A Mathematical Approach to Dual-Axis Solar Tracking using Arduino"

Mr.D.Adinarayana Naik[1], Dr.G.Venu Gopal Krishna[2] Mr. Balaji Naik Mudavath[3],Dr.B Srinivas[4], Mr. Ch.Krishnarao Yadav[5],Mr.P.Manmadha Reddy[6]

[1,6] Assistant Professor ©, Department of Electrical and Electronics Engineering, Universisty College of Engineering,JNTUK,India

[2] Assistant Professor © ,Department of Mathematics, Universisty College of Engineering,JNTUK, India

[3] Assistant Professor ©, Department of Mechanical Engineering, Universisty College of Engineering,JNTUK,India

[4] Associate Professor, International School of Technology and Sciences for Women (ISTS) Rajanagaram, Rajamahendravarm,, India

[5] Assistant Professor © ,Department of Electronics and Communication Engineering, University College of Engineering, JNTUK,India

ABSTRACT

The energy extracted from solar photovoltaic (PV) depends on solar insolation. For the extraction of maximum energy from the sun, the plane of the solar collector should always be normal to the incident radiation. The diurnal and seasonal movement of the earth affects the radiation intensity received on the solar collector.

Sun trackers move the solar collector to follow the sun trajectories and keep the orientation of the solar collector at an optimal tilt angle. Energy efficiency of solar PV can be substantially improved using solar tracking system. In this work divided into two stages, which are software and hardware development. In software development, we have to simulate dual axis solar tracker by using four LDR sensors.

While in the hardware development, an automatic solar tracking system has been designed and developed using LDR sensors and DC gear motors on a mechanical structure with gear arrangement.

Two-axis solar tracking has been implemented through active solar tracker based on comparator logic. Performance of the proposed system over the important parameters like solar radiation received on the collector, maximum electrical power per day, efficiency has been evaluated

INTRODUCTION

1.1 Background

Renewable energy technology has seen a large demand because of an increasing awareness of harmful pollutants and greenhouse gases that are associated with the production and burning of fossil fuels for electricity generation. The increased demand had a complementary effect to the cost of renewable energies, making them more accessible. Solar Photovoltaic (PV) systems are projected to reduce in cost by 65% from the year 2015 to 2025.

Electric power production by renewable technology is growing, while overall efficiency is increasing for established systems such as wind turbines and solar panels. Other more established forms of renewable power, such as geothermal, and hydroelectric, are becoming more prevalent in the overall reduction of dependency on fossil fuels.

The controller system on this dual axis sun tracker utilizes four Light Dependent Resistor (LDR), light intensity sensors which are blocked into four parts. Two of the four LDR sensors are put on the North East and North West from the PV panel, and the other two are placed on the South West and South East. Those sensors are working on the basis of the Voltage Divider principle associated to the light intensity level. The result of a comparison between those four sensors is used to actuate two vertical stepper motors and horizontal stepper motor controlled using Arduino UNO. The control is completed by means of giving signal to the stepper motor until the four sensors get equal light intensity. In this way, the PV panel will thus be in a vertical position towards the entering sunray.

1.2 Literature survey

"Mathematical Modelling and Characteristic analysis of Solar PV Cell" Bijit Kumar Dey 1 Imran Khan 2 Nirabhra Mandal 3 Ankur Bhattacharjee. The electrical characteristics of a solar pv cell have been simulated and discussed in detail. The mathematical model of a single solar cell is designed in MATLAB/simulink environment and the IV and PV have been studied analytically.

Waseem Aslam, Yonghai Xu 1 , Abubakar Siddique 1 , Ayesha Batool 1, M.Nadeem Aslam presented the paper on Method of dual axis solar tracking. They have given description of the basic principle of a solar cell with its equivalent circuit of photovoltaic cell and obtained the model equations of a considered pv cell. They used buck boost converter as impedance machine device between input and output by changing duty cycle of the converter and fed the power to the load. Simulation and experimental analysis has been given.

Siddique , M. W. Hassan, M. K.Aslam, M. N.Aslam, and Y. Xu , "A Prototype Model for Generating Electricity Using Solar Parabolic Dish , Stirling Engine and Solar Tracking System,". This paper describes the design and implementation of an energy efficient solar tracking system from a normal mechanical single axis to a dual axis. For optimizing the solar tracking mechanism electromechanical systems were evolved.

C. Y. Lee, P. C. Chou, C. M. Chiang, and C. F. Lin, „Sun tracking systems: A review,‟ Sensors, In this paper the dual-axis solar tracking system is designed, built, and tested based on both the solar map and light sensor based continuous tracking mechanism. These light sensors also compare the darkness and cloudy and sunny conditions assisting daily tracking. The designed tracker can track sun's apparent position at different months and seasons; thereby the electrical controlling device requires a real time clock device for guiding the tracking system in seeking solar position for the seasonal motion.

LITERARUTRE REVIEW

2.1 Introduction

Over the years, researchers have developed smart solar trackers for maximizing the amount of energy generation. Before the introduction of solar tracking methods, static solar panels were positioned with a reasonable tilted angle based on the latitude of the location. In this competitive world of advanced scientific discoveries, the introductions of auto-mated systems improve existing power generation by 50%.

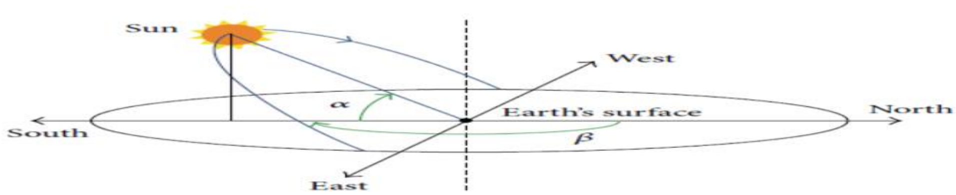

Figure 2.1: Illustration of the solar angles: (a) altitude angle, α; (b) azimuthal angle, β.The solar path corresponds to a day in the early fall or late winter seasons in the northern hemisphere, that is, just prior to the spring equinox or just after the fall equinox. Solar noon is the time of day when β = 180 degree, that is, the sun is directly at south and is halfway between sunrise and sunset.

There are mainly two types of solar trackers on the basis of their movement degrees of freedoms. These are single axis solar tracker and dual axis solar tracker.
Again these two systems are further classified on the basis of their tracking technologies. Active, passive, and chronological trackers are three of them.

Previous researchers used single axis tracking system which follows only the sun's daily motion. But the earth follows a complex motion that consists of the daily motion and the annual motion. The daily motion causes the sun to appear in the east to west direction over the earth whereas the annual motion causes the sun to tilt at a particular angle while moving along east to west direction.

Figure 2.1 shows the daily and annual motion of the sun. The sun's location in the sky relative to a location on the surface of the earth can be specified by two angles as shown in Figure 2.1. They are the solar altitude angle (α) and the solar azimuthal angle (β). Angle α is the angle between the sun's position and the horizontal plane of the earth's surface while angle β specifies the angle between a vertical plane containing the solar disk and a line running due south.

Solar tracking is best achieved when the tilt angle of the solar tracking systems is synchronized with the seasonal changes of the sun's altitude. An ideal tracker would allow the solar modules to point towards the sun, compensating for both changes in the altitude angle of the sun (throughout the day) and latitudinal offset of the sun (during seasonal changes). So the maximum efficiency of the solar panel is not being used by single axis tracking system whereas double axis tracking would ensure a cosine effectiveness of one.

In active tracking or continuous tracking, the position of the sun in the sky during the day is continuously determined by sensors. The sensors will trigger the motor or actuator to move the mounting system so that the solar panels will always face the sun throughout the day. If the sunlight is not perpendicular to the tracker, then there will be a difference in light intensity on one light sensor compared to another. This difference can be used to determine in which direction the tracker has to be tilted in order to be perpendicular to the sun. This method of sun tracking is reasonably accurate except on very cloudy days when it is hard for the sensors to determine the position of the sun in the sky.
Pressure between two points at both ends of the tracker. The imbalance is caused by solar heat creating gas pressure on a "low boiling point compressed gas fluid, that is, driven to one side or the other" which then moves the structure. However, this method of sun tracking is not accurate.

A chronological tracker is a time-based tracking system where the structure is moved at a fixed rate throughout the day as well for different months. Thus the motor or actuator is controlled to rotate at a slow average rate of one revolution per day (15 per hour). This method of sun tracking is more energy efficient.

Fig 2.2 Movements of panel: shows the entire movement of solar panel in order to track the solar energy without loss in tracking with the help of four sensors in four edges of the panel.
To track the sun's movement accurately dual axis tracking system is necessary. The active/continuous tracking system tracks the sun for light intensity variation with precision.

2.2 Review of sun tracking system

Overall, the sun tracking system has two types of design: single axis and dual axis. However, this project focuses on the design and implementation of dual axis sun tracker, and an analysis of the "energy gain" produced as a result of the application. The dual axis sun tracker system is considered as the most optimal and ideal sunlight direction tracker system for its flexibility to move and shift to any direction. This system tries to place the PV panel in a way where it could constantly be perpendicular to the incoming light so that generating optimum energy.

The tracking system implemented in this project is the active tracking method, in which in this method, the position of the sun is determined by the response signal received from four LDR sensors. Those signals are employed to trigger the stepper motor to move so when the response signal turns zero (equal), the motor will stop moving. The zero-response signal is an indication that the PV panel has been perpendicular to the upcoming sunray.

Fig 2.3 shows the Horizontal and Vertical movements of the solar panel: when the sun is on its daily motion horizontal axis takes the action, when the sun is on its annual motion vertical axis comes into account.
In the figure 2.3 two different axis i.e Horizontal movement and Vertical movement can track according to sun's motion. In northern hemisphere solar panel should be placed in the southern sky.

MATHEMATICAL MODELLING

3.1 Introduction

The solar energy is sustainable, renewable from of energy and it is very clean. As there is acute shortage of non-renewable forms of energy, it is necessary to harness the solar energy. From the past two decades or so, solar energy harvesting has become a hot topic. Many research institutions around the world are focusing on how to harness the solar energy optimally. A solar cell works by converting the light to electricity. This electrical power can be used to drive various loads and to charge the battery.

The solar cell has the nonlinear output characteristics which are called IV and PV characteristics. These characteristics are the functions of illumination, temperature and output voltage of the PV module. So, the curve is nonlinear. Therefore, it is necessary to make the cell operate at its maximum power point so that it can be used for various PV system applications. Also, the nature of these curves determines the efficiency of the panel.

There are three important factors that determine the efficiency- Panel efficiency, converter efficiency and efficiency of MPPT algorithm. It is not easy to improve the efficiency of the panel and converter circuit. The best possible way to improve the overall efficiency is to design an efficient algorithm for tracking maximum power. Also, energy generated through the photovoltaic effect cannot be directly used for powering most electronic circuits. A battery charger circuit is used to store the energy and then to power various electronics circuits whenever required.

3.2 Basic working principle of a solar cell

Semiconductor devices absorb light and coverts part of the energy of the absorbed photons to carriers of electricity – electrons and holes.

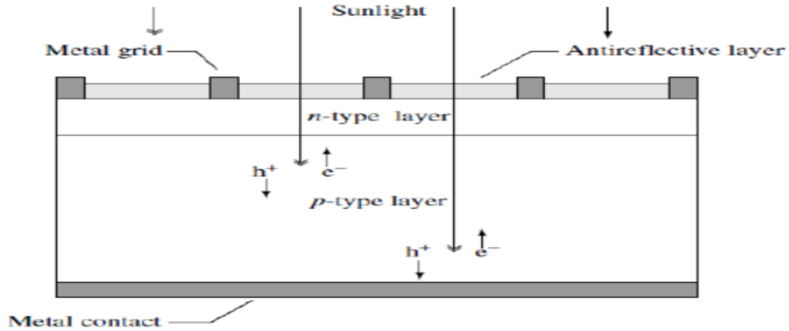

Fig.3.1 Outline structure of a Solar Cell shows the mechanism where sunlight is converted into energy to provide electricity for the range of appliances by the use of silicon cell. Solar cell or PV cell is the basic unit of a PV source, which is a simple P-N junction diode, formed by semiconductor material. A simple conventional solar cell structure is shown in the above figure.

The incidental sunlight comes perpendicularly on the solar cell. Electrical Contacts are formed by metallic grid of the diode and allows light to fall on the Semiconductor between the grid lines and thus it is absorbed and converted into Electrical energy. An antireflective layer between the grid lines enhances the amount of light transmitted to the semiconductor. This is achieved through diffusion or implantation of dopants with specific impurities. The diode's other side electrical contact is done by a metallic layer on the back of the solar cell plate.Electromagnetic radiation from sunlight constitutes of photons particles which carry specific amounts of energy. By means of photovoltaic effect the electricity can be generated from the available photon energy.

The three particular points of interest for any PV cell are:

- The short-circuit (SC) condition is characterized by a zero voltage at the PV module terminals and by short-circuit current ISC.
- The open-circuit (OC) condition is characterized by a zero current in the PV panel terminals and by an open-circuit voltage VOC.
- The MPP, at which the current value is IMPP, the voltage value is VMPP and the power

PMPP = VMPP x IMPP is the maximum the PV panel is able to deliver in the temporary operating conditions

From Figure 2 it is evident that the temperature has a significant effect on the open-circuit voltage value, while it has a negligible effect on the short circuit current value. On the other hand, the irradiance value has a direct effect on the short circuit current of the cell while negligible effect on the open circuit voltage value.

3.3 Single diode model of a solar PV cell

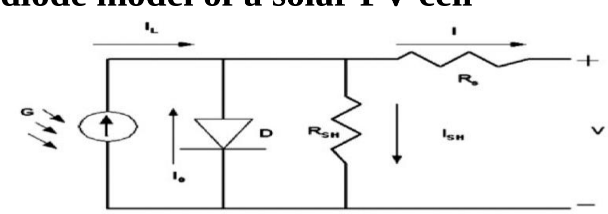

Fig 3.2 Single diode circuit shows: Equivalent circuit model define the entire I-V curve of a cell, module or array as continues function for a given set of operating condition. Il: light current (A), I0: diode reverse saturation current (A), Rs: series resistance, Rsh: shunt resistance, n: diode ideality factor.

The empirical analysis aimed to model a circuit that closely exhibits the behavior of solar cell is equipped with a p-n junction diode to model the physical effects of p-n junction occurring inside the cell. The current generator represents the photo-induced current, which is dependent on the characteristics of the semiconductor material used for the cell, and especially, it is linearly dependent on the cell area, irradiation level, and temperature.

3.4 Mathematical Modeling of a Solar PV Cell

In this section, using the single diode model using the single diode model we construct mathematical model of PV cell. The equations used in the modeling of the PV cell are as follows:

Applying KCL in the single diode model, we get

$$I = Iph - Id - Ish \qquad \text{………….. 3.1}$$

Photo current is given by,

$$Iph = [Isc + Ki(T-298)](G/1000) \qquad \text{…………...3.2}$$

Saturation Current is given by,

$$I0 = Irs\left(\frac{T}{Tn}\right)^{3} \exp[q.Ego.\frac{\frac{1}{Tn}-\frac{1}{T}}{n.k}] \qquad \text{……………3.3}$$

Reverse Saturation Current is given by,

$$Irs = Isc/(e^{\frac{q.Voc}{n.Ns.k.T}} - 1) \qquad \text{…………….3.4}$$

Current through Shunt Resistor is given by,

$$Ish = V + I.Rs/Rsh \qquad \text{…………….3.5}$$

Diode Current is given by,

$$Id = I0[\exp\left(q.\frac{V+I.Rs}{n.k.Ns.T}\right) - 1] \qquad \text{……………..3.6}$$

Output Current is given by,

$$I = Iph - I0\left[\exp\left(\frac{q.(V+I.Rs)}{n.k.Ns.T}\right) - 1\right] - Ish \qquad \text{…………….3.7}$$

At Standard Test Conditions (STC) (25°C, 1000W/m2):

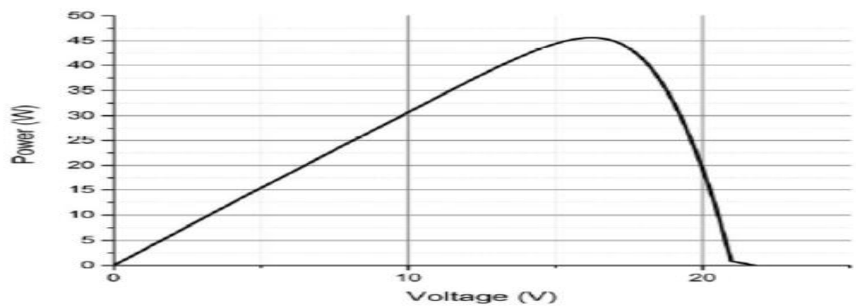

Fig.3.3. P-V simulated characteristics (at STC) shows: In P-V simulated characteristic graph X-axis and Y-axis is Voltage and Power at standard test conditions which helps to determine PV characteristics at both temperature(T) and ir-radiance(G) as variables and constants.

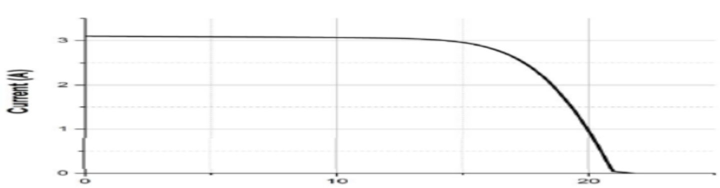

Fig.3.4. I-V simulated characteristics (at STC): In I-V simulated characteristic graph X-axis is Voltage and Y-axis is current and the maximum waveform is drawn between current and voltage.

BLOCK DIAGRAM, WORKING PRINCIPLE AND SYSTEM HARDWARE

4.1 Introduction

This chapter includes the detail description of block diagram, working principle and the hardware components which were used with their details.

4.2 Block diagram

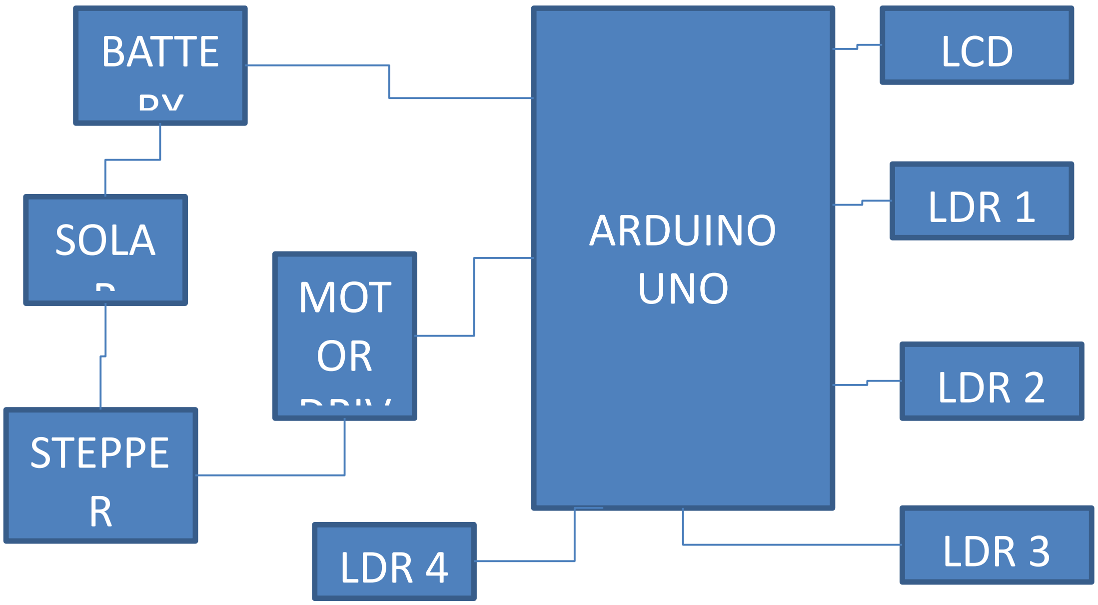

Fig 4.1 Block diagram shows how the circuit was connected in the practical prototype In this block diagram, arduino uno is the brain of the system. Here, we use LDR sensor to sense the light with maximum intensity and adjusts the panel to make the intensity on four sensors is even if its uneven. We use four LDR sensor at four sides, and give signal to the Arduino and Arduino give command to the motor drive, where motor drive works has as a interface it takes the command from the Arduino at low signal and give the high power to the stepper motor to drive the motor, here motor drive works as a back to back power. In this prototype, we use three stepper motor, two of the steppers to track the sunlight in east to west rotation throughout the day and the other one has to rotate north to south direction.

Through the motor, solar panel has to be rotate and trap the maximum light intensity from the solar energy and convert it into electrical energy and store those energy in the battery and through battery we power supply to the Arduino Uno where the Arduino needs the external power supply to run the whole system, And through the Arduino the LCD display is connected to know the direction of the rotation of the solar panel.

4.3 Working

Here, in this project, we employ solar panel which is attached to a motor for rotation. The angle of inclination of the solar panel is done to maximize the energy storage. The solar panel is directed according to a sensor network so that they are exposed to maximum sunlight. This in turn charges the battery with high efficiency. The microcontroller is also responsible for optimizing the power consumption and recharging the battery.

The micro controller cautiously reading the LDR values. The microcontroller comparing the two LDR values, the LDR1 is greater than LDR2 the solar panel is rotating LDR2 side, otherwise LDR2 greater than the LDR1 it rotating the LDR1 side.

The micro controller which LDR get higher value that side solar panel is rotating. This method is using to power generation is get more.

Optimization is done by the microcontroller by constantly monitoring the battery level. A threshold value is set and whenever the battery charge decreases beyond the threshold value, the microcontroller detects it and takes the appropriate measures.

4.4 System components

This chapter gives a detailed description of the system architecture of the Arduino-based dual axis solar tracker using light sensors. It will describe the integration of various components and sensors in the design of the controller.

Here solar circuits are controlled by the Arduino UNO that uses ATmega328P.The controller measures the input and output voltages with a voltage divider and sensors. The controller uses the data provided by the inputs and outputs to adjust the duty cycle for each circuit.

4.5 System Layout

The ATmega328P microcontroller on the Arduino UNO board compares the data from the voltage dividers and sensors at the input and output for solar circuits. The duty cycle is adjusted depending on the state of charge of the battery and the input sources. The inputs and outputs are read at the analog pins are shown in fig 4.1 below

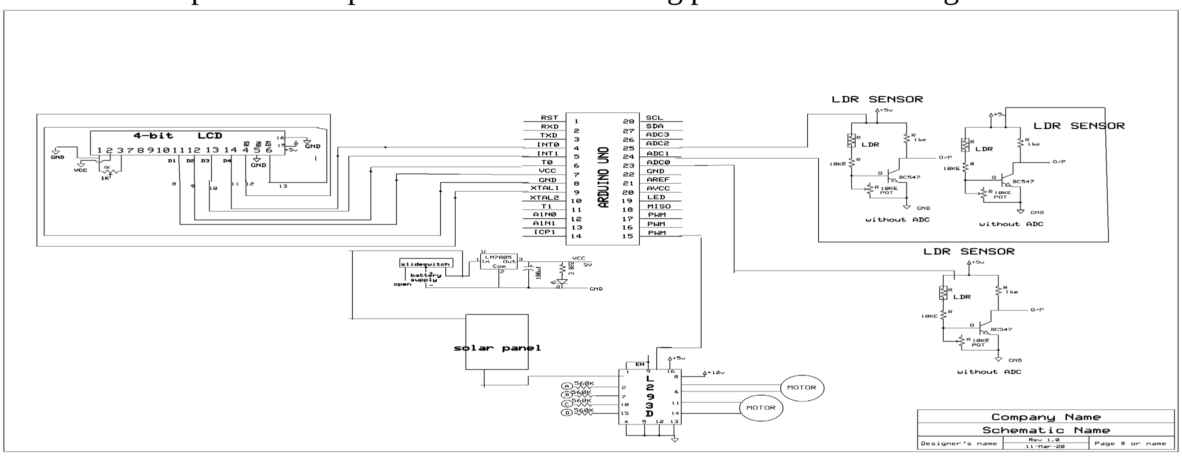

Fig4.2 Layout of the dual axis solar tracker which include an Arduino board

Fig4.2 shows the System Layout of the dual axis solar tracker which include an Arduino board, a 4-bit LCD display, solar panel, LDR sensors and their connections.

4.6 Component Selection

For future design consideration, the controller should be constructed to handle the solar panel used at the project site.

4.6.1 Arduino Uno

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

Fig 4.3 Arduino Uno

Fig 4.3 Arduino Uno shows: clear labeling of Arduino Uno with position of analog pins, digital pins, power pins, USB interface, header and leds. How it is an open source microcontroller board based on the microchip ATmega328P microcontroller and developed by arduino. The board is equipped with set of digital and analog input/output pins that may be interfaced to various expansion board and pin diagram with various pins in figure 4.3 below.

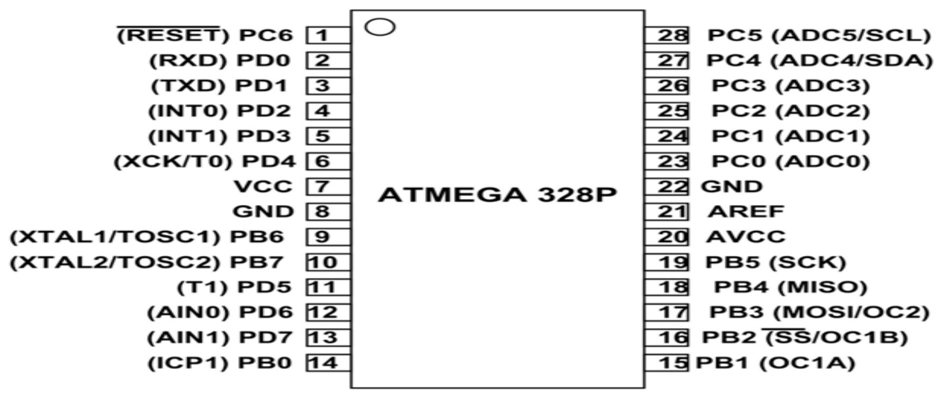

Fig 4.4 pin diagram

SYSTEM SOFTWARE

5.1 Introduction

In this chapter, the reader has to know the complete details of softwares used in the project and how they have been used.

5.2 Softwares used

- Keil µ vision using Embedded C programming
- Arduino UNO
- Matlab

5.2.1 Embedded C

The programming Language used here in this project is an Embedded C Language. This Embedded C Language is different from the generic C language in few things like

a) Data types
b) Access over the architecture addresses.

The Embedded C Programming Language forms the user friendly language with access over Port addresses, SFR Register addresses etc.

Signed char:

- Used to represent the – or + values.
- As a result, we have only 7 bits for the magnitude of the signed number, giving us values from -128 to +127.

5.2.2 Keil μ vision using Embedded C programming

It is possible to create the source files in a text editor such as Notepad, run the Compiler on each C source file, specifying a list of controls, run the Assembler on each Assembler source file, specifying another list of controls, run either the Library Manager or Linker (again specifying a list of controls) and finally running the Object-HEX Converter to convert the Linker output file to an Intel Hex File. Once that has been completed the Hex File can be downloaded to the target hardware and debugged. Alternatively KEIL can be used to create source files; automatically compile, link and covert using options set with an easy to use user interface and finally simulate or perform debugging on the hardware with access to C variables and memory. Unless you have to use the tolls on the command line, the choice is clear. KEIL Greatly simplifies the process of creating and testing an embedded application.

5.3 Source Code

Below is the program that will interface stepper motor and LDR with Arduino for solar tracking copy this code and upload it to your Arduino board.

Code:

```
#include<LiquidCrystal.h>
LiquidCrystal lcd(13,12,11,10,9,8);///serial port pins:0,1
#define L1 A0
#define L2 A1
#define L3 A2
#define L4 A3
int sensor=A4;
int motor1Pin1 = 4; // MOTROR PIN 1
int motor1Pin2 = 5; // MOTROR PIN 2
Int motor2Pin1 = 6; // MOTROR PIN 3
Int motor2Pin2 = 7; // MOTROR PIN 4
Int state,E,W,N,S,i,j;
int flag=0,temp_read;        //makes sure that the serial only prints once the state
void setup()
{
Serial.begin(9600);
lcd.begin(16,2);
delay(500);
lcd.clear();
lcd.setCursor(0,0);
lcd.print(" DUAL AXIS");
lcd.setCursor(0,1);
lcd.print("SOLAR  TRACKING");
delay(1000);
}
void loop()
{
int temp1=digitalRead(L1);
int temp2=digitalRead(L2);
int temp3=digitalRead(L3);
int temp4=digitalRead(L4);
delay(100);
if(temp1==1 && temp2==0  && temp3==0  && temp4==0  )
{
lcd.clear();
lcd.setCursor(0, 1);//move courser to second line
lcd.print("DIRECTION:EAST");
```

```
delay(1000);
E=E+1;
if(E==1)
{
W=0;S=0;N=0;
Reverse();
Reverse();
Reverse();
Reverse();
Reverse();
Reverse();
Reverse();
Reverse();
Reverse();
}
}
if(temp1==0 && temp2==1  && temp3==0  && temp4==0  )
{
lcd.clear();
lcd.setCursor(0, 1);//move courser to second line
lcd.print("DIRACTION:WEST");
delay(1000);
W=W+1;
if(W==1)
{
E=0;S=0;N=0;
Forward();
Forward();
Forward();
Forward();
}
}
if(temp1==0 && temp2==0  && temp3==1  && temp4==0  )
{
lcd.clear();
lcd.setCursor(0, 1);//move courser to second line
lcd.print("DIRACTION:NORTH");
delay(1000);
N=N+1;
if(N==1)
{
N=0;
E=0;S=0;W=0;
for(i=0;i<10;i++)
{
Forward1();
}
}
}
if(temp1==0 && temp2==0  && temp3==0  && temp4==1  )
{
lcd.clear();
lcd.setCursor(0, 1);//move courser to second line
```

```
lcd.print("DIRACTION:SOUTH");
delay(1000);
S=S+1;
if(S==1)
{
E=0;W=0;N=0;
for(i=0;i<10;i++)
{
Reverse1();
}
}
}
}
void Forward()
{
digitalWrite(motor1Pin1, LOW);
digitalWrite(motor1Pin2, HIGH);
delay(100);
digitalWrite(motor1Pin1, LOW);
digitalWrite(motor1Pin2, LOW);
delay(1000);
}
void Forward1()
{
digitalWrite(motor2Pin1, HIGH);
digitalWrite(motor2Pin2, LOW);
delay(100);
digitalWrite(motor2Pin1, LOW);
digitalWrite(motor2Pin2, LOW);
delay(1000);
}
void Reverse()
{
digitalWrite(motor1Pin1, HIGH);
digitalWrite(motor1Pin2, LOW);
delay(100);
digitalWrite(motor1Pin1, LOW);
digitalWrite(motor1Pin2, LOW);
delay(1000);
}
void Reverse1()
{
digitalWrite(motor2Pin1, LOW);
digitalWrite(motor2Pin2, HIGH);
delay(100);
digitalWrite(motor2Pin1, LOW);
digitalWrite(motor2Pin2, LOW);
delay(1000);
}
void Stop()
{
digitalWrite(motor1Pin1, LOW);
digitalWrite(motor1Pin2, LOW);
```

```
}
void Stop1()
{
digitalWrite(motor2Pin1, LOW);
digitalWrite(motor2Pin2, LOW);
}
```

Hence after the code is dumped in Arduino board, based on irradiance and temperature on LDR the Arduino controls the movement of solar panel and aligns the sun's direction perpendicularly.

SIMULATION AND PROTOTYPE IMPLEMENTATION AND ITS RESULTS

6.1 Introduction to Simulation work

This chapter gives different tools available for electrical and electronic systems simulation and mathematical modeling of a single diode has done.

All the subsystems of the Simulink model of the drive system are shown.

6.2 Simulation Tools

Study of electric motor drives needs the proper selection of a simulation tool. Their complex models need computing tools capable of performing dynamic simulations. Today with the growth in computational power there is a wide selection of software titles available for electrical simulations such as ACSL, ESL, EASY5 for general systems and SPICE2, EMTP for simulating electrical and electronic circuits. SIMULINK is a toolbox extension of the MATLAB program. It is a program for simulating dynamic systems.

6.3 Module parameters for Modeling in simulink

Parameter	**Units**	**Symbol**	**Value**
Rated power	Watt(w)	Pmp	50W
Voltage at maximum power	Volts(v)	Vmp	17.46V
Current at maximum power	Ampere(A)	Imp	2.89A
Open circuit voltage	Volts(v)	Voc	21.8v
Short circuit current	Ampere(A)	Isc	3.11A
Total number of cells in series	-	Ns	36

6.4 Block diagrams for IV and PV characteristics

6.4.1 Main block diagram

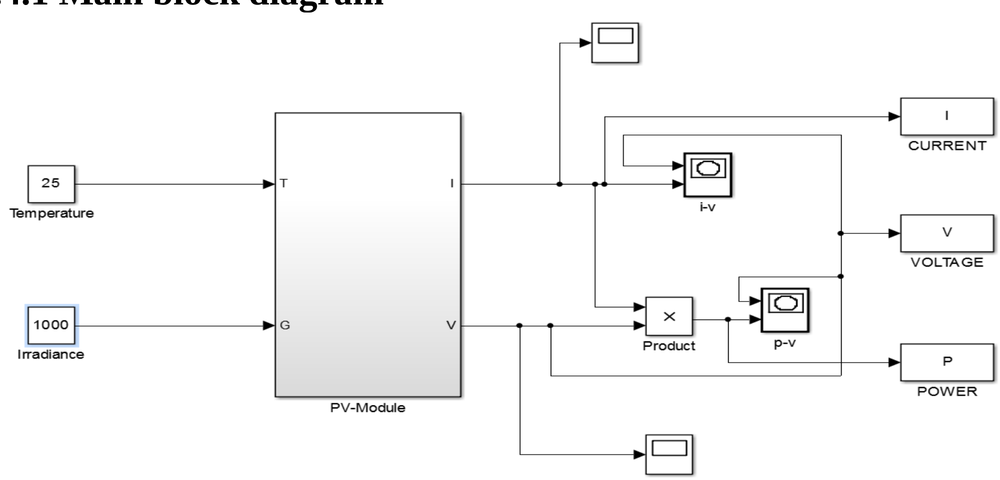

Fig6.1 simulation of Main block diagram

Fig6.1 simulation of Main block diagram: It is constructed using mathematical equations .User defined function blocks are used for modeling the block .The inputs to the PV-module are variable temperature and variable irradiance and the outputs are taken from respective scopes.

6.4.2 Sub-system of PV-Module

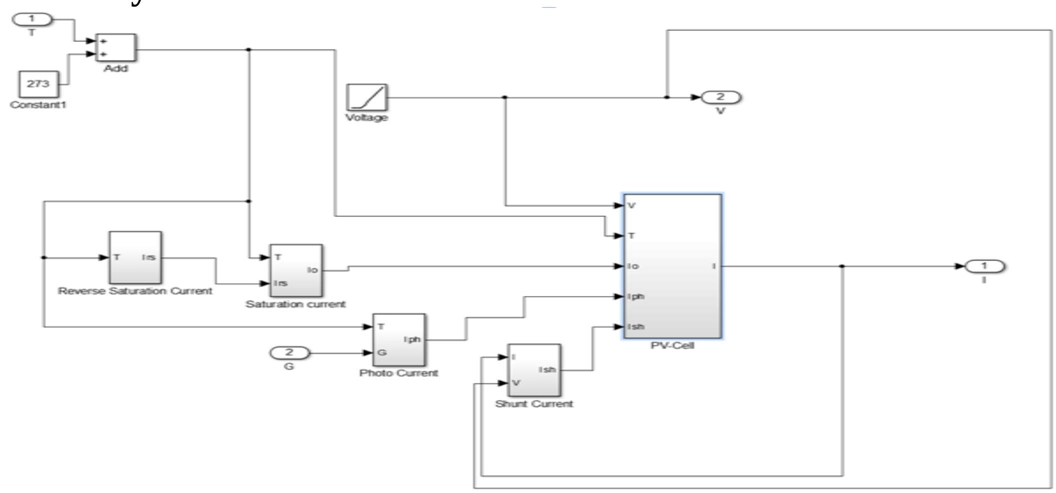

Fig6.2 Simulation of Sub-System of PV module

Fig6.2 Simulation of Sub-System of PV module: It is developed using the PV-cell .The inputs to the PV –cell is ramp voltage ,temperature ,saturation current, photo current and shunt current blocks .

6.4.2.1 Photo Current

The Photo current equation is given as,

$$Iph = [Isc + Ki(T\text{-}298)](G/1000) \qquad \ldots\ldots\ldots\ldots..6.1$$

Where, Isc is short circuit current (A)

Ki is short circuit current of a cell at 25 degree centigrade and 1000W/m`2,

T is Operating temperature (k), G is solar irradiation (W/m`2)

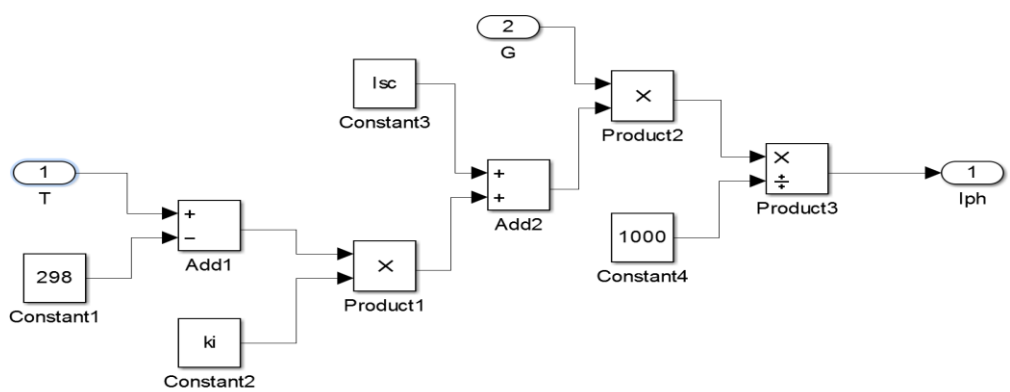

Fig6.3 Simulation of Photo current

6.4.2.2 Saturation Current

The saturation current equation is given as,

$$I0 = Irs\left(\frac{T}{Tn}\right)\text{`}3\ \exp[q.Ego.\frac{\frac{1}{Tn}-\frac{1}{T}}{n.k}] \qquad \ldots\ldots\ldots\ldots\ldots6.2$$

Where, Irs is reverse saturation current (A), Tn is Nominal temperature (k)

q is the Charge of electron (c), Ego is Band gap energy of semiconductor (ev)

n is ideality factor, k is Boltzmann constant

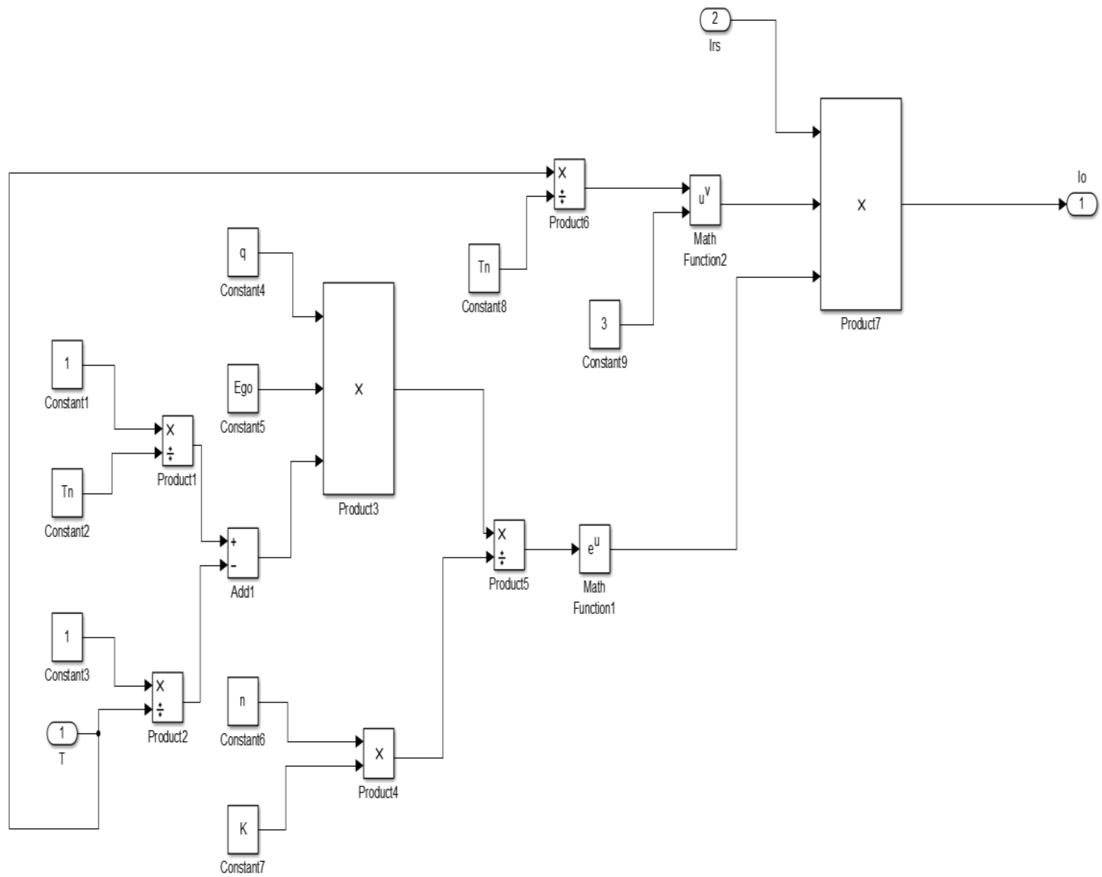

Fig6.4 Simulation of Saturation current

6.4.2.3 Reverse Saturation Current

The Reverse saturation current is given as,

$$Irs = Isc/(e^{\frac{q.Voc}{n.Ns.k.T}} - 1) \qquad \text{................6.3}$$

Where, Voc is open circuit voltage

Ns is number of cells connected in series

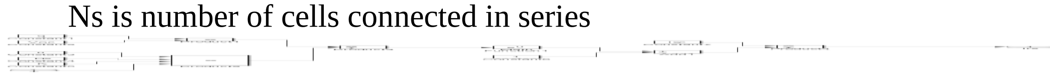

Fig6.5 Simulation of Reverse saturation current

6.4.2.4 Current through shunt resistor

Current through shunt resistor is given as,

$$Ish = V + I.Rs/Rsh \qquad \text{................6.4}$$

Where, Rs is series resistor (Ω)

Rsh is shunt resistor (Ω)

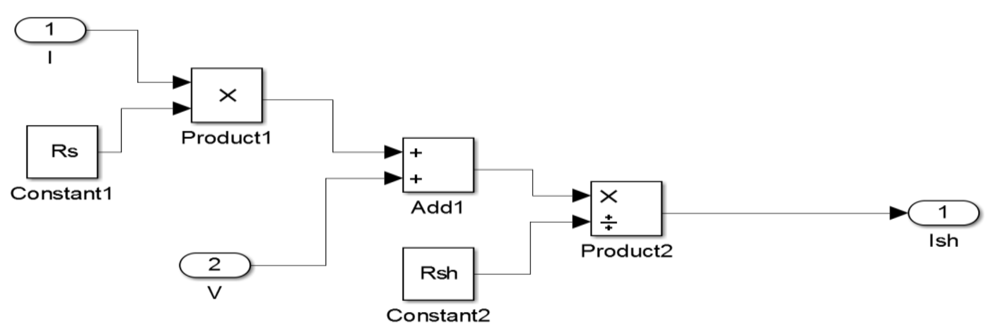

Fig6.6 Simulation of current through shunt resistor

6.4.2.5 Diode Current

Diode current is given as,

$$Id = I0[\exp\left(q.\frac{V+I.Rs}{n.k.Ns.T}\right) - 1] \qquad \text{……………..6.5}$$

6.4.2.6 Output current

Output current is given as,

$$I = Iph - I0\left[\exp\left(\frac{q.(V+I.Rs)}{n.k.Ns.T}\right) - 1\right] - Ish \qquad \text{…………….6.6}$$

6.5 Expected Results

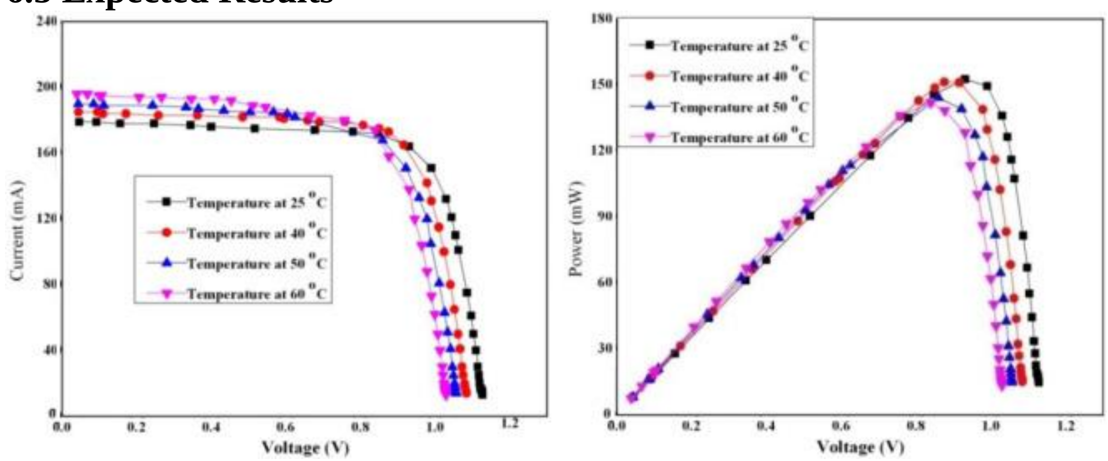

Fig6.7 shows the expected IV and PV characteristics of PV cell because it indicates the performance of a solar panel

6.6 Simulation Results

IV and PV Characteristics:

Solar Cell I-V and PV Characteristics Curves are basically a graphical representation of the operation of a solar cell or module summarizing the relationship between the current-voltage and power –voltage respectively at the existing conditions of irradiance and temperature.

6.6.1 Effect of Temperature Variation on IV & PV Characteristics

At constant irradiance (1000W/m^2) and variable temperatures of 15, 25, 35 degree Celsius.

Fig 6.8 is the IV characteristics at constant irradiance, as the temperature increases which in turn decreases the magnitude of voltage.

IV characteristics:

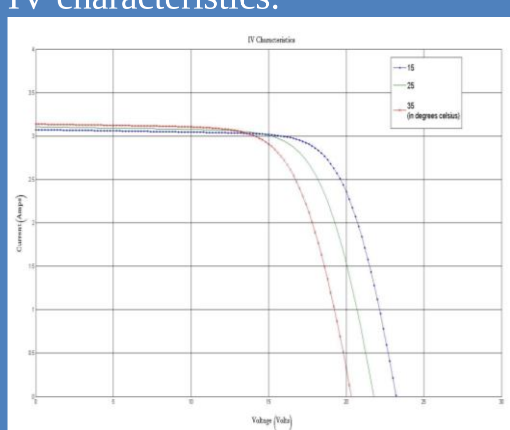

Fig 6.8 IV characteristics

PV characteristics:

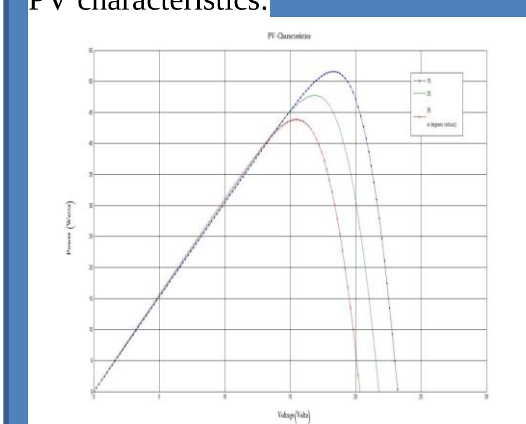

Fig6.9 PV characteristics

Fig6.9 describes that the PV characteristics, at constant irradiance as the temperature increases which in turn decreases the magnitude of power.

6.6.2 Effect of Irradiance variation on IV & PV Characteristics

IV characteristics:

At constant temperature, as the irradiance increasing which in turn increases the magnitude of current.

PV characteristics:

Fig6.11 PV characteristics is at constant temperature, as the irradiance increasing which in turn increases the magnitude of power.

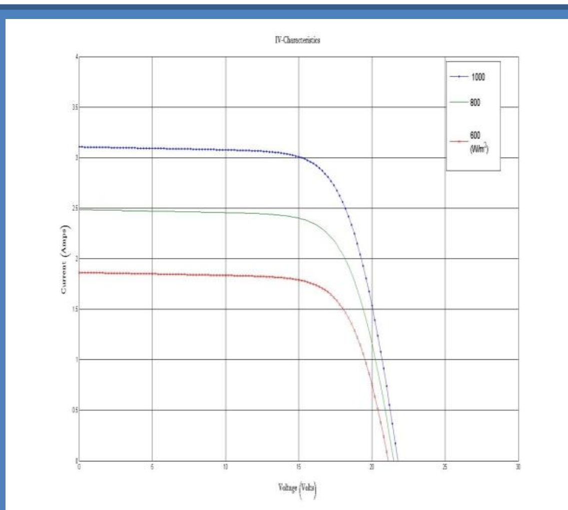

Fig6.10 IV characteristics

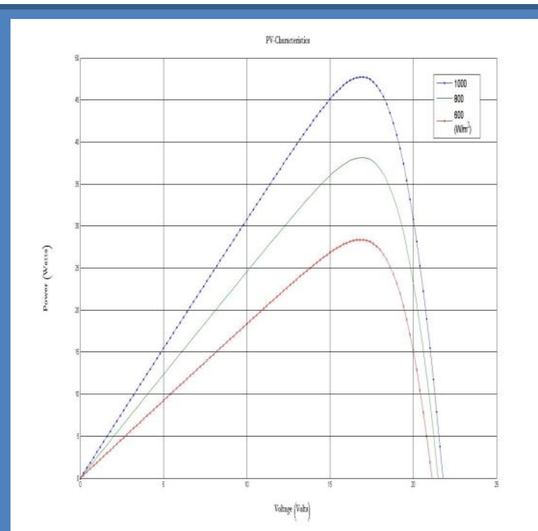

Fig6.11 PV characteristics

6.7 Prototype implementation

Fig 6.12 Prototype: In the above prototype we have taken the pictures of solar panel titled on the different angle to track the solar energy of the sun with different time interval.

6.7.1 Prototype at different times

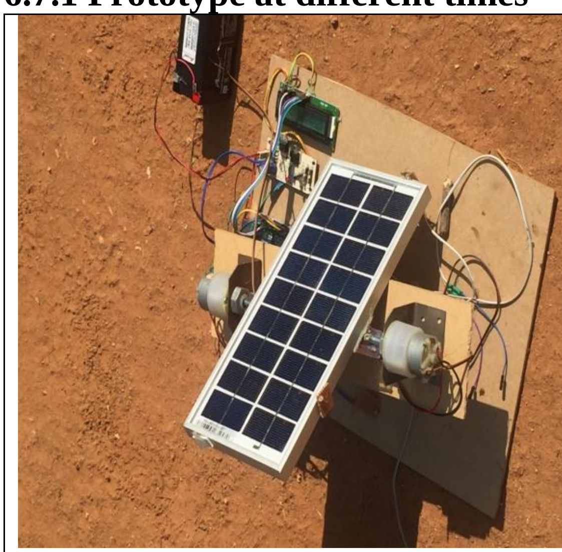

Fig 6.12 Prototype

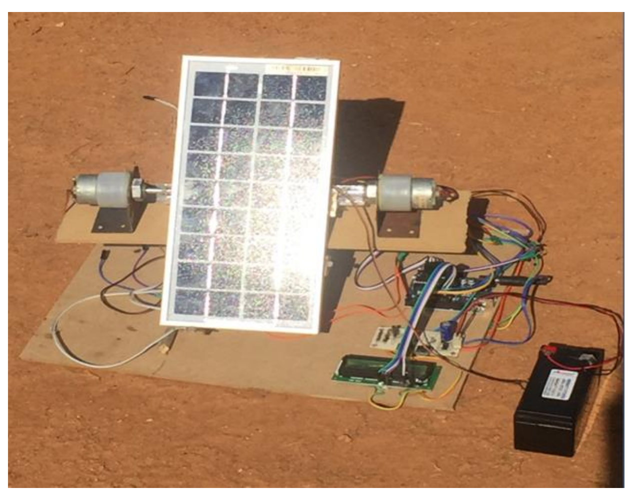

Fig6.13: At 10:30AM

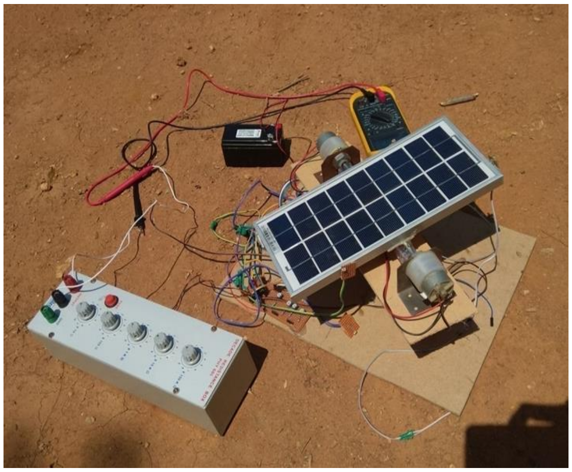

Fig 6.14: At 12:50PM

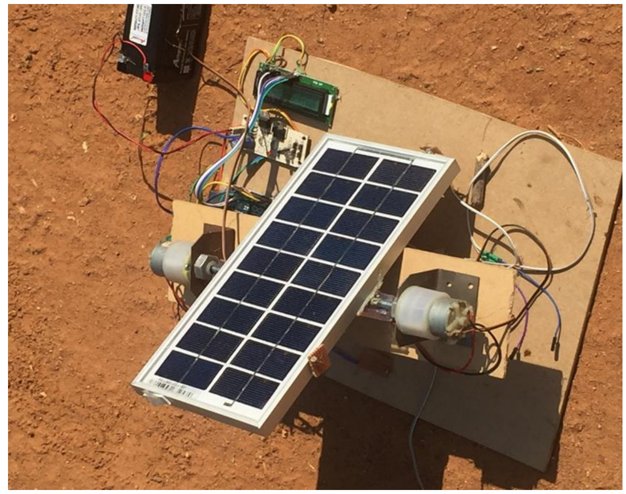

Fig6.15 at 3:30PM

6.8 Prototype Results

IV characteristics:

Fig6.16 IV characteristics: IV Characteristics: In the I-V characteristic X-axis is voltage (v) and Y-axis is current (mA) and from both the axis we plot the I-V characteristic as shown in the below fig.

PV characteristics:

Fig 6.17 PV-Characteristics: In the P-V characteristic X-axis is voltage (v) and Y-axis is power (W) and from both the axis we plot the P-V characteristic as shown in the above fig.

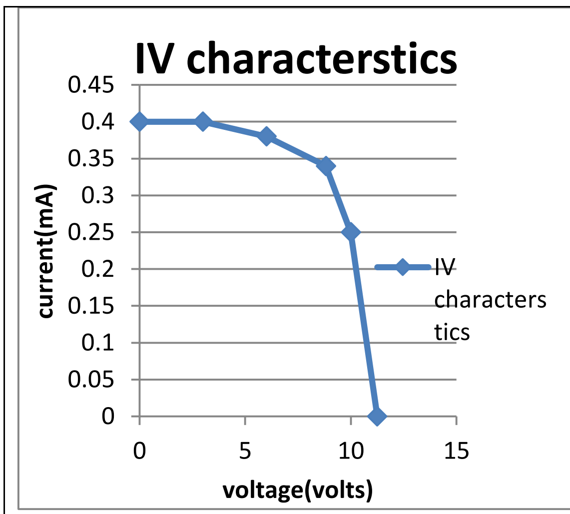

Fig6.16 IV characteristics

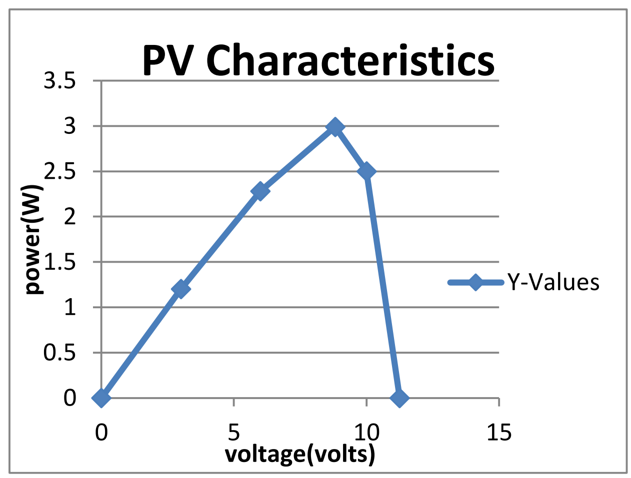

Fig 6.17 PV-Characteristics

Conclusion:

Renewable systems are becoming more affordable with better options than fuel generation in micro-systems, not only for the environment, but also the cost of operation. Fuel generators need to be replenished with fuel and oil, while renewable systems take advantage of the energy provided by the sun.

Solar radiation Tracker has played a vital role in increasing the efficiency of solar panels in recent years, thus proving to be a better technological achievement. The vital importance of a dual axis solar tracker lies in its better efficiency and sustainability to give a better output compared to a fixed solar panel or a single axis solar tracker. The tracking system is designed such that it can trap the solar energy in all possible directions. Generally, in a single axis tracker that moves only along a single axis it is not possible to track the maximum solar energy. In case of dual axis trackers, if the solar rays are perpendicular to panel throughout the year. Hence, maximum possible energy is trapped throughout the day as well as throughout the year. Thus, the output increases indicating that the efficiency more than a fixed solar panel (about 30 -40% more) or a single axis solar tracker (about 6-7% more).

Future Work:

We can say that it is just a mini model which can be replicated in larger scale in future. The following recommendations are can be considered for future expansion of this project:

• We can use helical type solar dishes instead of simple flat solar panels by which we can gain more and more solar intensity on the photovoltaic surface.

• We can use mirrors which will reflect more and more solar power to the photovoltaic surface.

• A phototransistor with an amplification circuit would provide improved resolution and better tracking accuracy/precision.

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