Ponni.A, Ranjitha.R, R. Dhanabal (2013) achieved 25% power efficiency calculated for dual –axis solar tracker more than the fixed amount using PIC18F877A micro controller. Rashid. Jing-Min W. and Chia-Liang L. (2013) achieved 28.31% power efficiency calculated for dual –axis solar tracker more than the fixed amount using LDR sensor, differential amplifier and comparator. Shyngys A., Amangldi B., Seitzhan O., and Zhanatovich K. (2013) achieved 31.3% power efficiency calculated for dual –axis solar tracker more than the fixed amount using LM324N micro controller. Mahir.A, Sanzidur.R, Sayedus.S and Mohammad.A (2014) achieved 25.62%

power efficiency calculated for dual –axis solar tracker more than the fixed amount using hybrid dual axis solar tracking system. Betha .V, Savita .N, Pankaj .S, Doppllapudi .R (2016) achieved 25% power efficiency calculated for dual-axis solar tracker more than the fixed amount using Automatic Solar Tracking System using DELTA PLC. Priyanka M., Akshay D. (2016) achieved 33.99% power efficiency calculated for dual –axis solar tracker more than the fixed amount using electronic components and motors and the system designed not include micro controller or PLC.

In this work, a smart automatic active structure using the feedback signal from the sun's light sensor (LDR) to ensure that the PV panel is always at the right angle to sun’s rays known as dual-axis solar cell tracker .The following implementation consist of Arduino UNO as a controller, LDR as light sensors, PV panel, two linear motors, charger controller, two DC rechargeable batteries, two dual-relay modules and auxiliary electronic components and a wood box that to improve the energy generated from PV panels up to 36%. The paper is organized as follows: Basic model and analysis in Sec. 2, proposed model in Sec. 3, results and discussion are shown in sec. 4, followed by the conclusion in Sec. 5.

2. METHODOLOGY

The tracking operation based on four light dependent resistors (LDR) sensors that have been installed in the four direction of the solar panel to measure the sunlight intensity as an input signal. The voltage generated from every LDR is sent to the analog inputs of the Arduino UNO controller to measure the largest input voltage using a program that has been developed based on C++ language. Arduino UNO controller sends an output digital signal to one of the comparators so the output of the comparator goes high state and the related relay modules is activated to make the linear motor move the PV panel to rotate to face the sun.

The sunlight intensity from four different directions is measured by LDRs. The voltages measured are defined as the sensing voltages produced by the east, west, south and north LDRs. The main propose is to draw maximum power from the PV panel, the tracking processes don’t stop until the PV panel is aligned orthogonally to the sunlight.

The next block diagram of the created dual tracking system is illustrated in Fig. 1.

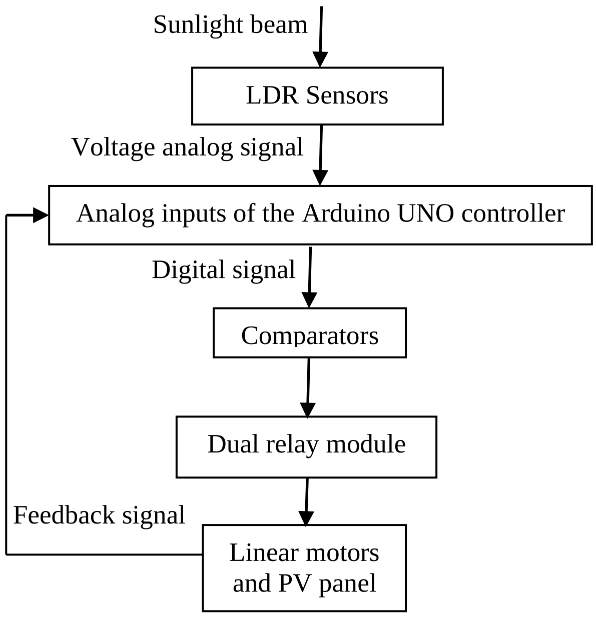

Fig.1, Block diagram of the tracker

To track the sun’s position quickly, the Arduino UNO controller programmed at a theoretical altitude and azimuth angles as shown in Figure 2, so the controller will response to the change of the position of the sun through following equations [16]:

$$\mathrm{Alt} = \sin^{-1}(\sin \mathrm{D} \sin \mathrm{L} \cos \mathrm{D} \cos \mathrm{L} \cos \mathrm{H})$$

$$\mathrm{Az} = \cos^{-1}\left[\left(\sin \mathrm{D} \cos \mathrm{L} - \cos \mathrm{D} \sin \mathrm{L} \cos \frac{\mathrm{H}}{\cos} \mathrm{Alt}\right]\right.$$

Where/ Alt: Altitude, Az: Azimuth, / D: Declination angle, L: Local latitude, H: Hour angle.

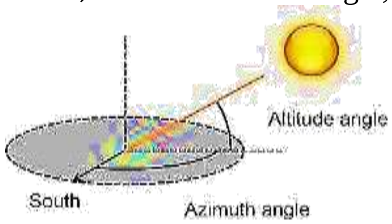

Fig.2, Azimuth and Altitude angles.

The theoretical value of altitude and azimuth angles that originate from sun-earth connections are converted into digital directions for driving DC linear motors to the relating position. At that point, the model consequently trims the elevation and azimuth angle of the PV panel as indicated by the input sign of the proposed LDR sensor module. Arduino UNO controller comprises of four LDR-sensors. The following model can follow the position of the sun in any case the mediation of a LDR sensor module and it is additionally ready to work in any case the intercession of sun-earth connections in this way, it is reliable under any climate conditions [17].

3. HARDWARE

3.1 The Practical Model Designed

Light dependent resistors (LDR) is used as sensor to track the sun's exact position two pieces senses the position of the sun in east and west side and other pair senses the position of the sun in north and south side [18,19].

The smart solar panel designed using the four LDRs will extract the feedback signals from the LDRs by using different electronics components then they send the feedback signal to the Arduino Uno which determines the direction of the movement of the two linear motors to ensure that the PV solar panel is always perpendicular to the incident angle of the solar rays [20, 21]. The practical model designed appears in Fig.3.

Fig.3, Practical Model Designed

3.2 Main components of the sun tracker :

3.2.1 The Arduino Uno

Arduino Uno represents the backbone of the whole system. It is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button [22].

3.2.2 Solar panel

It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are described as being photovoltaic, irrespective of whether the source is sunlight or an artificial light. In this project we use (25W 12V) solar panel is considered [23]. The solar panel designed to move in horizontal and vertical directions appears in Fig.4, 5.

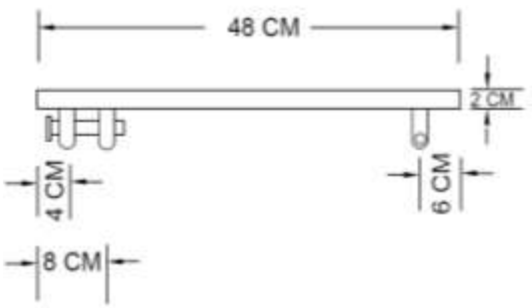

Fig.4, Side view for PV solar Panel installation

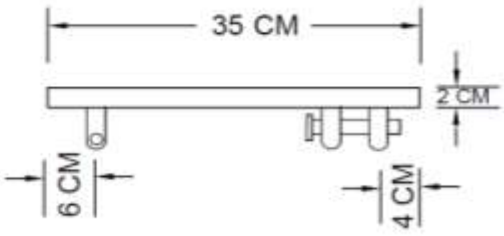

Fig.5, Front view for PV solar Panel installation

3.2.3 The linear DC motor

A linear motor is an electric motor that has its stator and rotor "unrolled" thus instead of producing a torque (rotation) it produces a linear force along its length. However, linear motors are not necessarily straight. Characteristically, a linear motor's active section has ends, whereas more conventional motors are arranged as a continuous loop. The specifications of linear motor are listed in table 1.1 and Fig.6 shows the DC linear motor fabrication.

Table 1.1, Specifications of linear motor

Motor	DC brush motor
Input	24/ 36V DC
Load Capacity	3000N
Standard Stroke Length	600mm
Drive Screw	ACME
Full Load Speed	5 mm/sec
Duty Cycle	20%
Temperature	-26˚C to 65˚C (-15˚F TO 150˚F)

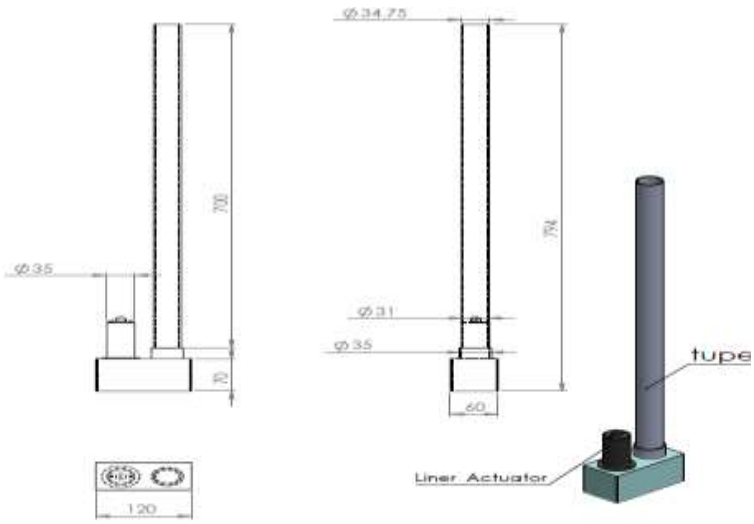

Fig. 6, Front and side view for DC motor

3.2.4 The wood box and the wood cover

Using Auto Cad we designed a wood box for all components of the model. The design of the covers is shown in Fig.7, Fig.8:

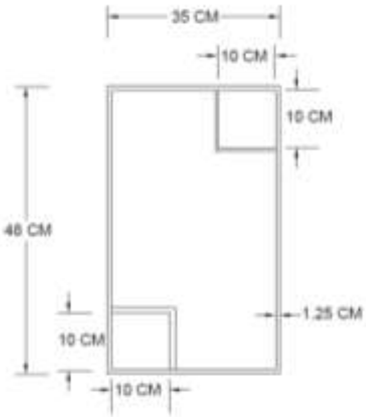

Fig.7 The horizontal view of the box

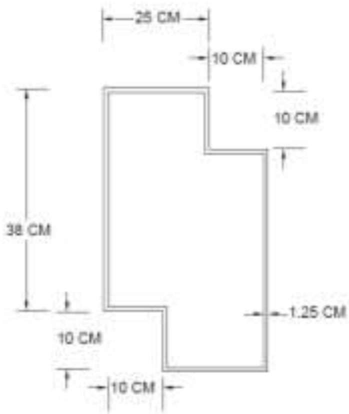

Fig.8 The horizontal view of the cover

3.2.5 The solar power controller

Solar Charge Controller Working using Microcontroller. A solar charge controller is basically a current or a voltage controller to charge the battery and to protect the cells from overcharging. . In this project we use (20A 12V) solar power controller [24].

3.2.6 The LDR

A photo resistor (or light-dependent resistor, LDR, or photo-conductive cell) is a light-controlled variable resistor. The resistance of a photo resistor decreases with increasing incident light intensity; in other words, it exhibits photoconductivity [25]. Fig.9 shows the LDR.

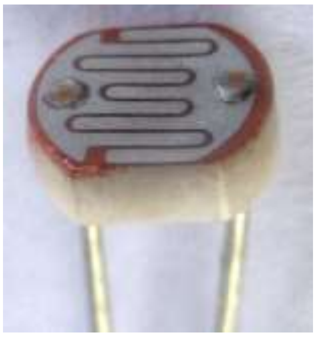

Fig.9 The LDR

4. SOFWARE

Processing is the main language that the Arduino programming language is based on which is similar to the C language. After the program is written in the Arduino IDE, it should be uploaded on the Arduino board for execution, [26]. The next flowchart, illustrate the developed program appears in Fig.10.

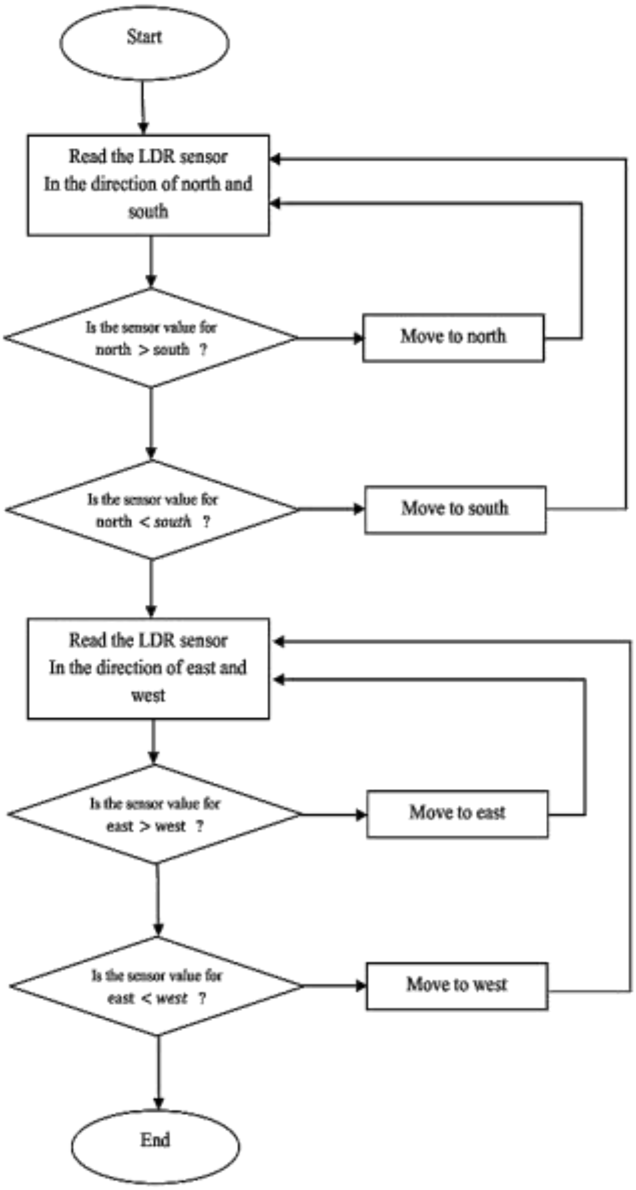

Fig.10 Flow chart of sun tracking algorithm

The software represent the backbone of the whole system that receive four digital extracted voltage signals and comparing them for making the decision that sent to the DC motors moking the PV panel rotating. The C++ code appears in the following lines Table 1.2:

```
int motor1_cw = 13;
int motor1_ccw = 12;
const int buttonPin=2;
int val;
int motor2_cw = 11;
int motor2_ccw = 10;
float ldr1 = A0;
float ldr2 = A1;
float ldr3 = A2;
float ldr4 = A3;
void setup() {
  pinMode(motor1_cw, OUTPUT);
  pinMode(motor1_ccw, OUTPUT);
  pinMode(motor2_cw, OUTPUT);
  pinMode(motor2_ccw, OUTPUT);
  pinMode(buttonPin, INPUT); }
 void loop() {
   int sensorValue1 = analogRead(A0);
   ldr1=sensorValue1*5/1024;
   val=digitalRead(buttonPin);
   int sensorValue2 = analogRead(A1);
   ldr2=sensorValue2*5/1024;
   int sensorValue3 = analogRead(A2);
   ldr3=sensorValue1*5/1024;
   int sensorValue4 = analogRead(A3);
   ldr4=sensorValue2*5/1024;
  if(ldr1 > ldr2)
  {  digitalWrite(motor1_cw, HIGH);
  digitalWrite(motor1_ccw, LOW); }
  if(ldr1 < ldr2)
  {  digitalWrite(motor1_cw, LOW);
  digitalWrite(motor1_ccw, HIGH);}
  if(ldr1 == ldr2)
  { digitalWrite(motor1_cw, LOW);
  digitalWrite(motor1_ccw, LOW); }
  else{}
    if(ldr3 > ldr4)
  { digitalWrite(motor2_cw, HIGH);
  digitalWrite(motor2_ccw, LOW); }
  if(ldr3 < ldr4)
  {  digitalWrite(motor2_cw, LOW);
  digitalWrite(motor2_ccw, HIGH); }
  if(ldr3 == ldr4)
  {  digitalWrite(motor2_cw, LOW);
  digitalWrite(motor2_ccw, LOW); }
  else{}
    if(val==HIGH)
   { digitalWrite(motor1_cw, LOW);
  digitalWrite(motor1_ccw, LOW); }
     if(ldr1 < ldr2)
  {  digitalWrite(motor1_cw, LOW);
  digitalWrite(motor1_ccw, HIGH); }
   else{};}
```

Table.1.2, c++ programming language

5. RESULTS

5.1 Relation between Power Generation and Time

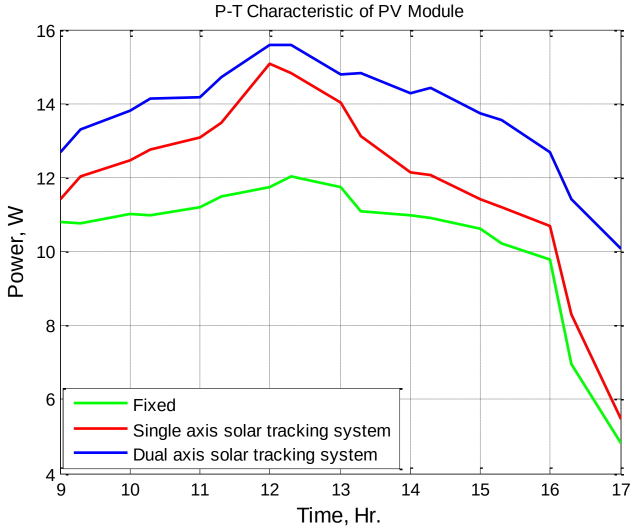

Fig. 11, The power characteristics versus time for all cases

The main propose of the designed tracker is to achieve higher generated values for the power. The next few tables shows the power and time values received from both fixed and tracking panel techniques for different times in a day.

From the tables it is seen that at 9:00 am there is much improvement in power values by tracking panel techniques compared to fixed panel. But as time goes on this difference in power between this two technology decreases. After that when the sun rotates more towards west this difference increases again.

In the fixed cell, the highest power generated from the panel is 12.04 watt at 12:30 pm and the smallest value is 4.83 watt at 5 pm as it shown in table 1.1.

In the tracking-single axis PV module, the highest power generated from the panel is 15.09 watt at 12:00 pm and the smallest value is 5.48 watt at 5 pm as it shown in table 1.2.

In the dual- axis tracking PV module, the highest power generated from the panel is 15.59 watt at 12:00 pm till 12:30 pm and the smallest value is 10.08 watt at 6 pm as it shown in table 1.3.

5.2 Relation between Current Generation and Time

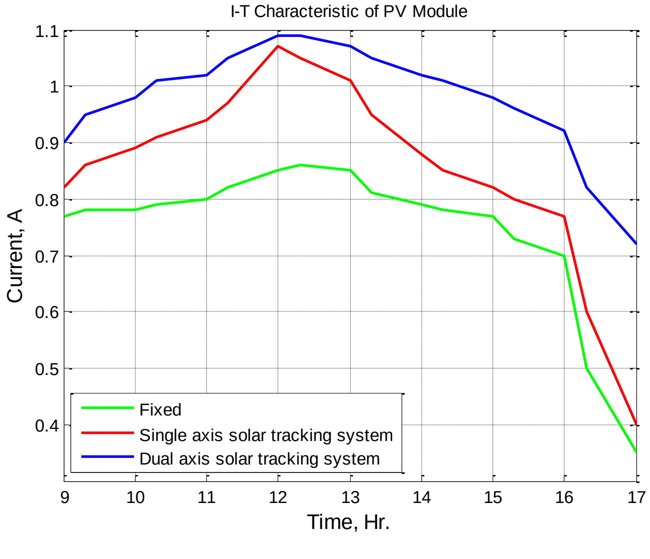

Fig. 12, The Current characteristics versus time for all cases

The next few tables shows the current and time values received from both fixed and tracking panel techniques for different times in a day.

In the fixed cell, the highest current generated from the panel is s 0.86 amps at 12:30 pm and the smallest value is 0.35 amps at 5 pm as it shown in table 1.1.

In the tracking-single axis PV module, the highest current generated from the panel is 1.07 amps at 12:00 pm and the smallest value is 0.4 amps at 5 pm as it shown in table 1.2.

In the dual- axis tracking PV module, the highest current generated from the panel is 1.09 amps at 12:00 pm till 12:30 pm and the smallest value is 0.72 amps at 5 pm as it shown in table 1.3.

Table.1.3 shows voltage, current, power and the time characteristics for the Fixed Cell

Status	Fixed Cell		
Date	16/8/2019		
Temperature	37 C		
Rain	0 mm		
Reads	V	I	P
Hour	Volt	Ampere	Watt
9 – am	14	0.77	10.78
9.30 – am	13.8	0.78	10.76
10 – am	14.1	0.78	11.00
10.30 – am	13.9	0.79	10.98
11 – am	14	0.80	11.2
11.30 – am	14	0.82	11.48
12 - pm	13.8	0.85	11.73
12.30 - pm	14	0.86	12.04
1 – pm	13.8	0.85	11.73
1.30 – pm	13.7	0.81	11.1
2 – pm	13.9	0.79	10.98
2.30 – pm	14	0.78	10.92
3 – pm	13.8	0.77	10.63
3.30 – pm	14	0.73	10.22
4 – pm	14	0.70	9.80
4.30 – pm	13.9	0.50	6.95
5 – pm	13.8	0.35	4.83

.

Table.1.4 shows the voltage, current, power and the time characteristics for the Single – axis tracking PV module.

Status	Single - axis tracking PV module		
Date	17/8/2019		
Temperature	37 C		
Rain	0 mm		
Reads	V	I	P
Hour	Volt	Ampere	Watt
9 – am	13.9	0.82	11.4
9.30 – am	14	0.86	12.04
10 – am	14	0.89	12.46
10.30 – am	14	0.91	12.74
11 – am	13.9	0.94	13.07
11.30 – am	13.9	0.97	13.48
12 - pm	14.1	1.07	15.09
12.30 - pm	14.1	1.05	14.81
1 – pm	13.9	1.01	14.04
1.30 – pm	13.8	0.95	13.11
2 – pm	13.8	0.88	12.14
2.30 – pm	14.2	0.85	12.07
3 – pm	13.9	0.82	11.40
3.30 – pm	14	0.80	11.20
4 – pm	13.9	0.77	10.70
4.30 – pm	13.8	0.60	8.28
5 – pm	13.7	0.40	5.48

Table.1.5 shows the voltage, current, power and the time characteristics for the Dual – axis tracking PV module.

Status	Dual – axis tracking PV module		
Date	25/8/2019		
Temperature	36 C		
Rain	0 mm		
Reads	V	I	P
Hour	Volt	Ampere	Watt
9 – am	14.1	0.90	12.69
9.30 – am	14.0	0.95	13.3
10 – am	14.1	0.98	13.82
10.30 – am	14.0	1.01	14.14
11 – am	13.9	1.02	14.18
11.30 – am	14.0	1.05	14.70
12 - pm	14.3	1.09	15.59
12.30 - pm	14.3	1.09	15.59
1 – pm	13.8	1.07	14.77
1.30 – pm	14.1	1.05	14.81
2 – pm	14.0	1.02	14.28
2.30 – pm	14.3	1.01	14.44
3 – pm	14.0	0.98	13.72
3.30 – pm	14.1	0.96	13.54
4 – pm	13.8	0.92	12.70
4.30 – pm	13.9	0.82	11.40
5 – pm	14.0	0.72	10.08

6. ANALYSIS

The first research for Deepthi.S, Ponni.A , Ranjitha.R, R. Dhanabal (2013) achieved 25% power efficiency, the second research for Jing-Min W. and Chia-Liang L. (2013) achieved 28.31% power efficiency , the third research for Shyngys A., Amangldi B., Seitzhan O., and Zhanatovich K. (2013) achieved 31.3% power efficiency, the fouth search for Mahir.A, Sanzidur.R, Sayedus.S and Mohammad.A (2014) achieved 25.62% power efficiency, the fifth search Betha .V, Savita .N, Pankaj .S, Doppllapudi .R (2016) achieved 25% power efficiency, the sixth search Priyanka M., Akshay D. (2016) achieved 33.99%.This project succeeds to achieve 36% power efficiency calculated for dual –axis solar tracker more than the fixed amount.
The recommendation for using cooling system for the PV panel because we notice that the power generated is inversely proportional with the heat of the PV solar panel and this effect badly on the power verses time diagram.

7. CONCLUSION

Dual solar tracker has been designed to improve energy generated performance to new levels. The energy generated is the overall system efficiency considering to the all hardware components connected to the system. The Dc motors, relays and other electronic components consume about 13% of the total power generated so if the system is tasted regardless to the power consumed in the hardware components the energy generated performance will be increase to be about 49%. The smart model obtains the maximum energy from the sun so the PV solar panel has to move in correct direction with correct angle and make the panel perpendicular to the sun in all circumstances also the tracker is using a limited number of components fitting in the small package so the tracker is considered to be cheap. Finally the tracker is environmentally friendly.
The future view for this project is to use smaller DC motors and to make performance better so the energy consumed will be lower.

REFERENCES

1- S. R. Nayak and C. R. Pradhan. (2012).”Solar Tracking Application”, IOSR Journal of Engineering (vol.2, no.6, pp. 1278-1281).
2- F.R. Rubio, M.G. Ortega, F. Gordillo and M. Lo´pez-Martı´nez. (2007). “Application of new control strategy for sun tracking”, Energy Conversion Mangment (pp. 2174-2184).
3- C. Saravanan, M. A. Panneerselvam and I. W. Christopher. (2011). “A Novel Low Cost Automatic Solar Tracking System”, International Journal of Computer Applications (vol.31, no.9, pp. 62-67).
4- A. Ponniran, A. Hashim and A. Joret. (2011). “A Design of Low Power Single Axis Solar Tracking System regardless of Motor Speed”, International Journal of Integrated Engineering (vol.3, no.3, pp. 5-9).
5- K.K. Chong and C. W. Wong.(2009). “General formula for one- axis sun tracking system and its application in improving tracking accuracy of solar collector”, Solar Energy (vol.83, no.3, pp. 298-305).
6- A. Ponniran, A. Hashim and H. A. Munir. (2011). “A Design of Single Axis Sun Tracking System”, In Proceedings of the 5th International Power Engineering and Optimization Conference, Selangor, Malaysia: 6-7 (pp. 107-110).
7- N. Barsoum. (2011). “Fabrication of Dual-Axis Solar Tracking Controller Project”, Intelligent Control and Automation (vol.2, pp. 57-68).
8- N. Barsoum and P. Vasant. (2010). “Simplified Solar Tracking Prototype”, Global journal on technology and optimization (vol.1, pp. 38-45).
9- Prabodh and S. Kumar. (2011). “Design, Development and Performance test of an Automatic Two-Axis Solar Tracker System”, In Proceedings of 2011 Annual IEEE India Conference, Hyderabad, India (pp.1-6).
10- S. Dasgupta, F. W. Suwandi, S. K. Sahoo and S. K. Panda. (2010). “Dual Axis Sun Tracking with PV Cell as the Sensor, Utilizing Hybrid Electrical Characteristics of the Cell to Determine Insolation”. In Proceedings of 2010 IEEE International Conference on Sustainable Energy Technologies, Kandy, Sri Lanka (pp. 1–5).
11- Z. Yan and Z. Jiaxing. (2010). “Application of Fuzzy Logic Control Approach in a Microcontroller-Based Sun Tracking System”, In Proceedings of 2010 WASE International Conference on Information Engineering, Beidaihe, China (pp. 161-164).
12- G. Ozuna, C. Anaya, D. Figueroa and N. Pitalua. (2011). “Solar Tracker of Two Degrees of Freedom for Photovoltaic Solar Cell Using Fuzzy Logic”, In Proceedings of the World Congress on Engineering 2011, London, UK (vol.2, pp. 1410–1413).
13- G. Li, X. Shi, C. Fu and G. Zhou. (2008). “Design and Implementation of a Novel MPPT Controller Based on Sun Tracking Technology”, In Proceedings of the 11th International Conference on Electrical Machines and Systems, Wuhan, China (pp. 2611–2615).
14- A. Hanieh. (2010). “Solar Photovoltaic Panels Tracking System”, In Proceedings of the 6th WSEAS International Conference on Dynamical Systems and Control, Sousse, Tunisia (pp. 30–37).
15- M. Serhan and L. El-Chaar. (2010). “Two Axis Sun Tracking System: Comparison with a Fixed System”, In Proceedings of International Conference on Renewable Energies and Power Quality, Granada, Spain.
16- A. S. Al-Ammri, F. I. Al-Attar and Farouk F. Ahmed. (2015). “Performance Test of Two axis Solar Tracker System with Distinct Tracking Strategies”, AASCIT Journal of Energy August (vol.2, no.5, pp. 57-60).
17- T. S. Zhan, W. M. Lin, M. H. Tasi, and G. S. Wang. (2013). “Design and Implementation of the Dual axis Solar Tracking System”, IEEE 37th Annual Computer software and Application Conference (pp. 276- 277).

18- H. L. Tsai, Ci-Siang Tu and Yi-Jie Su. (2008).”Development of Generalized Photovoltaic Model Using MATLAB /SIMULINK”, Proceedings of the World Congress on Engineering and Computer Science, San Francisco, USA.
19- Akihiro Oi. (2005). “Design and Simulation of Photovoltaic Water Pumping System”, A Thesis Presented to the Faculty of California Polytechnic State University, San Luis Obispo.
20- John T. Agee and Adisa A. Jimoh. (2010). “Control of a 3KW Polar-Axis Solar Power Platform with Nonlinear Measurements” (pp. 44-50).
21- H. Cooper, 2004, “An Antenna Servo test Bed for the Deep Space Array Network”, IPN Progress Report (pp.42-157).
22- N. Sharmal and B. Sharma. (2016). “An Analysis of Automatic Dual Axis Sun Tracking Solar System”, International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering (Vol. 4, Issue 12).
23- B. Vastav, S. Nema, P. Swarnkar and D. Rajesh. (2016). “Automatic Solar Tracking System using DELTA PLC”, International Conference on Electrical Power and Energy Systems (ICEPES), Maulana Azad National Institute of Technology, Bhopal, India.
24- A. Karthika, S. Jayanthi and G. Deivamani. (2019). “DUAL AXIS SOLAR TRACKING SYSTEM USING ARDUINO”, International Research Journal of Engineering and Technology (IRJET) (vol. 6).
25- S.Magibalan, M.Saravanan, G.Sathees kumar, G.Sathish and C.Saravanan. (2018). “FABRICATION OF DUAL AXIS SOLAR TRACKING SYSTEM”, JETIR (Vol. 5, Issue 3).
26- M. Engin and D. Engin. (2013). “Optimization Mechatronic Sun Tracking System Controller’s for Improving Performance”, In Proceedings of 2013 IEEE. International Conference on Mechatronics and Automation, Takamastu, Japan (pp. 1108-1112).