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Dual Axis Solar Tracking System

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ABSTRACT- *Solar panels are devices that convert light energy into electricity. These devices use sunlight to generate power. The Solar Panels work best when the sun's intensity is maximum. As the angle of the sun varies throughout the day and seasons, this affects the amount of electricity a solar power system will generate. To make the solar power systems work more efficiently, this project will include the design and construction of a microcontroller-based solar panel tracking system. Solar tracking allows more energy to be produced because the solar array can remain aligned to the sun. In this project, we will design a dual-axis solar tracker that allows solar panels to move on two axes, aligned both north-south and east-west. This type of system is designed to maximize solar energy collection throughout the year. This project will make use of the Light Dependent Resistor (LDR) which is important to detect the sunlight by following the source of the sunlight location. Arduino Uno microcontroller is used to control the motors based on LDR. This project discusses the development of a prototype for a dual-axis solar tracking system.*

1. INTRODUCTION

In this project electrical energy from solar panels is derived by converting energy from the sun rays into electrical current.To achieve maximum solar energy through solar panels digital automatic sun tracking system is proposed.

This system is built by using balanced concept of four signals from the different sensors. In this project we used Light Dependent Resistor (LDR) as a light sensor which is optoelectronic device is mostly used in light varying sensor circuit and in light and dark activated switching circuits. If the solar panel is not perpendicular to the sun it will create a variation in light intensities sensed by the light sensors, which are actually separated by divider who creates a shadow on one side of light sensor. Data will be received from the sensors and then the microcontroller Arduino will help in control the movement of the motors via motor driver IC (L298n). To confirm the solar panel is perpendicular towards the Sun Arduino will send the processed data to the Bi-directional DC-geared motor via motor driver IC (L298n). This Motor driver IC(L298n) controls the rotation of the motor either to rotate clockwise or anticlockwise, so solar panels attached to the motors will be reacted according to the direction of the motors. The position of the panel must always be perpendicular to the light source to get maximum intensity of light and zero voltage difference. The position of the sun will changes according to the position of installed solar tracker and make the panel no more perpendicular to the sun which affects the output power. Therefore, dual-axis solar tracking moves the solar panel to be always perpendicular to the sun. The tracker will track the sun throughout the years and maintain the output power generated by the solar panel.

The solar panel is aligned according to the intensity of sunlight under the control of the microcontroller. This microcontroller uses much less voltage than a DC motor, so, we need to Interface a DC motor with the microcontroller, usually H-bridge is the preferred way of interfacing a DC motor. An LDR is a component that has a (variable) resistance that changes with the light intensity that falls upon it.So in this project we have used four LDRs to sense the light falling on the solar panel is perpendicular to all four directions. So, the values of all four LDR should be the same to achieve the correct direction for the solar panel.

A DC geared motor is a device that uses DC electricity to produce mechanical energy. The energy in electric current causes the DC geared motor to spin. Any devices attached to the motor can then take advantage of this spinning motion to create another type of motion. In a gear motor, the magnetic current turns gears that are either in a gear reduction unit or an integrated gearbox. A second shaft is connected to these gears. Gear head or gear motor was used in solar trackers which has the advantage of producing high torque.

The amount of power available to a solar panel is proportional to the amount of light that reaches it. The more light it gets, the more power it produces.By using a single-axis solar tracker can only capture the minimum power tracking sunlight in one direction which is the elevation movements from east to west by rotating the structure along the vertical axis. The use of single-axis tracking can increase the electricity yield by as much as 27% to 32%, but by using a dual-axis solar tracker, it can capture the maximum sunlight in two movements at the same time, so, dual-axis tracking increases the electricity output as much as 35% to 40%. Dual-axis solar trackers allow for two degrees of flexibility, offering a much wider range of motion. The primary and secondary axes work together to allow these trackers to point the solar panels at specific points in the sky.

2. LITERATURE REVIEW

For preparing the best design of Dual Axis Solar Tracker System, a lot of technical papers and reduction processes were studied before deciding upon the most feasible process for the project.

The following list presents a list of the main papers referred to till now regarding the project.

2.1- M.M. Abu Khader observed an experiment under Jordanian climate on the cause of utilizing two-axis sun tracking systems. They found that the power outcome improved by 30-45% compared to a static system for a particular day.

2.2- Dhanalakshmi.V, Lakshmi Prasanna H.N presented a smart dual axis solar tracker. They used arduino uno for the development of their proposed model. After the experiment, they observed that maximum voltage was tracked about 25% to 30% and the generating power increased by 30% compared to a static system.

2.3- M.Kacira overlooked the cause of a dual axis solar tracking with development of power energy compared to a fixed PV panel in Sanliurfa, Turkey. They found that everyday power gain is 29.3% in solar radiation and 34.6% in power generation for a particular day in the month of july.

2.4- In 2017, Chaitali Medhane, Tejas Gaidhani implemented a microcontroller based dual axis model working on a solar panel. Through this model, they observed that the solar panel extracted maximum power if the solar panel was aligned with the intensity of light received from the sun. It improves the power output and also precautions necessary for the system from rain and wind.

2.5- S.B. Elagib, N.H. Osman describes the development of a solar tracking system based on solar maps using microcontroller, which can forecast the real detectable position of the sun by latitude's location for maximizing the efficiency of energy level. Their main motive of this design was to work with minimal operator interaction in the isolated areas where there is lack of network coverage.

3. OBJECTIVE

1. To design a solar tracker that can work in X and y direction (dual axis).

2. Design with systems that work at most efficiency to give the desired output.

3. To install different kinds of sensors that will act as a feedback loop for proper functioning of the overall system.

4. The goal is to design in such a way that different components can be easily added and replaceable if required.

5. Aim is to design to have a simple and efficient algorithm which can better form in any circumstances.

6.More Simplicity in design so that we can add additional panels in case required.

4. PROBLEM DEFINITION

1. Problem is that solar trackers do not fluctuate continuously, which leads to use of unnecessary energy to drive the motors.

2. The constraint is to study different parameters and to summarise their data and to restrict solar plate motions motion in either direction to get maximum sunlight.

3. Challenges are how it works in case there is obstacle in direction of sunlight i.e. clouds in the sky or in case of lighting the idea is to make a smart system that will automatically gets shut down to save energy, the system will have to react wisely in rainy or lightning conditions

4. The different sections of design do not cause hurdles in order to add necessary components which are part of simple and compact design.

5. METHODOLOGY

During our project we have been through the following steps-

1. Study the literature related to Solar tracker design and its improvement in performance referring to various resources.

2. Obtaining design data of existing models of dual axis solar tracker and selecting the preferable design.

3. Selection of all hardware and software aspects of the system.

4. Modelling of the system as per design objectives.

5. Assembling the system as per designed model.

6. Checking the system performance under various conditions.

7. Rectifying any issues and finalizing the system.

6. DESIGN AND DEVELOPMENT

The dual axis solar tracking system is divided into two sub parts: the electrical and mechanical system. The electrical system consists of all the electronic components connected to each other forming a circuit. While the mechanical system consists of all the mechanical components assembled to produce the required motion of the PV panel.

6.1 Electrical System- The electrical system performs three main tasks i.e sensing the signal, analyzing the signal and commanding the movement of the PV panel. The main components in this system are LDRs, Microcontroller, Motor Driver, Geared Motor and PV panel. This system can be explained easily by using a Flowchart.

6.1.1 Flowchart-

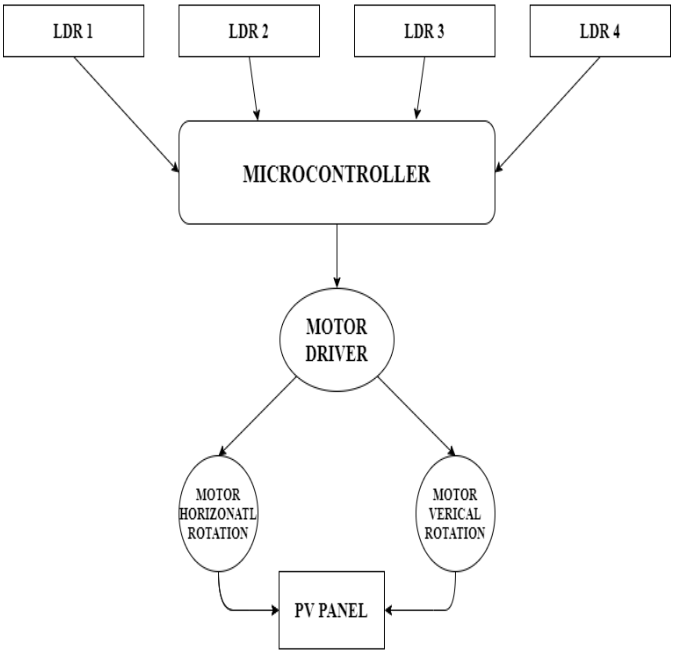

Fig 1: Flowchart.

As we see in the flowchart, there are four Light Dependent Resistors (LDRs) which are placed on a common plate with a solar panel. Light from a source strikes on them by different amounts. Due to their inherent property of decreasing resistance with increasing incident light intensity, i.e. photoconductivity, the value of resistances of all the LDRs is not always same. Each LDR sends an equivalent signal of their respective resistance value to the Microcontroller which is configured by required programming logic. The values are compared with each other by considering a particular LDR value as reference These two-geared motors are arranged in such a way that the solar panel can move along horizontal-axis as well as vertical-axis. The microcontroller sends appropriate signals to the geared motors based on the input signals received from the LDRs. One gear motor is used for tracking along horizontal-axis and the other is for vertical-axis tracking.

6.2 Mechanical System- The solar panel rotates in horizontal and vertical direction and to provide this rotation the mechanical system is designed. This system includes Shaft, Support Plates and Base Plate. The shaft is placed between the two support plates and is connected to a gear motor. The PV panel is glued to the shaft to provide vertical movement to the panel. The horizontal movement is provided by the support plates and base plate in which the Support plates are glued perpendicular to the opposite sides of the base plate. To connect these components with the Gear motor a hole is drilled on the base plate to move the whole system on the horizontal axis.

Fig 2 : Solar Tracking along both axes.

7. COMPONENTS

Sr.No.	Component Names	Component Description	Quantity
1	LDR Sensor		4
2	IR Sensor	STL015V1_0	4
3	Connecting Wires		
4	Arduino UNO	Atmega328 P	1
5	Motor Driver	L298	1
6	Gear Motor	10 rpm	2
7	Battery	Hi-Watt 9V	2
8	Battery Caps		2
9	Base Plate	Wooden	1
10	Supporter Plates	Metal/ Wooden	2
11	Motor Shaft	Metal Rod	1
12	Solar Plates	4V, 60maH Output 70*70m	4

13	Capacitor	100 microFarad	1
14	Voltage Regulator	780S	1

8. SOFTWARE AND EQUIPMENTS

Assembly language is considered to be the best for projects that need minimum memory, the highest execution speed, and precise control of peripheral devices but since writing in this language is a tedious task with more knowledge in C programming, we choose to write our source code in the C language.This section is intended to give some basic introduction and useful information about the software and tools that we employed in to develop our system.

8.1 PROGRAM

```
void setup() {

// initialize digital pin 13 as an output.

pinMode(2, INPUT);

pinMode(3, INPUT);

pinMode(4, INPUT);

pinMode(5, INPUT);

pinMode(6,OUTPUT );

pinMode(7,OUTPUT );

pinMode(8,OUTPUT );

pinMode(9,OUTPUT );

}

// the loop function runs over and over again forever

void loop()

{

if( digitalRead(2)&&digitalRead(3)&&digitalRead(4)&&digitalRead(5)==HIGH)

{

digitalWrite(6,LOW);

digitalWrite(7,LOW);

digitalWrite(8,LOW);

digitalWrite(9,LOW);

}

else if( digitalRead(2)&&digitalRead(4)==HIGH)

{

digitalWrite(6,HIGH);

digitalWrite(7,LOW);

digitalWrite(8,HIGH);

digitalWrite(9,LOW);

}

else if( digitalRead(3)&&digitalRead(5)==HIGH)

{

digitalWrite(6,LOW);

digitalWrite(7,HIGH);

digitalWrite(8,LOW);

digitalWrite(9,HIGH);

}

else if( digitalRead(2)&&digitalRead(5)==HIGH)

{

digitalWrite(6,HIGH);

digitalWrite(7,LOW);

digitalWrite(8,LOW);

digitalWrite(9,HIGH);

}

else if( digitalRead(3)&&digitalRead(4)==HIGH)

{

digitalWrite(6,LOW);

digitalWrite(7,HIGH);

digitalWrite(8,HIGH);

digitalWrite(9,LOW);

}

else if( digitalRead(2)==HIGH)

{
```

```
digitalWrite(6,HIGH);
digitalWrite(7,LOW);
digitalWrite(8,LOW);
digitalWrite(9,LOW);
}
else if( digitalRead(3)==HIGH)
{
digitalWrite(6,LOW);
digitalWrite(7,HIGH);
digitalWrite(8,LOW);
digitalWrite(9,LOW);
}
else if( digitalRead(4)==HIGH)
{
digitalWrite(6,LOW);
digitalWrite(7,LOW);
digitalWrite(8,HIGH);
digitalWrite(9,LOW);
}
else if( digitalRead(5)==HIGH)
{
digitalWrite(6,LOW);
digitalWrite(7,LOW);
digitalWrite(8,LOW);
digitalWrite(9,HIGH);
}
else
{
digitalWrite(6,LOW);
digitalWrite(7,LOW);
digitalWrite(8,LOW);
digitalWrite(9,LOW);
}
}
```

8.2 SOFTWARE IMPLEMENTATION

The software implementation consists of coding the algorithm of the tracking system in the Arduino UNO environment and uploading it in the microcontroller. The algorithm is based on the analog values returned by the left LDR and the right LDR, as well as the top LDR and bottom LDR. For tracking, the average values from two right LDRs and two left LDRs are compared and if the left set of LDRs receive more light, the horizontal gear motor will move in that direction (Rotates Clockwise(CW)). The gear motor will continue to rotate until the difference result is between a positive threshold value (10) and a negative threshold value (-10), which means that the solar tracker is approximately perpendicular to the light source. If the right set of LDRs receive more light, the horizontal servo motor moves in that direction (Rotates Counterclockwise (CCW)) and will continue to rotate until the difference result is between 10 and -10. The same way is used for elevation tracking. We also determined the average radiation between the four LDRs, the idea being that at the end of the day, when the solar projection is null, the solar tracker returns to its initial position, waiting for a new day. At noon, when the sunlight is at maximum, the gear motors must be stopped. However, we found that the resistance values of the LDRs are not the same, even if they have the same reference and have been placed at the same right at noon in front of the sun. This means that the readings of the LDR voltages are not equal. Therefore, the difference between the average value of the left set of LDRs and the average value of the right set of LDRs will be unstable around zero, in which case the gear motor will constantly turn. This explains the use of the threshold value as a hysteresis band in the algorithm, which aims to reduce the power consummation and assuring smooth moves of the gear motor. That means if the difference result is in the hysteresis band, the horizontal gear motor always stops. And if the difference result is outside the hysteresis band ([-10, 10]), the gear motor will start to rotate CCW or CW.. The same principle is used for vertical gear motor operation. The use of the average values and the threshold in the algorithm make the solar tracker robust and also does not consume too much energy. The used algorithm is based on simple instructions that do not require extensive calculations. Low- cost microcontrollers can easily implement this algorithm in order to reduce the system cost.

9. ASSEMBLY AND OPERATION

9.1 ASSEMBLY

Solar tracking designs are often structured to suit the seasonal solar energy variation of the target environment. A number of studies came up with unique designs such as the Azimuth Altitude Dual Axis Solar Tracker which incorporates four photovoltaic sensors that provide inputs for the microcontroller. The microcontroller reads the sensor output and based on the read data the microcontroller gives an output to the motor driver. The motor driver controls the direction and rotation of the geared DC motors. The solar Tracking system has the following three subsystems which perform unique roles: 1. An input sensor stage that converts received solar energy to a voltage. 2. A control stage which makes decisions and determines the extent and direction of the solar panel movement. 3. The driving mechanism performs the physical solar panel movement.

A) INPUT SENSOR STAGE

In this stage the components solar panel, voltage regulator, capacitor and usb cable are used. These components are connected such that the solar power is converted into a usable power supply of required voltage. The solar panels are connected in series to increase the overall output voltage. The solar panels are connected to a capacitor of 1000 microFarad. Capacitor is a passive 2 terminal device used to store energy electrostatically in an electric field. It is connected to smoothen the power supply. The capacitor is further connected to the voltage regulator. It consists of three terminals (out, in and gnd) and is used to automatically maintain a constant voltage. The usb cable is connected to the output terminal of the voltage regulator.

B) CONTROL STAGE

This stage consists of the microcontroller in our case Arduino UNO, 4 LDR's and 4 IR sensors. The LDR's are very responsive to light when the light is stronger then the resistance is lower which means when the light intensity increases then the value of resistance for the LDR will be decreased drastically to below 1k. These LDR's are connected to the IR sensors. IR sensors consist of photodiodes which receive the Infrared rays reflected by an object. In our project this photodiode is replaced by the LDR's so the change in resistivity is amplified by the op-amp which is used by the Arduino UNO. The microcontroller of our system is the Arduino UNO. The output of LDR is connected to four input terminal pins of the Arduino. The Arduino works on a program fed into it and uses the input to rotate the geared motors as desired through the motor driver.

C) DRIVING MECHANISM

The driving mechanism consists of components: the motor driver, geared DC motors, motor shaft, support plates, etc. The output of the Arduino is given to the input of the motor driver whose 2 output motor driving terminals are connected to the two motors which rotate according to the signal received. The 2 motors are of 10 rpm for slow and smooth motion of the solar plates. The support plates are used to create a structure such that the plates could be placed in a manner so that the motor can rotate the plates in two directions (updown)and(left-right).

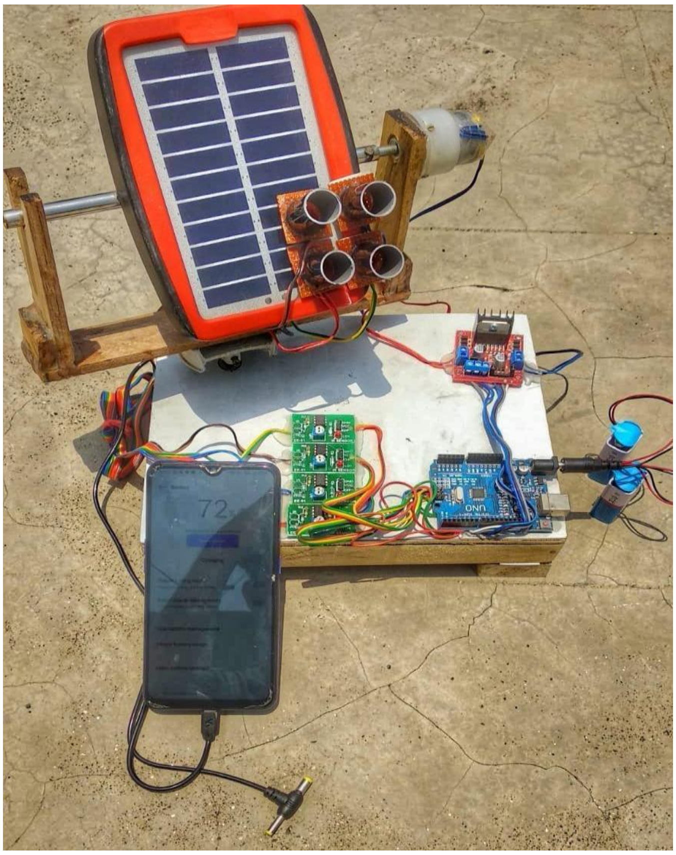

Fig 1: Working model of Dual Axis Solar Tracking System.

9.2 CONSTRUCTION

STEP 1 : First we have to construct a structure frame for the solar panel which is capable of rotating along both axes.

STEP 2 : Now mount the solar panel on the frame and then place the four LDR setup on it.

STEP 3 : Now to make a circuit to control the structure, make the following circuit:

1. Connect all four LDR to the IR-sensors by replacing its photodiode.

2. Connect the Vcc of the motor driver (L298N) to the +5V of Arduino.

3. Connect Vcc of all four IR-sensors to the +5V of the motor driver (L298N).

4. Common the GND of all IR-sensors, Arduino, and motor drivers.

5. Connect the OUT of all IR-sensors to the Digital Pin 2, 3, 4, and 5 of the Arduino respectively.

6. Connect IN1, IN2, IN3, and IN4 of the motor driver to the Arduino Digital Pin 6, 7, 8, and 9 respectively.

7. Connect OUT1 and OUT2 of the motor driver to one Gear motor. And OUT3 and OUT4 to another Gear motor.

8. Connect a 9V Battery to the Arduino and a 12V Battery to the motor driver(L298N).

The completed circuit will look like the figure given below:

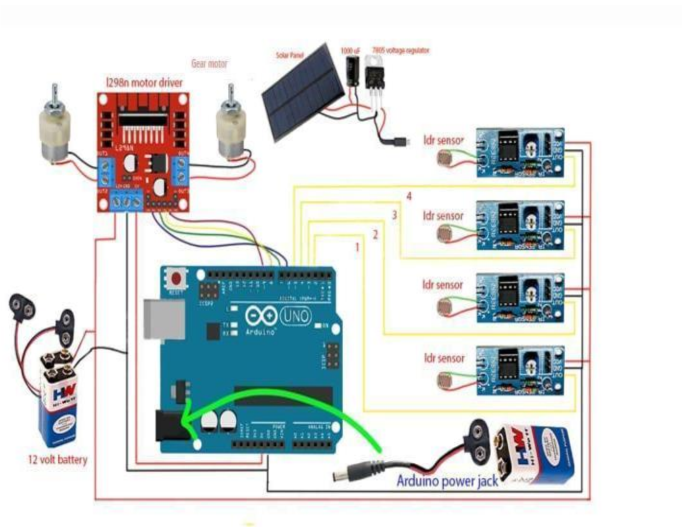

Fig 2 : Circuit Diagram

STEP 4 : Now upload the code using USB cable to the Arduino, and the prototype is ready to work.

9.3 OPERATION

The main operation of the dual axis solar tracker system is very easy to understand. As we know the LDR's sense the change in intensity of light the change in resistance is amplified by the opamp in the IR sensor which sends the signal in binary form to the Arduino UNO. This signal is used by the microcontroller according to the program fed into it to rotate the motors through the motor driver into the direction desired. The motors are placed such that left to right and up to down motions are acquired, for this one motor is placed at the bottom of the solar panel while the other is placed horizontally to the solar panel through the support plates and motor shaft. Now, the algorithm used to rotate the panel is such that it compares the intensity change in the LDR's. The microcontroller ensures that all the LDR's have the same intensity of light on them when there is an error detected, that is if there is change in intensity of light in the LDR's the controller rotates the panel towards the LDR which sensed this change and thus acquires stability again. The microcontroller performs a computation and gives a corresponding output to the mechanical system to position the solar panel for maximum light reception. The four light dependent resistors are placed side by side separated by a thin wall. The concept of the thin wall is to allow shadow to be casted on one side and light to reflect on the other side so as to determine where the light source is coming from so that the solar panel can be turned in the direction of the light source. The motor driver consists of internal circuits which will be powered by a 9V battery and is used to run the two gear motors at constant speed. The solar panel of 16V is used to give power output. The power output is made constant by using capacitor and voltage regulator. The usb cable is used to get the power through the system. The working model of Dual Axis Solar Tracking System is operational.

10. OBSERVATION

The readings for both the static panel and dual-axis tracker are taken on 14 April 2021 from morning 8 am to evening 6 pm for every one hour. The Climatic conditions recorded on that day are as follows-Dry climate and temperature of 35 degree Celsius (high). The following readings are tabulated and a graph was generated as follows-

HOURS	STATIC PANEL			DUAL AXIS		
	V	mA	mW	V	mA	mW
08.00 AM	8.2	0.7	5.74	10.22	2.90	29.63
09.00 AM	8.4	1.15	9.66	10.40	3.0	31.2
10.00 AM	8.7	1.29	11.2	10.45	3.02	31.55
11.00 AM	9.8	1.88	18.4	10.5	3.20	33.6
12.00 PM	9.8	2.23	21.8	10.63	3.18	33.8
01.00 PM	10.4	2.50	26	10.81	3.33	35.99
02.00 PM	10.7	2.96	31.6	10.75	3.38	36.33
03.00 PM	9.9	2.75	27.2	10.40	3.31	34.42
04.00 PM	8.4	2.6	21.8	10.53	3.30	34.74
05.00 PM	8.2	2.12	17.3	10.40	3.10	32.24
06.00 PM	8.0	1.42	11.3	10.30	2.90	29.87
AVERAGE POWER			18.3			33.03

	8	9	10	11	12	13	14	15	16	17	18
Static Panel	5.74	9.66	11.22	18.42	21.85	26	31.67	27.22	21.84	17.38	11.36
Dual Axis System	29.63	31.2	31.55	33.6	33.8	35.99	36.33	34.42	34.74	32.24	29.87

Fig 1 : Graphical representation.

11. RESULT

The proposed model of the dual axis solar tracker is capable of tracking the sun throughout the year. The dual axis tracker provides higher output power when compared to single axis tracker and fixed panel. According to the measured readings the efficiency of the dual axis tracker is found to be 81.68% higher than that of fixed panel.

12. CONCLUSIONS

From this study the main conclusions obtained are:

1. Proposed system is low cost and compact as compared to the other tracking systems in use for the same application.

2. It is very easy to program and modify because it is Arduino based and no external programmer is required. 3. The designed system is automatic and provides better efficiency of the panel.

4. Reflection on the Solar panel has been decreased and the efficiency of solar energy generation is increased .

5. Solar trackers are slightly more expensive than their stationary counterparts, due to the more complex technology and moving parts necessary for their operation. But solar trackers generate more electricity in roughly the same amount of space needed for fixed tilt systems, making them ideal for optimizing land usage.

The purpose of renewable energy from this paper offered new and advanced ideas to help the people. It has been proved through previous research that a solar tracking system with single-axis freedom can increase energy output by approximately 20%, whereas the tracking system with double axis freedom can increase the output by more than 40%. Therefore, this work in this paper is to develop and implement a dual-axis solar tracking system with both degree of freedom and the detection of the sunlight using sensors. The proposed system is eco-friendly.

12. FUTURE SCOPE

➢ Challenges are how it works in case there is obstacle in direction of sunlight i.e. clouds in the sky or in case of lighting the idea is to make system smart that it automatically gets shut down to save energy.

➢ IoT based support is provided so we can fetch amount of power generated in our computer system or smartphone in real time.

➢ Aim is to develop system that is able to operate without battery using its own power generated through sunlight.

➢ More Simplicity in design so that we can add additional panel, if required.

➢ Idea is to make a project that match industrial standards and act as an additional blueprint for the planned future project of India named (One Sun One World One Grid)

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