NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY

School of Electrical Engineering and Computer Sciences

ELECTRICAL CIRCUIT ANALYSIS
(EE-211)

PROJECT REPORT

Title: DUAL AXIS SOLAR TRACKING SYSTEM

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Abstract

Because of the high demand for green and sustainable energy, research on solar energy harvesting has become one of the most popular engineering research topics, particularly on renewable energy. Many research studies are devoted to the design and development of efficient and dependable solar power systems. Solar tracking and control have become one of the most important components of a solar power system for improving and optimising efficiency of solar energy absorption.

Tracking helps in the wider projection of the panel to the Sun with increased power output. It could be dual or single axis tracker. Duality ragged up with better compatibility as far as tracking of the sunlight from both the axis is concerned. Commercially single tracker is cheaper to use through booming of power is considerable and therefore a minuscule increase in the price is worthy and acceptable, provided maintenance cost should float around on an average level.

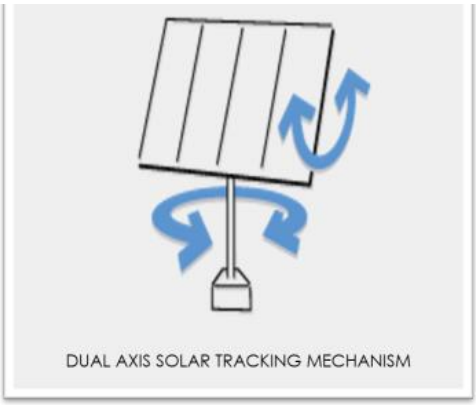
This project's goal is to evaluate the performance of a dual-axis solar tracking system. It is made up of three major structures: the inputs, the controller, and the output. The LDRS provides input, the Arduino serves as the controller, and the servo motor serves as the output. The main controller in this project, the Arduino, receives analogue input from LDRs and converts it to a digital signal using an analog-to-digital (A- D) converter. The controller then sends the signal to the servo motor to determine the position of the solar panel. The performance and characteristics of the solar tracker device are experimentally analysed.

Chapter # 1: Introduction

1.1 Project Definition

Sustainable power source gather by solar panel in form of sunlight is converted in to power which would then be able to be utilized to give capacity to electric loads. Several individual solar cells are contained by solar panels which are themselves made out of layers of silicon, phosphorous which gives the negative charge, and boron which gives the positive charge. Solar panels ingest the photons and in doing as such start an electric flow. The subsequent energy produced from photons striking the outside of the solar panel enables electrons to be struck out of their nuclear circles and discharged into the electric field created by solar cells which at that point move these free electrons into a directional flow and this procedure is called Photovoltaic effect.

The aim of this project is to ensure the sunlight rays are falling perpendicularly on the solar panel to give the maximum solar energy. Normally a solar panel converts only 30 to 40 per cent of the incident solar radiation in to electrical energy. An automated system is required to get a constant output, which should be capable to constantly rotate the solar panel. The sun tracking system was made as a prototype to solve the problem. Solar trackers are devices used to orient photovoltaic panels, reflectors, lenses or other optical devices toward the sun. Since the sun's position in the sky changes with the seasons and the time of day, trackers are used to align the collection system to maximize energy production.



DUAL AXIS SOLAR TRACKING MECHANISM

The unique characteristic of this system is that instead of taking the earth as its reference, it takes the sun as a guiding source. The sunlight is monitored by the active sensors and rotates the panel towards the direction where the intensity of sunlight is maximums.

1.1 Project Objectives

Our project is based on the following objectives:

- Ability to manually rotate the tracker with the usage of a controller alongside theoverall ecliptic.
- The solar panel tracks the sun from east to west mechanically for maximum intensityof light.
- To consume maximum solar energy through solar tacking panel.
- Design and improve a solar panel
- High performance and efficiency of Solar panel.

1.4 Project Applications

The main applications for this project are;

- It could be fabricated and increased in dimensions to be used during camping forseveral purposes.
- It can be modified to make a concentrated solar-hybrid form which can save almostall the cost of running it.
- It can be use domestically and on largest scales.
- It can implement on large PV panels.
- It can also be used for power generation at remote places.
- It may be used as domestic backup power systems.
- It can be used for solar street lightning system.
- It may be used in water treatment technologies and solar heating.

Chapter # 2: Literature Review

2.1 Project Background

Fossil fuels have been facing reduction with passing time and generation of power is becoming a bigger challenge. Talking about renewable sources, the conversion of solar energy into electrical energy by using photovoltaic panels is prioritized. The watts delivered by the solar panel are directly proportional to the relative angle of the sun in reference to the earth. Thus, the delivery of the watts is reduced when tis relative angle changes. In this regard the efficiency of the PV panel can be increased by using solar tracking system. The pay load is moved towards the sun by solar trackers throughout the day.

This project highlights different forms of tracking system as well as their pros. The main types of tracking systems are either a single axis solar tracker or a dual axis solar tracker. The single axis system depends on a single horizontal or vertical axis. The direction of the axis is based on the location of the system where it is going to be placed. The dual axis is a system that includes both a horizontal and vertical axle. This type of tracking system can track the motion of the sun exactly around the world in any location.

2.2 Previous Work

Haneih (2009) conducted a study in Amman Jordan focusing on the demand of the sun tracking for solar panels. This study basically discussed about increasing efficiency of PV panels in dessert regions. The author explained that by using part of the power output of the solar panel two degrees of freedom orientation can be achieved. If we consider the symmetry of the system, the kinematics of the system can be controlled using astronomic calculation. Solar tracking sensors and feedback control loops can be used to add close loop control to the system. This solves the problem of cloudy days. The author further explained that special consideration should be given to the grid arrangement of panels in the collecting plants.

In another study conducted by Rao et al (2012) a project using ARM7 TDMI processor was explained. The processor did the task of gather input from sensor and giving command to the motor to track the sun. ARM7 TDMI processor was used to design and implement closed loop algorithm which form the bases of monitoring controller. This resulted in maximum current from solar panel to increase the energy production.

2.3 Comparative Work

The literature on tracking process for the dual axis sun tracker by a sliding mode control law was reviewed by Rhif et al (2010). The power production can be increased up to 40 percent by using this autonomic dual axis sun tracker. The result showed the usefulness of the sliding mode control in the tracking process, its strength and the high quality of the sliding mode observer.

It was stated by Madhu et al (2012) that the sun is tracked from east to west by singleaxis tracker whereas the daily east to west movement of the sun and the seasonal declination movement was tracked by two axis tracker. A large area of sunlight is focused into a small beam by using lenses or mirror. Sunlight is converted into electric current using the photo electric current by PV. Test results suggest that the increase in electricity efficiency of monitoring solar plate in everyday days is 26 to 38% compared to fixed plate. And during cloudy or rainy daysit's varies at any degree

Generally, solar panels are motionless and do not monitor the movement of the sun. In this project a solar tracker device that tracks the movement of sun throughout the sky and tries to maintain the solar panel perpendicular to the rays, ensuring that the maximum quantity ofsunlight is incident on the panel during the day. The solar tracking system starts following thesun right from sunrise, in the course of the day until night, and starts all over again from thedawn next day. The solar panels are powerful means of storing energy, their performance at doing so is immediately associated with their perspective with the sun. Because PV cells get the maximum power from facing the solar, a stationary solar panel collects less sunlight one which follows the sun throughout the sky. In this project the dual axis system is used that includes both a horizontal and vertical axis.

Chapter # 3: System Design

3.1 Design Constraints and Design Methodology

3.1.1 : Sustainability:

As an entire system design should be capable of preserve it self physically and functionally and it is simple not fragile system apart from the solar panels as they require special care. To make up the expense of the device the system needs to work for quite a while. The unique characteristic of this system is that instead of taking the earth as its reference, it takes the sun as a guiding source. The sunlight is monitored by the active sensors and rotates the panel towards the direction where the intensity of sunlight is maximums.

3.1.2 : Environmental Concern:

There will be abundant availability of solar energy in the nature because the sun emits energy at an extremely large rate. The world's energy demand could be fulfilled if all the solar energy is converted in to useable forms. Solar energy can be converted to more usable energy forms through solar tracking solar panel. There is unprecedented interest in renewable energy, particularly solar energy. Our project solar tracking solar panel highlights the use of abundant source of energy which is going wasted unused.

3.1.3 : Economic:

The major constraint of the project was the financial concerns related with the creation of the system. Solar energy can reduce the electricity bills of households since solar energy can be used to supplement other resources of energy. One might install a solar tracking system with a solar panel considering the advantages like the efficiency increases by 20-60% that is equivalent to more money. The space requirement is reduced for solar park and they sustain the same outputthe profit time of the investment is reduced. Long-term maintenance concerns for tracking systems are drastically reduced by advancement in technology and reliability in electronics and mechanism.

3.1.4 : Safety:

Our design has also been planned to sustain safety at all times during its functional lifespan. The solar tracking solar panel system is securely mounted to prevent it from becoming afailing hazard.

3.2 Engineering Design Standards

For any project to have strong standing in the engineering world engineering standards should be applied in it. The components used in solar tracking solar panel are listed below with their engineering standards and details.

Figure # 3.1: Technical specs of servo motor SG90

Table # 3.1: Components and Weight

Weight	**13.4g**
Dimension	22.8×12.2×28.5mm
Stall torque	2.0kg/cm (4.8V); 2.2kg/cm (6V)
Operating speed	0.09sec/60degree (4.8V); 0.08sec/60degree (6.0V)
Operating voltage	4.8V~ 6V
servo wire length	25 cm

3.3 Product Subsystems and selection of Components

3.3.1 Tools

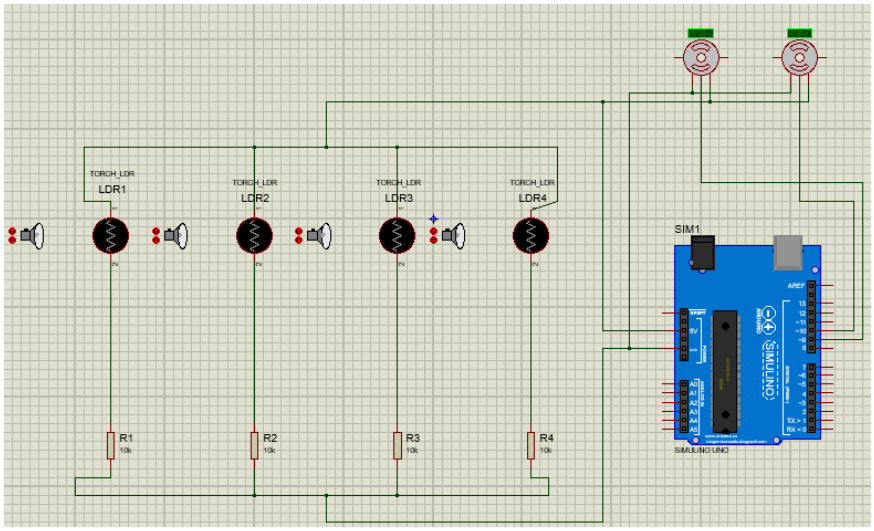
- Wire Stripper/ Cutter
- Several Small Screw Drivers
- Rubber Feet Cable Wrap or Twist Ties highly recommended

3.3.2 Electronics:

- 5.5V Solar Cell
- Arduino Uno + USB Cable
- Arduino Sensor Shield
- x 9g Metal Gear Servos
- 1 x 5 Port Terminal Block
- 1 x 4 Port Terminal Block (or 3 port will do)
- x 10K Ohm Resistors
- x Light Detecting Resistors
- x JST Socket Connector Cables
- Jumper Wires

3.4 Working:

- LDR'S are used as the main light sensors .Two servo motors are fixed to the structure that holds the solar panel. The program of Arduino, Matlab is uploaded to micro controller
- LDR'S sense the amount of sun light falling on them. Four LDR'S are divided into top, bottom, left and right.
- For east-west tracking, the analog values from two top LDR'S are compared and if the top set of LDR'S receive more light ,the vertical servo will move in that direction.
- If the bottom LDR'S receive more light ,the servo moves in that direction.
- For angular deflection of the solar panel, the analog values from two left LDR'S and two right LDR'S are compared .If the left set of LDR'S receive more light than the right set, the horizontal servo will move in that direction.
- If the right set of LDR'S receive more light, the servo moves in that direction.



Circuit Diagram

3.5 Theory and Theoretical Calculations

3.5.1 Coding Arduino

For solar tracker system to be functional very important step is to code the Arduino. Only after the coding of the arduino which is attached to the system, solar panel will act as solar tracker. For this purpose we will be installing arduino on the mobile phone which will be attached via USB. While programming we will make sure to set our board type to Uno. We will be able to modify and manage the speed and range of the servos and the sensitivity of the sensors with the coding.

```
#include <Servo.h>
Servo horizontal; // horizontal servo
int servoh = 180;
int servohLimitHigh = 175;
int servohLimitLow = 5;
// 65 degrees MAX

Servo vertical; // vertical servo
int servov = 45;
int servovLimitHigh = 60;
int servovLimitLow = 1;

// LDR pin connections
// name = analogpin;
int ldrlt = A0; //LDR top left - BOTTOM LEFT <--- BDG
int ldrrt = A3; //LDR top rigt - BOTTOM RIGHT
int ldrld = A1; //LDR down left - TOP LEFT
int ldrrd = A3; //ldr down rigt - TOP RIGHT

void setup(){
horizontal.attach(9);
vertical.attach(10);
horizontal.write(180);
vertical.write(45);

delay(2500);
}
void loop() {
int lt = analogRead(ldrlt); // top left
int rt = analogRead(ldrrt); // top right
int ld = analogRead(ldrld); // down left
int rd = analogRead(ldrrd); // down right
int dtime = 10; int tol = 90; // dtime=diffirence time, tol=toleransi
int avt = (lt + rt) / 2; // average value top
int avd = (ld + rd) / 2; // average value down
int avl = (lt + ld) / 2; // average value left
int avr = (rt + rd) / 2; // average value right
int dvert = avt - avd; // check the diffirence of up and down
int dhoriz = avl - avr;// check the diffirence og left and rigt
```

```
if (-1*tol > dvert || dvert > tol)
 {
 if (avt > avd)
 {
 servov = ++servov;
 if (servov > servovLimitHigh)
 {servov = servovLimitHigh;}
 }
 else if (avt < avd)
 {servov= --servov;
 if (servov < servovLimitLow)
 { servov = servovLimitLow;}
 }
 vertical.write(servov);
 }
if (-1*tol > dhoriz || dhoriz > tol) // check if the diffirence is in the
tolerance else change horizontal angle
 {
 if (avl > avr)
 {
 servoh = --servoh;
 if (servoh < servohLimitLow)
 {
 servoh = servohLimitLow;
 }}
 else if (avl < avr)
 {
 servoh = ++servoh;
 if (servoh > servohLimitHigh)
 {
 servoh = servohLimitHigh;
 }
 }
 else if (avl = avr)
 {
 delay(5000);
 }
 horizontal.write(servoh);
 }
  delay(dtime);
 }
```

3.6 Manufacturing and Assembling (Implementation)

The current project is based on tracking solar panels. These panels change their orientation in relation to solar radiation. This orientation helps in getting full benefit of optimal angle between solar panels and solar radiations. This increases the efficiency and results in maximum production of energy. A custom Arduino shield, sensor holder and code have been used in this project. Initially, declaration of both servos is done and creation of object. This serves to control the servo motors. To secure the reference servo positions, the variables posx and posy have been used. The working of the motors has been established by selecting a tolerance or a constant value. On the servo object, the servos are attached on digital pins. Pin Mode in used to select analog pins as input. The setting of servos is made to mid-point or original position. This is set with a 1000 ms or 1sec delay. This is helpful in catching up with the user. To read the analog values, three variables are selected. These variables are mapped into integer's value from 0 to 1023. It will stay on its original location if the difference between the two variables is less then tolerance value. Otherwise a movement is shown towards the direction of maximum intensity of light. This is done by increasing or decreasing the values of posx and posy. The loop is repeated. This takes place till a value is achieved which is greater than the minimum tolerance. Position is set to150° if the value becomes greater than 150° and it is kept at30° if the value is less than 30°. These angles are chosen as lower and upper limit angles.

Chapter # 4: System Testing and Analysis

4.1 Experimental Setup, Sensors and data acquisition system

4.1.1 Multimeter

In order to collect data from our project solar tracking solar panel we need to calculateand evaluate all the important parameters. To asses our systems performance need to require. For this purpose, we took the help of our lab technician for the data collection with multimeter. Multimeter is used in our project to find the voltage being produced by the solar panels at many different stages, when solar panel was incident by sunlight. First the voltage checked when sunlight was perpendicular to the solar panel. Second time voltage checked when solar panel wastracking the sunlight. We repeated this process throughout the day time.

Additionally, we are also required to obtain the amount of power it produces which we did it using the $\boldsymbol{P_{OUT} = VI}$ formula. This formula gave us the power output, the power being produced and then we found the power input using$\boldsymbol{P_{IN} = DNI.}$ Then we calculated the efficiency of the system using both of these formulas.

4.2 Results, Analysis and Discussion

2.134watts is the average power obtained from solar panel without tracking and 3.18wattspower is obtained from solar panel with tracking. 41.64% is the improved efficiency neglecting the power consumption of motor. So the proposed dual axis tracking system presents efficient system to connect solar energy which ensures that consumption of energy is more than the fixed solar panel.

In our project the hardware of solar tracking solar panel design and the implementation ofthe design has been proposed. Our result shows that the solar tracking system increases the efficiency of the solar panel. Solar tracking solar panel is completely automatic and it ensures theminimum low cost. So, it is a dual axis system which maximizes the efficiency and can be obtained over a period of time. Normally a solar panel converts only 30 to 40 per cent of the incident solar radiation in to electrical energy. An automated system is required to get a constant output, which should be capable to constantly rotate the solar panel. The sun tracking system wasmade as a prototype to solve the problem. It will be automatic and keeps the panel in forward- facing of sun until that is visible.

Chapter # 05: Challenges and Decision Making

Throughout the project we faced a lot of challenges and problems which needed to be resolved and rectified in order to deliver a successful project. We had to take lot of decisions while working on our project. How to manage time was of the biggest problem which was faced throughout the project. However, we were able to resolve all of these problems efficiently with teamwork. The problems which we faced are as follows.

5.1: Equipment and Device Problems

- **Servo Motor**

  A custom arduino shield, sensor holder and code have been used in this project.Initially, declaration of both servos is done and creation of object. This serves to controlthe servo motors. To secure the reference servo positions, the variables posx and posy have been used. The working of the motors has been established by selecting a toleranceor a constant value. On the servo object, the servos are attached on digital pins

- **Coding Arduino**

  For our solar tracker system to be functional very important step is to code the Arduino. Only after the coding of the arduino which is attached to the system, solar panelwill act as solar tracker. For this purpose installed arduino on the mobile phone which then attached via USB. After several trials we were able to code the arduino.

5.2: Testing & Safety Issues

The test that we run on our project was done in day light. When the sun rays were on their peak to run and charge its battery. The aim was to ensure the sunlight rays are falling perpendicularly on the solar panel to give the maximum solar energy. An automated system was set to get a constant output, which should be capable to constantly rotate the solar panel. The suntracking system was made as a prototype to solve the problem

5.3 : Design Problems

The problem which we faced after completing the solar tracking system was that it was not moving with the rays of sun. Our project was based on tracking system so to ensure the sunlight rays are falling perpendicularly on the solar panel to give the maximum solar energy, we have done several experiments. After three attempts we were able to design an automatedsystem, an automated was set to get a constant output, which should be capable to constantly rotate the solar panel. Another problem that was faced was coding the arduino. For our solar tracker system to be functional very important step is to code the Arduino. Only after the coding of the arduino which is attached to the system, solar panel will act as solar tracker. For this purpose we will be installing arduino on the mobile phone which will be attached via USB. While programming we will make sure to set our board type to Uno.

5.4: Project Bill of Materials & Budget

The table below shows the parts we purchased order and fabricated from the market. It includesthe total amount spent on our project in Saudi Riyals (SAR).

Table # 5.5: Project Bill of Materials

Materials	Cost (Rs.)
Solar panel	100
Servos	600
Coil Screw Small other parts	100
Manufacturing	300
Total Sum	**1100**

Chapter # 6: Project Analysis

6.1 Life-Long Learning

Through our working with the project it is significant to have many effective learning, which reflects lots of benefits and advantages in our life learning. This project was started as a team and to set out achievable goals was our first priority. Before starting a project proper research was conducted regarding the implementation of the plan. We ensured that each member of team had ostensible information on the subject. Proper equipment was utilized for the research. We learned a lot form our blunders throughout the project and tried to work on trial anderror basis.

6.1.1 : Software Skills:

In order to achieve our objective in a professional manner it is very important to use technological advances and skills. At the point when we started our project we alluded to online websites to familiarize ourselves that which designs are in market and how can we improve. Then we designed our project by finding all constraints and started doing simulations. In addition, it is significant to get viable use for working up project's design utilizing the various kinds of software skills and to program technical connections depending on the mechanical and technical powers. With the help of these softwares we were able to solve all the problems smoothly and quickly.

6.1.2 : Hardware Skills:

We used very simple and straightforward hardware skills for our project. All parts which are best suitable for our engineering standards were purchased for manufacturing purpose. However, multimeter is used for calculation and evaluation of system performance that gave us the values of current and voltage. To support the hardware system in operating system the team was professionally provided with database.

6.1.3 : Time Management:

One of the main challenges in the beginning for the team was to manage the time duringworking on project. We had less than four months to complete our project; we managed our time in such a manner that we were able to finish our project and to do testing beforehand. It was necessary to organize our work through team meetings and setting suitable and professional schedule for operating the different parts in the project. Gantt chart plays an important role in helping us managing our time in respect to the different tasks. Team ideas were shared for making the best in suitable assigned time.

6.1.4 : Project Management:

To fulfill any task in a proper manner and on time project management is one of the most important factors. The first thing we did before working on our project was to make Gantt chart. Gantt chart is a kind of project management plan. In that we had specified all the tasks, their due dates and who was responsible for doing those tasks. The task was divided equally among each member and each group member was responsible for his task. It is necessary for each member in the team to focus on the task and give enough time for previewing and reviewing the missions according to the work plan which shows the responsibilities and procedures in all stages.

6.2 Impact of Engineering Solutions

6.2.1 : Society:

The use of solar tracking system is increasing with advancement of technology. The efficiency of solar panels is more important than ever because of the increasing demand for solar energy. The aim of this project is to ensure the sunlight rays are falling perpendicularly on the solar panel to give the maximum solar energy. An automated system is required to get a constant output, which should be capable to constantly rotate the solar panel; it will help society to make use of more reliable energy.

6.2.2 : Economy:

We used simpler and less expensive parts because the cost of manufacturing was a big concern for us during the project. We have used Arduino sensor shield, nut and screws which areeconomically affordable material. This has too fold benefits, less manufacturing and maintenance cost. A simple system has fewer chances of breaking down and therefore leading to less maintenance cost. There is no use of implementing the project if it cannot pay more than its manufacturing cost.

6.2.3 : Environment:

The main implication of this solar tracking system functionality is to ensure environmental preservation. Globally, the production of existing solar panel can be increased by the execution of simple machinery. The idea of investing in solar tracking system is sure to become a promising idea with successful results. This system can assist in struggle against climate change if implemented successfully. Moreover, this economy friendly system can reducethe demand of fossil fuel around the globe.

6.3 : Contemporary Issues Addressed

The issue of global warming has led to the use of scientific technologies that do not promote global warming. Solar tracking systems come under the category of good energyresource. The efficiency of solar tracking system depends on the angle of the axis. This system ensures the maximum accumulation of sunlight by tracking it and motioning along the movement of sun. The solar panel tracks the sun from east to west mechanically for maximum intensity of light. Furthermore, it deals with the issue of modification to make a concentrated solar-hybrid form which can save almost all the cost of running it. It addresses the issue of cost expenses and design of the solar energy panel was also major concern. It must also be taken in consideration that how assembling of every nut, bolt and screw must be done.

Chapter # 7: Conclusion & Future Recommendations

7.1 Conclusion

The current project is based on tracking solar panels. These panels change their orientation in relation to solar radiation to increase the efficiency and results in maximumproduction of energy and helps in getting full benefit of optimal angle between solar panels and solar radiations. The execution of solar tracking system was made clear because of our sufficient research and preplanning of our goals and objectives. The main agenda of this project was to make simple machinery on low cost basis. Trial and error method help us in achieving our goal. We made use of our engineering knowledge in this three month project and were successful in developing and designing low cost solar tracking system. Because the issue of global warming must be controlled by making use of alternatives that are environmental friendly.

7.2 Future Recommendations

The goals of this project were outlined keeping in mind the timeline and resources that were attainable. However this initial design can be subjected to many improvements.

- Initially this design represents a miniature scale model which can be modified into a much larger scale.Easy to bend cables can be used which do not apply any force on the motor when it is rotating the solar panel.
- To get a better tracking precision, a photo transistor with and amplification circuit can be used. Furthermore accuracy can also be increased by utilizing dual axis design versus single axis design.
- Future projects can make use of microcontroller. This microcontroller can serve as standalone unit in the fabricated circuit.
- Single-axis and dual-axis photovoltaic tracking system, with appropriate control systems, the electrical energy can increase from 22-56%, compared to fixed PV system.
- Active tracking systems use electrical drives to move the axis, which can consume a huge amount of electrical energy because of improper control systems. Therefore, it is necessary to optimize the power consumption of electrical drives, which can be done by reducing the number of motor movements.
- Sensor-based photovoltaic tracking systems are more expensive because of additional sensor devices, but provide lower tracking error (0.14), compared to sensor less photovoltaic tracking systems (0.43-).
- Novel innovative tracking systems will include dynamic weather forecasting and cooling of the PV system with wind or water.

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