Sun tracking Solar system

Making more efficient solar system leveraging PIC microcontroller and stepper motor

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by

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Cover Image: Description + Source

Preface

The basis for this project originally stemmed from our research into increasing the efficiency of solar cells using Quantum Dots and from our interest in different energy crisis solutions.
With the population increasing at an exponential rate, the need for better and more viable power source is ever growing. In times of such dire crisis, solar energy will be a very great resource. How will we be able to help our nation take on the problem of energy? It is not only our curiosity which drives us to increase the efficiency of solar systems and to make them more accessible to every individual, but also our responsibility towards the future generation who will face the wrath of our greediness on the Earth's resources.
We'd like to thank every one who has motivated us and provided us with the required guidance in order to make this possible.Especially, Dr. Rishu Chaugar who has shown us how to properly use PIC16F877A and how we can utilize it for different projects.

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1

Introduction

The world population is increasing day by day and the demand for energy is increasing accordingly. Oil and coal, the main source of energy nowadays, are expected to end up from the world during the recent century which explores a serious problem in providing the humanity with an affordable and reliable source of energy. The need of the hour is renewable energy resources with cheap running costs. Solar energy has become a preferred because of its ubiquity, abundance and sustainability, regardless the intermittency of sunlight, solar energy is widely available and completely free of cost. It is harnessed (converted to other forms of energy) by using techniques such as solar heating photovoltaic cell, solar thermal energy, solar architecture and artificial photosynthesis. Photovoltaic is solid-state device that simply makes electricity out of sunlight, silently and with little to no maintenance, no pollution and no significant depletion of material resources. However, it is costly to install but in a long term it can save more energy and offers more reduction in cost. Solar panels, also called photovoltaic or PV module as it directly converts sunlight into electricity. A photovoltaic module is an interconnected collection of cells combined into one item. When a number of solar or photovoltaic modules are installed together, this is commonly referred to as a solar array. Many schemes have been developed to incorporate the same. The most widely renowned till date are:

a. Static Solar Panel Systems

b. Time based Moving Solar Panel Systems

c. Maximum Power Point Tracking Solar Panel Systems.

We will be looking into " Maximum Power Point Tracking Solar Panel Systems" in this project.

Solar tracker is an electro-mechanical device for orienting a solar photovoltaic panel toward the sun to get maximum intensity of light and to keep the position of panel perpendicular to the light source. Solar powered equipment works best when pointed at or near the sun, so a solar tracker can increase the effectiveness of such equipment. The tracker will enable the panel to follow the path of the sun and produce more power as it absorbs more sunlight. In single axis solar tracking, 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.

In this project we have used PIC16F877A with bi directional stepper motor inorder to make the solar tacker.

2
Hardware

This section deals with the hardware of the model. The study, arrangement , cost of all the parts used.

2.1. Parts used

Below is the listing and description of all the parts that have been used in making of the prototype.
Note- Look into respective data sheets for more information.

2.1.1. PIC16F877A

This powerful (200 nanosecond instruction execution) yet easy-to-program (only 35 single word instructions) CMOS FLASH-based 8-bit microcontroller packs Microchip's powerful PIC® architecture into an 40- or 44-pin package and is upwards compatible with the PIC16C5X, PIC12CXXX and PIC16C7X devices. The PIC16F877A features 256 bytes of EEPROM data memory, self programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART). All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

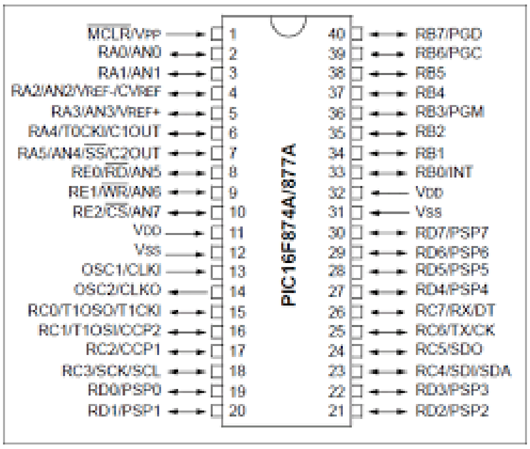


Figure 2.1: pin diagram of PIC16F877A

2.1.2. NEMA 17 2.5 Kg-cm Bipolar Stepper Motor

Bipolar stepper motor are able to produce step by very accurate step by step rotation in both directions which make them perfect for sun tracking project. NEMA 17 is able to produce 2.5kg-cm torque and operates upon 1.5A. As it can go in both directions the total number of phases it posses is 2.

2.1.3. L293d

L293D devices are quadruple high current half-H drivers. The L293 is designed to bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. It is designed to drive inductive loads such as relays, L293D) solenoids, DC and bipolar stepping motors. Each output is a complete totem-pole drive circuit with a Darlington transistor sink and a pseudo Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN.

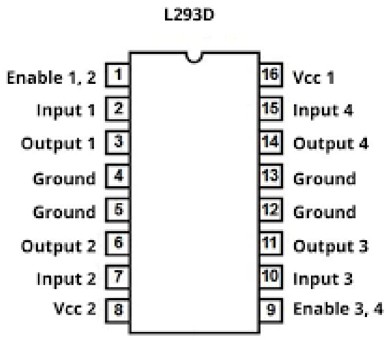


Figure 2.2: pin diagram of L293d

2.1.4. Light Dependant Resistor

Light dependent resistors, LDRs or photoresistors are used in electronic circuit designs where it is necessary to detect the presence or the level of light. They are connected in circuits and when depending upon the amount of light present the resistance changes.

Figure 2.3: LDR

2.1.5. Solar Panel

For this project the T.A.T.A.P.O.V.E.R solar panel has been used. The maximum power which can be supplied by the solar panel is 20W and its Open Circuit Voltage is 21.6V.

2.1.6. Battery

A 12V Lead acetate battery is used in order to store the energy from solar panel. The main reason for selecting lead - acetate battery over Li-ion one is because of it's charge effectiveness.

2.1.7. Charge Controller

Solar Charge Controller is an electronic device which manages the power going into the battery bank from the solar array. It ensures that the deep cycle batteries are not overcharged during the day and that the power doesn't run back to the solar panels overnight and drain the batteries.

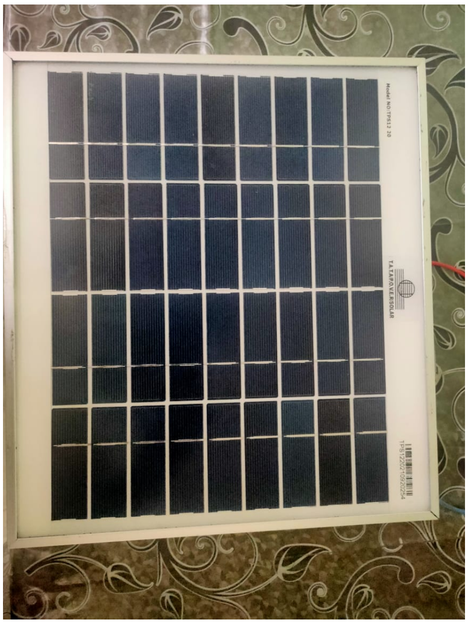


Figure 2.4: Solar panel

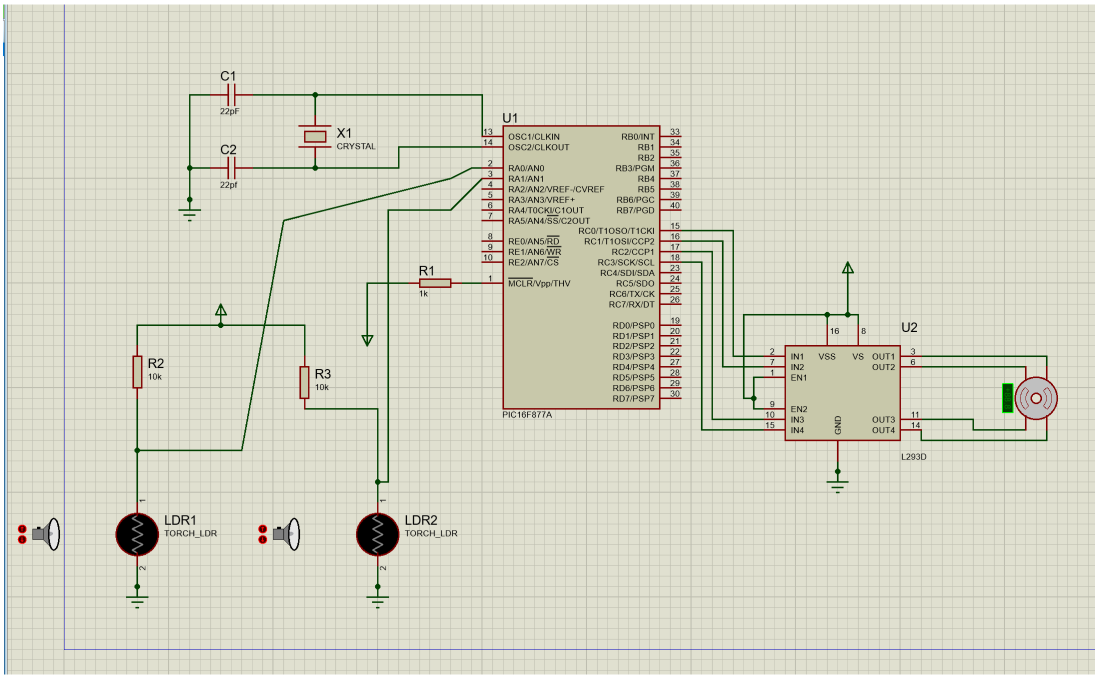
2.1.8. Wooden frame work
The frame has been made out of wood and it supports the solar panel on an epox rod. The epox rod has been connected to the motor via two gears.

2.1.9. Buck converter
A buck converter is used in order to decrease the voltage from 9V to 5V. This 5V has been used by the microcontroller and other ICs

2.1.10. Other Parts
Apart from all the main parts mentioned above there are also a few parts that will be required. The list is as follows:
1. Resistors
2. 4MHz crystal
3. Capacitor - 22pf
4. Bread board
5.Jumper Wires

2.2. Schematic
The bi polar motor has been connected to the PIC16F877a through L293d motor controller 4 of whose pins are connected to the port C. PWM method is used in order to micro step the motor, that being the reason two of the pins for L293d are connected to CCP pins.
Further the LDRs are connected to the PORTA and an external oscillator has been connected which has been used to genrate the clock.
The figure below shows schematic for the whole circuit.

2.3. Prototype
The completed prototype is shown below. All the above materials have been used in order to create the prototype. The approximate cost of the prototype comes to about Rs. 2000/- .



Schematic

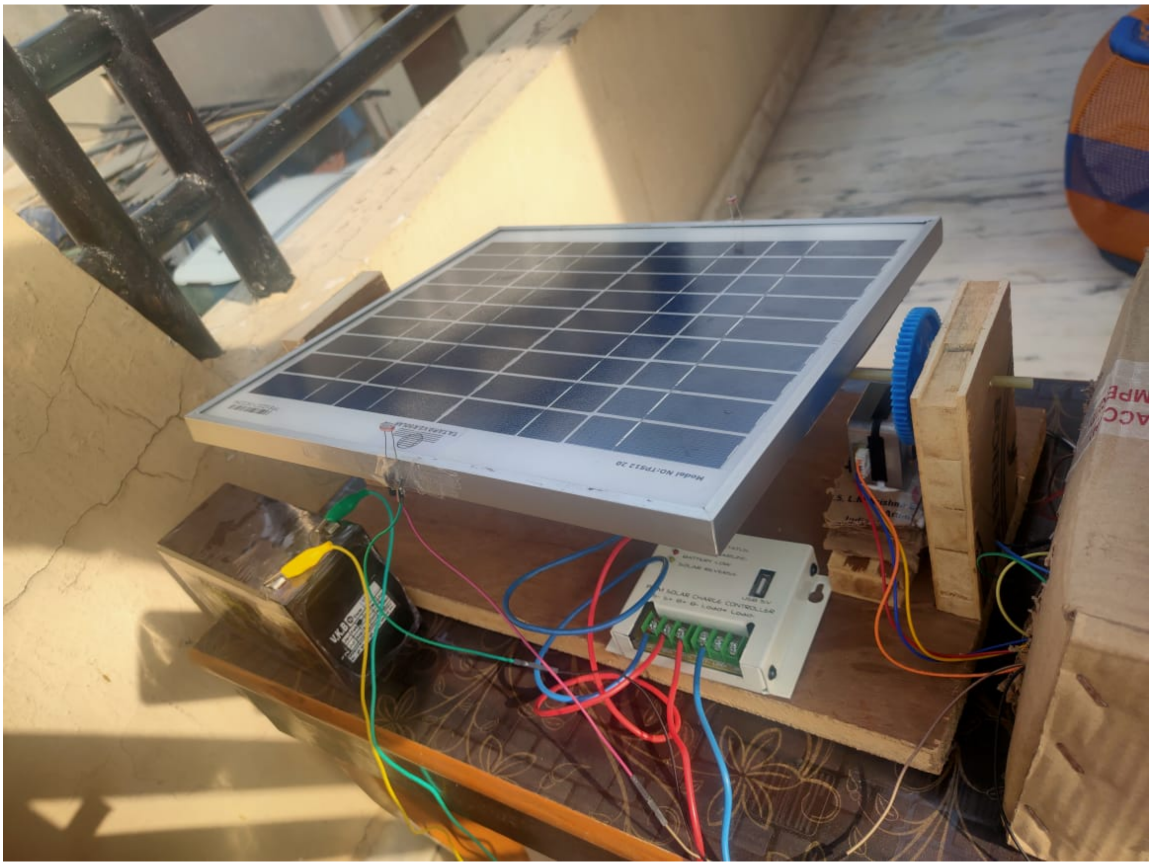


Figure 2.5: Prototype

2.4. Hardware connections

The figure below shows connections between all the ICs. The 9V battery which provides the system with power has been kept outside the box due to congestion. The 9V are directly provided to the motor and a buck converter is used in order to step down the voltage from 9V to 5V which provides for the microcontroller and other ICs.

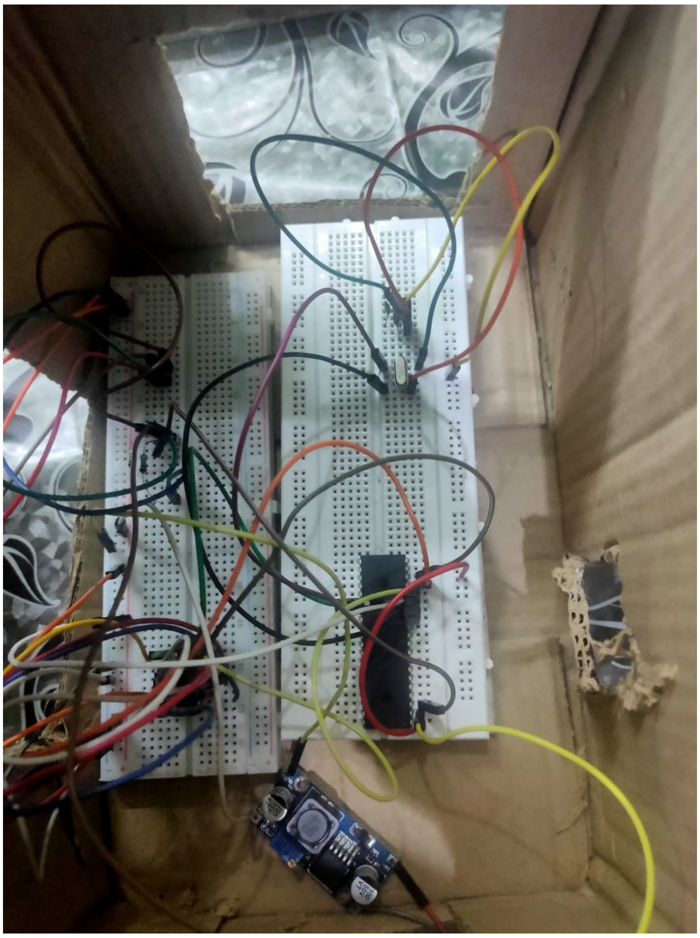


Figure 2.6: Hardware connections

3
Software

3.1. Algorithm

The algorithm reads the value of inputs which are provided by the LDRs and is stored in the values of V1 and V2. It further compares the value of V1 and V2, if the value of the V1 and V2 are lesser than the expected value during the day(800) then the solar panel remains in the starting position and when the values cross the threes hold, they are compared between each other and the solar panel moves accordingly.

If the value of V1 is bigger than the value of V2 then the solar panel moves toward 1st LDR and stops when the values become approximately same. After each iteration this process is repeated until night. After sunset the whole solar panel resets in the starting position.

The whole algorithm is shown in the flowchart below.

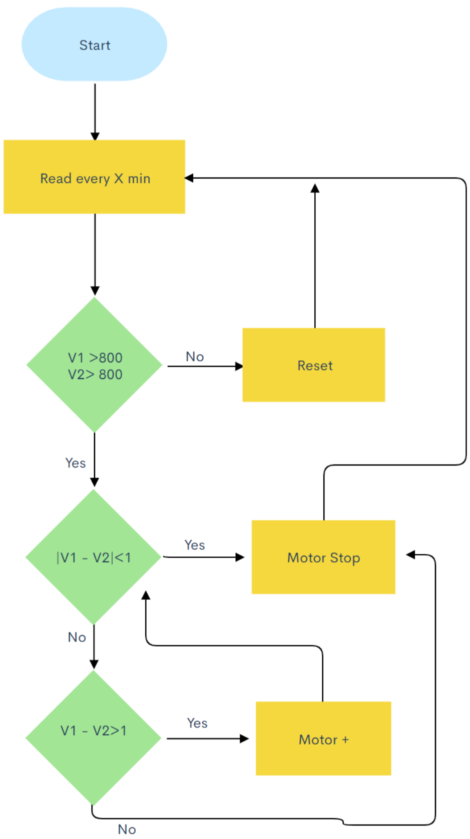


Figure 3.1: Prototype

3.2. Code

```
    #include<pic.h>
#define delay for(i=0;i<=1000;i++)

#define _XTAL_FREQ 4000000
#include <xc.h>


int mode;         //1 = forward ; 0 = reverse
int ready;        //1 = stop ; 0 = start
int dummy;

__CONFIG( FOSC_HS & WDTE_OFF & PWRTE_OFF & CP_OFF & BOREN_ON & LVP_OFF & CPD_OFF & WRT_OFF & DEBUG_O

unsigned int adc1();
unsigned int adc2();
void motor_clockwise(); // one step clockwise
void motor_reset(); // reset
void motor_stop(); // the motor will remain static
int i;

void main()
{
    unsigned int val1;
    unsigned int val2;
    TRISA0=1;
    PORTC = 0b11111111;            //RA0 is input (ADC)
    val1 = adc1();
    val2 = adc2();
    while(1) {
        val1 = adc1();
        val2 = adc2();
        while((val1 > 800) & (val2> 800)){
            val1 = adc1();
            val2 = adc2();
            if((val1-val2)<1 || val2 - val1 < 1){

            motor_stop();

            }
            else{
                // loop for moving motor
                while((val1 - val2)> 1){
                    motor_clockwise(); //takes a step each time in the clock wise direction
                }


            }
        _delay(720); // there is a 12 min stop at the each iteration


        }
        motor_reset();
        _delay(720);
    }
}
```

```
void motor_clockwise(){
    TRISC = 0;  //Clearing this bit will make PORTC as output.
CCP1CON = 0x0F;  //configuring CCP1CON register for PWM mode
CCP2CON = 0x0F;
int i = 0;
T2CON = 0x04;  // enable T2CON without Prescaler and postscale configuration.
PR2 = 255;
while(i<2)
{
char pw_sin[] = {0,25,50,74,98,120,141,162,180,197,212,225,236,244,250,253,255};
    for(int j = 0;j<16;j++){
CCPR1L = pw_sin[j];  //generated 75% duty cycle
CCPR2L = pw_sin[j];
TRISC = 0;
i ++ ;
 }
}
}
void motor_reset(){
    PORTC = 0b00001100;
}
void motor_stop(){
    PORTC = 0;
}
//
// reading the LDR
unsigned int adc1()
{
    unsigned int adcval;

    ADCON1=0xc0;
    ADCON0=0x85;                    //the three centre bits decide which line is selected - 000 - AN
    while(GO_nDONE);                //wait until conversion is finished
    adcval=((ADRESH<<8)|(ADRESL));    //store the result
    adcval=(adcval/3)-1;

    return adcval;
}
// for taking the next input all we need to do is change the bit select register
unsigned int adc2()
{
    unsigned int adcval;

    ADCON1=0xc0;
    ADCON0=0x8D;                    //AN1
    while(GO_nDONE);                //wait until conversion is finished
    adcval=((ADRESH<<8)|(ADRESL));    //store the result
    adcval=(adcval/3)-1;

    return adcval;
}
```

4

A theoretical proof that solar trackers are more efficient

We have said that adding our sun tracking platforms increase the efficiency of your solar systems. This section will give you a basic theoretical proof of how do we go about doing this?
The flux of a vector field is defined as

$$\phi = \int_A \vec{h}.\hat{n}.da \tag{4.1}$$

where $\vec{h}$ is a vector field , $\hat{n}$ gives us unit area vector and A gives us the total area upon which we want to calculate the flux.
For the following discussion lets treat solar radiation as a vector field comprising of parallel rays. We are gonna call this $\vec{S}$ and the flux generated by the solar radiation will be our main tool.
On a summer day in India the sun rises at 5:30 in the morning and sets around 18:30 in the evening, the peak amount of sunlight is seen around 12 in the noon. The intensity of the sunlight follows the curve given below. Now, the efficiency of solar system depends upon how much time does the solar

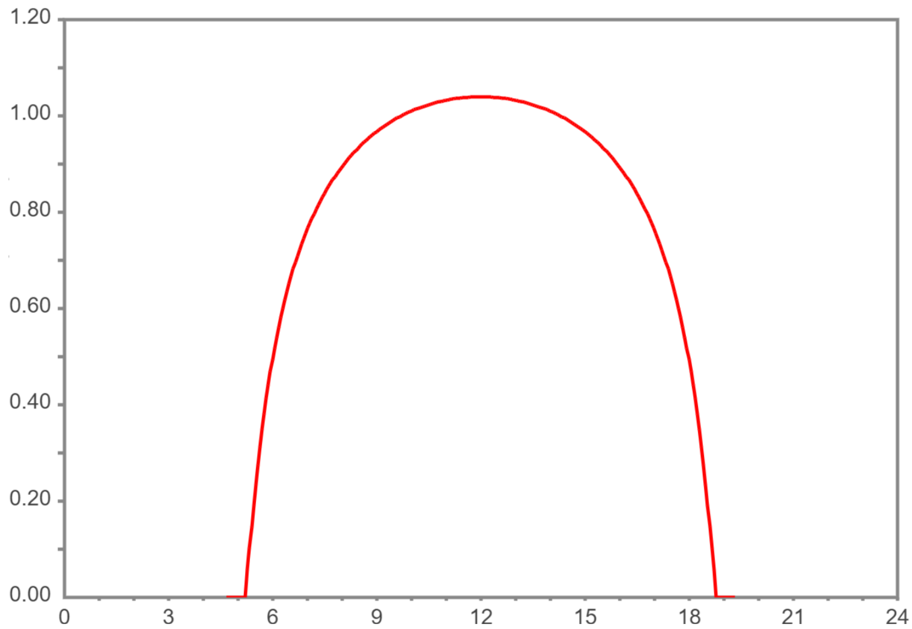


Figure 4.1: Intensity of Sunlight

panel face the sun rays directly. So one can say that Solar flux throughout the day and Efficiency are proportional.

$$Efficiency \propto \int_{t1}^{t2} \left[\int_A \vec{S}.\hat{n}.da \right] dt \tag{4.2}$$

So lets define

$$I = \int_{t1}^{t2} \left[\int_A \vec{S}.\hat{n}.da \right] dt \tag{4.3}$$

The value of $\vec{S}$ will depend upon the position of sun and as the position of the sun further depends upon the time of the day, the value of $\vec{S}$ will also depend upon the time and it can be given as

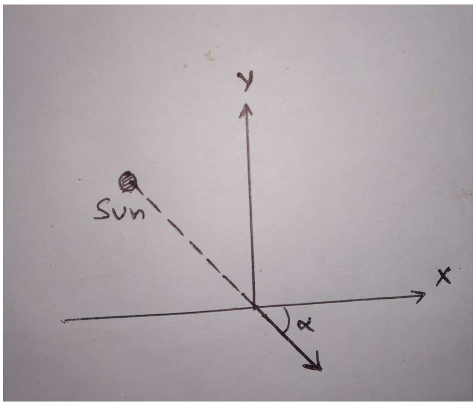


Figure 4.2: $\hat{S}$

$$\vec{S} = S_0(t)[cos(w_0t)\hat{i} - sin(w_0t)\hat{j}$$

where $S_0(t)$ gives the intensity of sun and w_0 is the angular frequency of the sun with respect to the position of the solar system.
The value of $\hat{n}$ will depend upon whether we are considering the solar tracking system or the the static one.

4.1. Static Solar panel

The value of $\hat{n}$ for this solar system will be fixed and as the general inclination angle is $30°$ we will choose the value of θ as 60. Making the value of $\hat{n}$ as

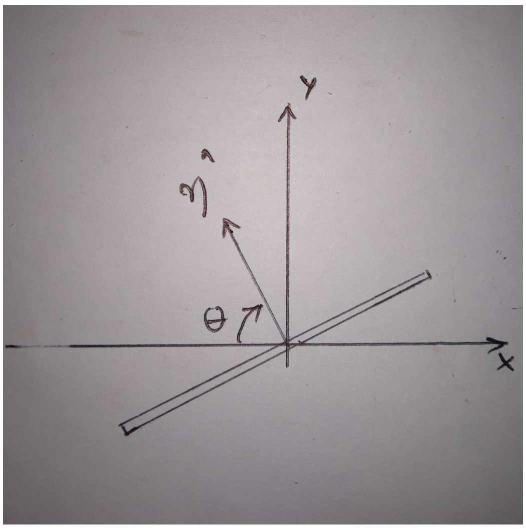


Figure 4.3: $\hat{n}$

$$\hat{n} = -cos(\theta)\hat{i} + sin(\theta)\hat{j}$$

$$\hat{n} = -0.5\hat{i} + 0.866\hat{j}$$

We will substitute these in equation (3.3) ,

$$I = \int_{t1}^{t2} \left[\int_A S_0(t)[cos(w_0t)\hat{i} - sin(w_0t)\hat{j}].[-0.5\hat{i} + 0.866\hat{j}].da \right] dt \tag{4.4}$$

$$I = \int_{1}^{13} S_0(t)A[-0.5cos(w_0t) - 0.866sin(w_0t)]dt \tag{4.5}$$

the integration for this is done using trapezoidal numerical integration which has been done using MATLAB. The value of w_0 has been taken as 13.857(as the sun is going from -90 to +90 in about 13 hours). This leads for the value of **I = 7.2785**

$$I_{static} = 7.27 \tag{4.6}$$

4.2. Solar Tracker

The value for $\hat{n}$ also varies exactly like S_0

$$\hat{n} = -cos(w_0t)\hat{i} + sin(w_0t)\hat{j}$$

putting this in equation (3.3) we get

$$I = \int_{t1}^{t2} \left[\int_A S_0(t)[cos(w_0t)\hat{i} - sin(w_0t)\hat{j}].[-cos(w_0t)\hat{i} + sin(w_0t)\hat{j}].da \right] dt \tag{4.7}$$

$$I = \int_{1}^{13} S_0(t)A[-1]dt \tag{4.8}$$

ignoring the negative sign and performing numerical integration upon the system we will get the value **I = 11.35**.

$$I_{tracker} = 11.35 \tag{4.9}$$

4.3. Efficiency increase

As efficiency is directly proportional to the value of I. We can use the above data to show the increase in the efficiency of the solar system.

$$\Delta Efficiency = \frac{I_{tracker} - I_{static}}{I_{static}} * 100 \tag{4.10}$$

Therefore

$$\Delta Efficiency_{theoretical} = 56.12\% \tag{4.11}$$

This shows that our system is much more efficient. But due to a lot of errors this is not exact.
The errors that might be affecting our calculations :
1. The algorithm only moves the motor every few minutes so the following of the solar panel is not continuous.
2. Loss due to resistance.
3. Calculation errors.
Due to the above mentioned errors and much more the net efficiency of solar tracking system generally drops to $40\% - 50\%$.

$$\Delta Efficiency_{practical} = 40\% - 50\% \tag{4.12}$$

This proves that our technology makes your solar panels much more efficient and by our help you will be able to produce the same amount of electricity by using 40% less solar panels than you were using previously .

5

Results and Discussions

We used a voltmeter in order to measure the amount of voltage that the solar panel delivers to the battery via the charge controller. After taking measurements after every hour we plotted a graph between voltage produced by fixed solar panel and by the sun tracking solar panel.
It was found that the sun tracking solar panel produced similar voltage through out the day, proving the fact that direct sun rays have been obtained by the solar system. On the other hand a peak can be observed for the fixed solar panel.

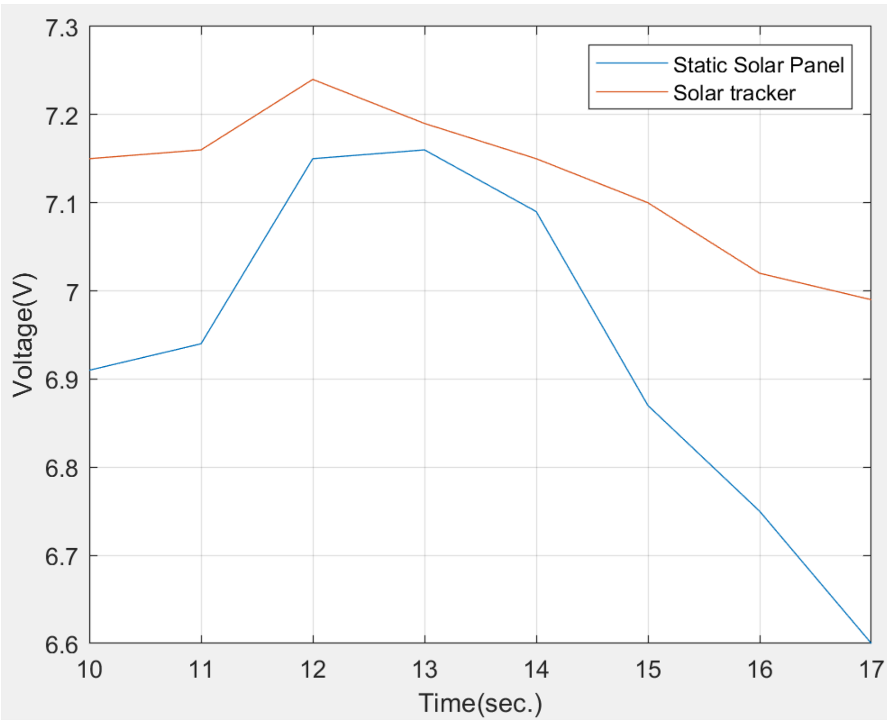


Figure 5.1: Static solar panel vs sun tracking solar system

The graph above proves that the sun tracking solar panel is much more efficient than the static solar panel.

6

Conclusion

We have been able to make a sun tracking solar system with satisfactory performance.At each time increment of one hour, sensing arrangement detected the direction of maximum sunlight intensity and oriented the motor in the direction of sun. The output voltage of the solar panel with the tracking arrangement was found to be more than the static arrangement in which the direction of the panel remain same throughout the day approximately This project ensures that the percentage usage of available solar energy on solar panel has increased during the day, thus increasing its output voltage available to the load, thus fulfilling the basic aim of the work.It is a cost-effective re-programmable embedded system that can easily be upgraded to suit in future other tracking algorithms.The system developed can be successfully implemented to drive large or small solar panels both for commercial purposes as well as domestic applications.

Figure 6.1: sun tracking solar system

6.1. Future Directions

1. The value for X has been taken 12 for now. But more experiments can be done which will help optimize the value of X for maximum output.
2.Developments can be made regarding the design of the structure, for example by adding covers for the motors and also improving the design of the sensor holder by making it waterproof.
3. It can be designed as more user friendly system.

6.2. References

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