DIGITAL SOLAR TRACKER

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CANDIDATE'S DECLARATION

We Vadnam Swayam Prakash (ECE/64/13), Akash Gupta (ECE/69/13), Sujeet Kumar (ECE/61/13) students of B.Tech Electronics and communication Engineering Department, National Institute of Technology, Srinagar hereby declare that we own the full responsibility for the information, results etc. provided in this Project Report entitled "**DIGITAL SOLAR TRACKER**" submitted to Dr. W. Wilfred Godfrey (Associate Professor) ABV-IIITM Gwalior.

We have taken care in all respect to honour the intellectual property right and have acknowledged the contribution of others for using them in academic purpose and further declare that in case of any violation of intellectual property rights or copyrights we, as the candidates, will be fully responsible for the same.

Our supervisor should not be held responsible for full or partial violation of copyright or intellectual property right.

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Signature

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CERTIFICATE

This is to certify that the project report entitled "**Digital Solar Tracker**", submitted by **Vadnam Swayam Prakash (Roll. No. ECE/64/13), Akash Gupta (Roll. No. ECE/69/13) and Sujeet Kumar (Roll. No. ECE/61/13)** of **National Institute of Technology, Srinagar** is an authentic record of project work carried out by them at **ABV-Indian Institute Of Information Technology & Management, Gwalior** under my supervision and guidance during January-February 2016.

The Report which is based on candidates' own work, has not been submitted elsewhere for a degree/diploma.

In my opinion, this innovative project should be encouraged and developed further.

Date:

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ABSTRACT

Through this project, we design, develop and implement a **Digital Solar Tracker** in which LDRs are the main sensors and to make the solar panel faces the sun , we use stepper motors as actuators. A **Solar Tracker** is a device that orients a payload toward the sun. Payloads are usually solar panels, parabolic troughs, fresnel, reflectors, mirrors or lenses. These trackers can be seen in a large-scale solar plant where the panels align themselves to the position of the sun which in turn increases the power production.

As being one of the renewable sources, these are widely used in most of the areas where more power generation is needed.

Further we use a compatible microcontroller of **8051** family for processing, controlling and interfacing the signals and peripherals. The compiler used for generating the .hex file is **KEIL µ version4**.

CONTENTS

Introduction: Solar Tracking System

A **Solar Tracker** is a device that orients a payload toward the sun. Payloads are usually solar panels, parabolic troughs, fresnel, reflectors, mirrors or lenses.

For flat-panel photovoltaic systems, trackers are used to minimize the angle of incidence between the incoming sunlight and a photovoltaic panel. This increases the amount of energy produced from a fixed amount of installed power generating capacity. In standard photovoltaic applications, it was predicted in 2008-2009 that trackers could be used in at least 85% of commercial installations greater than one megawatt from 2009 to 2012. However, as of April 2014, there is not any data to support these predictions.

In concentrator photovoltaics (CPV) and concentrated solar power (CSP) applications, trackers are used to enable the optical components in the CPV and CSP systems. The optics in concentrated solar applications accept the direct component of sunlight and therefore must be oriented appropriately to collect energy. Tracking systems are found in all concentrator applications because such systems do not produce energy unless pointed at the sun.

Basic Concept

The effective collection area of a flat-panel solar collector varies with the cosine of the misalignment of the panel with the Sun.

Sunlight has two components, the "direct beam" that carries about 90% of the solar energy, and the "diffuse sunlight" that carries the remainder - the diffuse portion is the blue sky on a clear day and increases proportionately on cloudy days. As the majority of the energy is in the direct beam, maximizing collection requires the sun to be visible to the panels as long as possible.

The energy contributed by the direct beam drops off with the cosine of the angle between the incoming light and the panel. In addition, the reflectance (averaged across all polarizations) is approximately constant for angles of incidence up to around 50°, beyond which reflectance degrades rapidly.

Direct power lost (%) due to misalignment (angle *i*)					
i	**Lost = 1 - cos(*i*)**		***i***	**hours**[7]	**Lost**
0°	0%		15°	1	3.4%
1°	0.015%		30°	2	13.4%
3°	0.14%		45°	3	30%
8°	1%		60°	4	>50%[8]
23.4°[9]	8.3%		75°	5	>75%[8]

Project Objective

As the non-renewable energy resources are decreasing, use of renewable resources for producing electricity is increasing. Solar panels are becoming more popular day by day. We have already gone through **how to install solar panel for home**.

Solar panel absorbs the energy from the Sun and is stored in the battery. This energy can be utilized when required. Utilization of the energy stored in batteries is mentioned in below given applications.

Solar panels should absorb energy to a maximum extent. This can be done only if the panels are continuously placed towards Sun direction. So solar panel should continuously rotate in the direction of Sun. This article describes about circuit that rotates solar panel.

So, through this project, we want to design, develop and implement a **Digital Solar Tracker** in which LDRs are the main sensors and to make the solar panel faces the sun , we use stepper motors as actuators.

Here we use a compatible microcontroller for processing and interfacing the signals and peripherals.

Other Technologies

Concentrated photovoltaic trackers are used with refractive and reflective based concentrator systems. There are a range of emerging photovoltaic cell technologies used in these systems. These range from conventional, crystalline silicon-based photovoltaic receivers to germanium-based triple junction receivers.

Single axis trackers

Single axis trackers have one degree of freedom that acts as an axis of rotation. The axis of rotation of single axis trackers is typically aligned along a true North meridian. It is possible to align them in any cardinal direction with advanced tracking algorithms. There are several common implementations of single axis trackers. These include horizontal single axis trackers (HSAT), horizontal single axis tracker with tilted modules (HTSAT), vertical single axis trackers (VSAT), tilted single axis trackers (TSAT) and polar aligned single axis trackers (PSAT). The orientation of the module with respect to the tracker axis is important when modeling performance.

Horizontal

Horizontal single axis tracker (HSAT)

4MW horizontal single axis tracker in Vellakoil, Tamil Nadu, India

Horizontal Single Axis tracker with Tilted Modules in Xitieshan, China. Commissioned in July 2014

The axis of rotation for horizontal single axis tracker is horizontal with respect to the ground. The posts at either end of the axis of rotation of a horizontal single axis tracker can be shared between trackers to lower the installation cost. Field layouts with horizontal single axis trackers are very flexible. The simple geometry means that keeping all of the axes of rotation parallel to one another is all that is required for appropriately positioning the trackers with respect to one another. Appropriate spacing can maximize the ratio of energy production to cost, this being dependent upon local terrain and shading conditions and the time-of-day value of the energy produced. **Backtracking** is one means of computing the disposition of panels. Horizontal trackers typically have the face of the module oriented parallel to the axis of rotation. As a module tracks, it sweeps a cylinder that is rotationally symmetric around the axis of rotation. In single axis horizontal trackers, a long horizontal tube is supported on bearings mounted upon pylons or frames. The axis of the tube is on a north–south line. Panels are mounted upon the tube, and the tube will rotate on its axis to track the apparent motion of the sun through the day.

Horizontal single axis tracker with tilted modules (HTSAT)

In HSAT, the modules are mounted flat at 0 degrees, while in HTSAT, the modules are installed at a certain tilt. It works on same principle as HSAT, keeping the axis of tube horizontal in north–south line and rotates the solar modules east to west throughout the day. These trackers are usually suitable in high latitude locations but does not take as much land space as consumed by Vertical single axis tracker (VSAT). Therefore, it brings the advantages of VSAT in a horizontal tracker and minimizes the overall cost of solar project.

Vertical

Vertical single axis tracker (VSAT)

The axis of rotation for vertical single axis trackers is vertical with respect to the ground. These trackers rotate from East to West over the course of the day. Such trackers are more effective at high latitudes than are horizontal axis trackers. Field layouts must consider shading to avoid unnecessary energy losses and to optimize land utilization. Also optimization for dense packing is limited due to the nature of the shading over the course of a year. Vertical single axis trackers typically have the face of the module oriented at an angle with respect to the axis of rotation. As a module tracks, it sweeps a cone that is rotationally symmetric around the axis of rotation.

Tilted

Tilted single axis tracker (TSAT)

Tilted single axis tracker in Siziwangqi, China

All trackers with axes of rotation between horizontal and vertical are considered tilted single axis trackers. Tracker tilt angles are often limited to reduce the wind profile and decrease the elevated end height. With backtracking, they can be packed without shading perpendicular to their axis of rotation at any density. However, the packing parallel to their axes of rotation is limited by the tilt angle and the latitude. Tilted single axis trackers typically have the face of the module oriented parallel to the axis of rotation. As a module tracks, it sweeps a cylinder that is rotationally symmetric around the axis of rotation.

Polar

Polar aligned single axis trackers (PASAT)

This method is scientifically well known as the standard method of mounting a telescope support structure. The tilted single axis is aligned to the polar star. It is therefore called a polar aligned single axis tracker (PASAT). In this particular implementation of a tilted single axis tracker, the tilt angle is equal to the site latitude. This aligns the tracker axis of rotation with the earth's axis of rotation.

Dual axis trackers

Dual axis trackers have two degrees of freedom that act as axes of rotation. These axes are typically normal to one another. The axis that is fixed with respect to the ground can be considered a primary axis. The axis that is referenced to the primary axis can be considered a secondary axis. There are several common implementations of dual axis trackers. They are classified by the orientation of their primary axes with respect to the ground. Two common implementations are tip-tilt dual axis trackers (TTDAT) and azimuth-altitude dual axis trackers (AADAT). The orientation of the module with respect to the tracker axis is important when modeling performance.

Dual axis trackers typically have modules oriented parallel to the secondary axis of rotation. Dual axis trackers allow for optimum solar energy levels due to their ability to follow the sun vertically and horizontally. No matter where the sun is in the sky, dual axis trackers are able to angle themselves to be in direct contact with the sun.

Tip–tilt

Dual axis tracker mounted on a pole. Project in Siziwangqi

A tip–tilt dual axis tracker (TTDAT) is so-named because the panel array is mounted on the top of a pole. Normally the east–west movement is driven by rotating the array around the top of the pole. On top of the rotating bearing is a T- or H-shaped mechanism that provides vertical rotation of the panels and provides the main mounting points for the array. The posts at either end of the primary axis of rotation of a tip–tilt dual axis tracker can be shared between trackers to lower installation costs.

Other such TTDAT trackers have a horizontal primary axis and a dependent orthogonal axis. The vertical azimuthal axis is fixed. This allows for great flexibility of the payload connection to the ground mounted equipment because there is no twisting of the cabling around the pole.

Field layouts with tip–tilt dual axis trackers are very flexible. The simple geometry means that keeping the axes of rotation parallel to one another is all that is required for appropriately positioning the trackers with respect to one another. Normally the trackers would have to be positioned at fairly low density in order to avoid one tracker casting a shadow on others when the sun is low in the sky.

Tip-tilt trackers can make up for this by tilting closer to horizontal to minimize up-sun shading and therefore maximize the total power being collected.

The axes of rotation of many tip–tilt dual axis trackers are typically aligned either along a true north meridian or an east–west line of latitude.

Given the unique capabilities of the Tip-Tilt configuration and the appropriated controller totally automatic tracking is possible for use on portable platforms. The orientation of the tracker is of no importance and can be placed as needed.

Azimuth-altitude dual axis tracker - 2 axis solar tracker, Toledo, Spain.

Azimuth-altitude

An azimuth–altitude dual axis tracker (AADAT) has its primary axis (the azimuth axis) vertical to the ground. The secondary axis, often called elevation axis, is then typically normal to the primary axis. They are similar to tip-tilt systems in operation, but they differ in the way the array is rotated for daily tracking. Instead of rotating the array around the top of the pole, AADAT systems can use a large ring mounted on the ground with the array mounted on a series of rollers. The main advantage of this arrangement is the weight of the array is distributed over a portion of the ring, as opposed to the single loading point of the pole in the TTDAT. This allows AADAT to support much larger arrays. Unlike the TTDAT, however, the AADAT system cannot be placed closer together than the diameter of the ring, which may reduce the system density, especially considering inter-tracker shading.

How different is ours from others?

The following points are the major differences that makes our Digital Solar Tracking System unique from other tracking systems which are in use:

- **Real Time Tracking / No Previous Data Approximations**

  In few of the all Solar plants, tracking is made based on the previous positions of the sun from a decade ago.

  And the whole system is programmed to move the required tracker according to the data, they collected while carrying out their experiments.

  But in our system, it is not the way tracking is done. Instructions to the tracker are given by the controller as soon as sensors find the exact position of the sun. So there is no chance of errors compared to the systems mentioned above as there is nothing like approximations here.

- **Working of a system is as simple as Sun Dial Experiment**

  We use shadow of a pole (Pole 1m is a part of tracking system) to track the position of sun. As if its shadow falls on the sensors, it provides the coordinates of the sun to the controller so that it works according to program methods given to the controller.

- **Low power consumption**

  As the controller uses simple embedded board which works with an input supply of 5V, there is no much consumption of power by the tracking system.

  Compared to the output power of the solar panel, the power consumed by the system will be around 0.05% of a typical solar system.

- **Cost Efficient**

Construction of Setup & Working

The project uses a solar panel coupled to two stepper motors to track the Sun so that maximum sun light is incident upon the panel at any given time of the day. This is better compared to light sensing method that may not be accurate always for example during cloudy days.

Use of solar panel to convert sun's energy to electrical is very popular, but due to transition of the Sun from east to west and also in north to south axes the fixed solar panel may be able to generate optimum energy. The proposed system solves the problem by an arrangement for the solar panel to track the Sun.

This tracking movement is achieved by coupling two stepper motors to the solar panel such that the panel maintains its face always perpendicular to the Sun to generate maximum energy. This is achieved by using a programmed microcontroller to deliver stepped pulses in periodical time intervals for the stepper motors to rotate the mounted panel as desired.

So this is a dual axis solar tracker which tracks the sun in both east-west and north-south axes.

The microcontroller used in this project is from 8051 family. The stepper motor is driven by an interfacing IC as the controller is not capable of handling the power requirements of the stepper motor. The project is provided with a dummy solar panel which can be used for demonstration purpose only.

Further the project can be enhanced by using RTC (Real Time Clock) to follow the Sun. This helps in maintaining the required position of the panel even if the power is interrupted for some time.

Hardware Requirements

- 8051 series Microcontroller
- Dummy Solar Panel
- Two Stepper Motor
- LDRs
- ADC 0809
- Connecting cables like JTAG, jumpers

Software Requirements

- Keil μ version 4 Compiler
- Languages: Embedded C
- ECEFlash P89V51RD2 Flash writer

So the tracking of sun is achieved by controlling the two steppers motors:

(STM1- for motion1, that is, east-west motion, STM2- for motion2, that is, north-south motion)

Description of the Setup

The main sensing elements used are LDRs (Light Dependent Resistors). These LDRs are placed in a circular array where these can be identified in a unique manner. The circular platform so formed contains a pole placed at the center of the circular pattern.

When the setup is placed in an open area in sunlight, the shadow formed due to the pole on the platform is the key thing to determine the coordinates of the sun.

For reference, the setup is placed at one particular stable horizontal location throughout the whole process of tracking the sun.

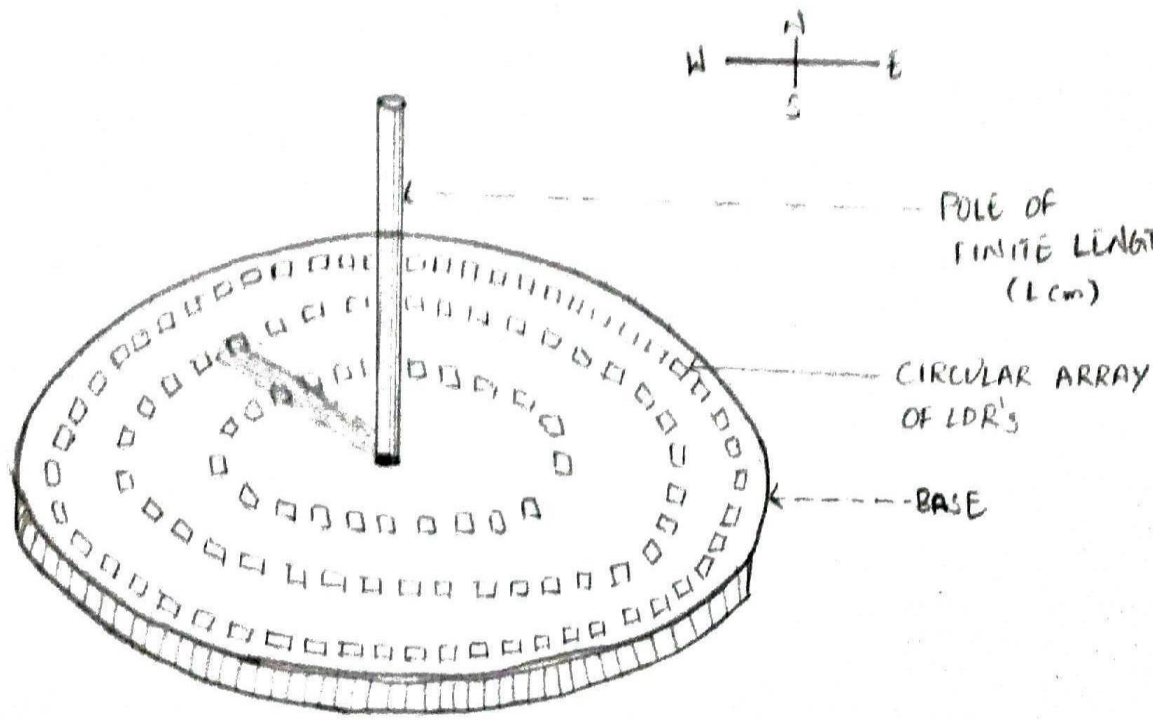

Fig.1 Side View of the Setup

For proper explanation of working, Let us assume few parameters regarding the circular platform (base of setup).

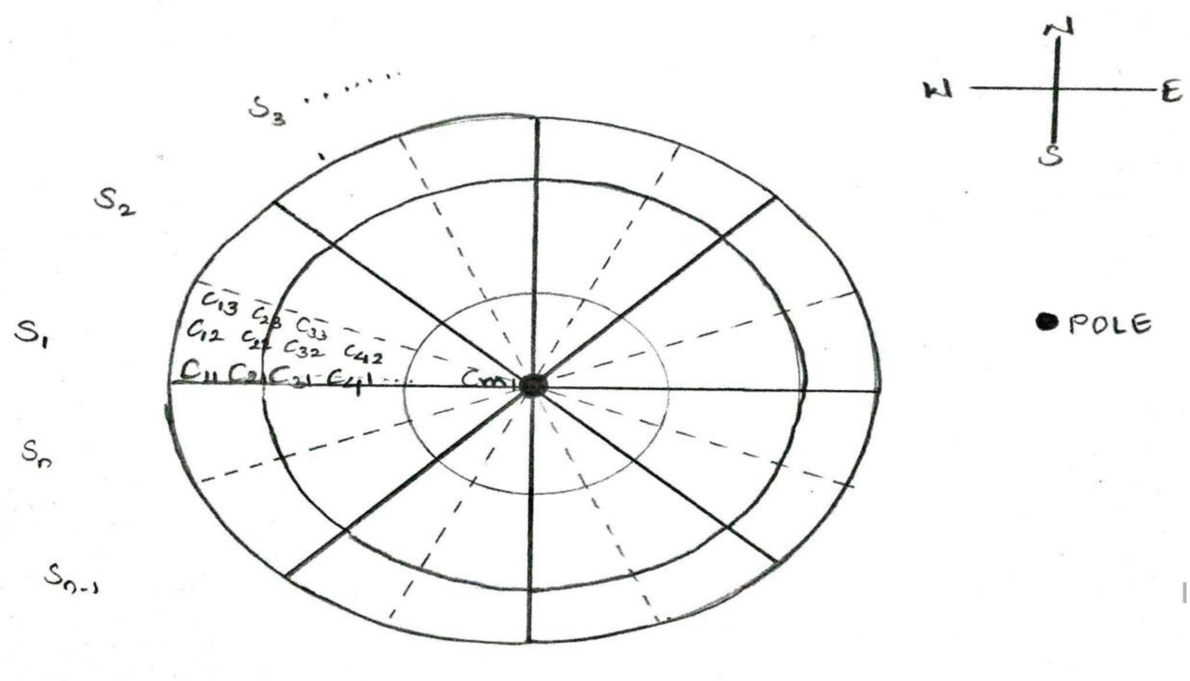

Fig2 Top View of the Setup with Parameters Explained

- Sectors (S1, S2, S3………….Sn)
- Concentric Circles (C1,C2,C3………..Cm)
- LDRs (C1a,C1b, C1c....//, C2a, C2b, C2c…//………//……..//)

By this, every sector is considered as a unique location on the setup base. A unique set of LDRs can be found in these sectors.

This can be clearly seen in the above figure.

Corrections

The setup is powered by 5V DC supply. All the LDRs are connected in parallel to the power supply.

Refer the below figure.

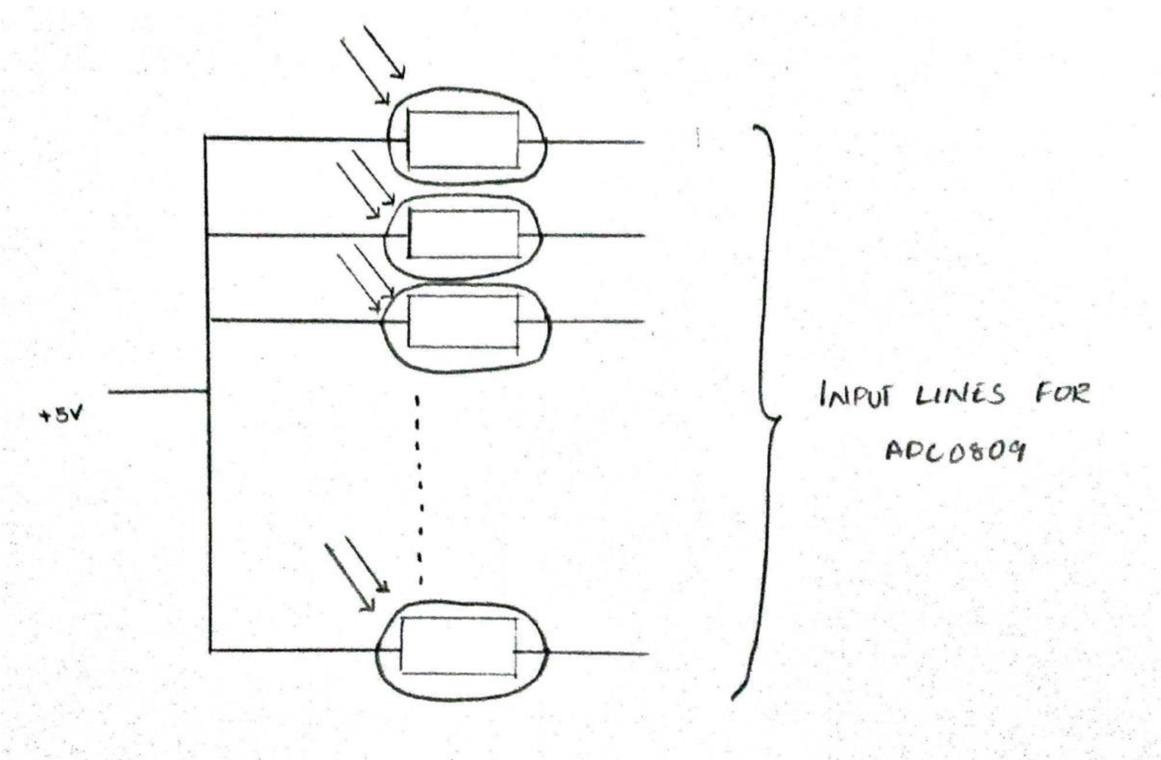

Fig3 Interfacing LDR setup with ADC0809

When the shadow created by the pole falls on the LDRs, the resistance of every LDR within the shadow increases creating a low potential at the other terminal of LDR. All these terminals collectively from the setup are transferred to ADC0809 which converts these analog signals into unique digital code(c1a c1b c1c….c2a c2b….)

This code is processed to control motion1 and motion2 so as to get the desired results.

How STM1/ Motion1 is controlled??

8051 family microcontroller is used as main controlling unit.

IC LM293D is used to drive the stepper motors.

Motion1 is deciding the plane in which the sun and the pole of the setup are enclosed.

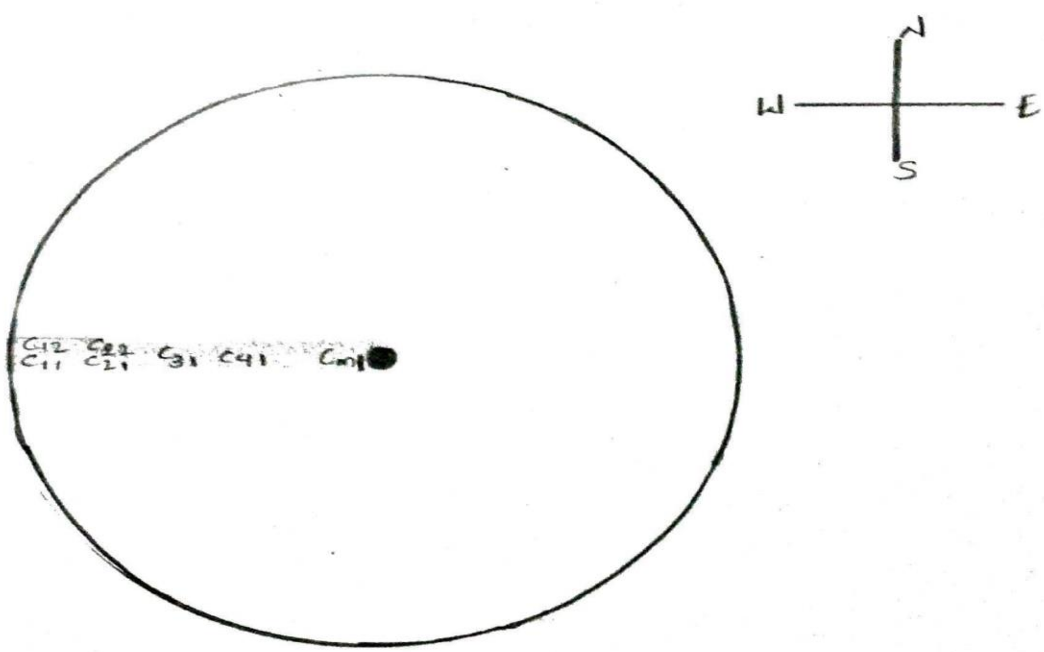

Fig4 Illustration Figure for Motion1

When shadow falls on the setup base, a code is generated out of ADC which is stored in microcontroller. In the figure, a set of LDRs are seen within the shadow so the mega code stored contains 0s at all bit places where C11, C21, C31, C41, C12, C22, Cm1 falls.

The microcontroller is programmed using Embedded C language, the above outcome is processed using conditional statements and motor1 is instructed to perform accordingly.

How STM2/ Motion2 is controlled??

Motion2 is determined by the elevation angle of the sun through the day and the STM2 is instructed according to the program.

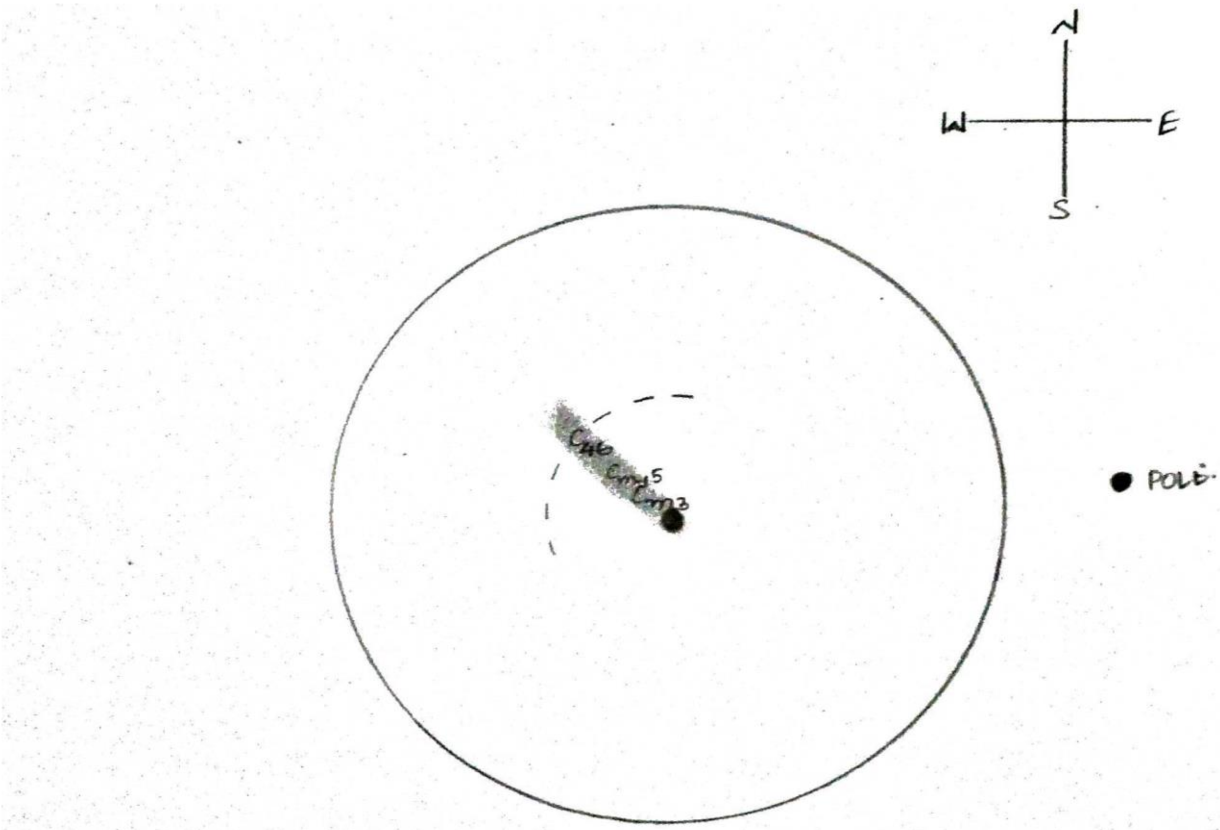

Fig5 Illustration Figure for Motion2

So the deciding factor to control this motion is the length of the shadow from the bottom of the pole, that is, it helps to figure out the last concentric circle intersecting the shadow. In the above demonstration figure C41 is found to be the last circle intersecting the shadow, as the radius of the circle remains constant all time, the controlling of motion2 is done by making the panel facing the sun for continuous change in elevation angle of the sun. Motion1 and Motion2 are simultaneously controlled to track the sun in both the axes (E-W and N-S).

Real Time Industrial Implementation

For the above described solar tracking system, the real time industrial implementation depends on the following points:

- More number of LDRs must be used to increase the sensing power and the required size should be small.
- Number of I/O pins of ADC used in the setup should as high as possible.
- The processing time of the microcontroller should be as less as possible. Hence it is better to use the efficient controlling unit.

Disadvantages

- Trackers add cost and maintenance to the system - if they add 25% to the cost, and improve the output by 25%, the same performance can be obtained by making the system 25% larger, eliminating the additional maintenance. Tracking was very cost effective in the past when photovoltaic modules were expensive compared to today. Because they were expensive, it was important to use tracking to minimize the number of panels used in a system with a given power output. But as panels get cheaper, the cost effectiveness of tracking using a greater number of panels decreases.

- Tracking is also not suitable for typical residential rooftop photovoltaic installations. Since tracking requires that panels tilt or otherwise move, provisions must be made to allow this. This requires that panels be offset a significant distance from the roof, which requires expensive racking and increases wind load. Also, such a setup would not make for a very aesthetically pleasing install on residential rooftops. Because of this (and the high cost of such a system), tracking is not used on residential rooftop installations, and is unlikely to ever be used in such installations.

- Tracking can also cause shading problems. As the panels move during the course of the day, it is possible that, if the panels are located too close to one another, they may shade one another due to profile angle effects. But it will reduce output during certain hours of the day (i.e. around solar noon) compared to a fixed array.

- Solar trackers are slightly more expensive than their stationary counterparts, due to the more complex technology and moving parts necessary for their operation.

Advantages

- According to the above described solar tracking system, it is simple to understand and implement on a large scale so as to achieve the required needs.

- Generally, Solar trackers generate more electricity than their stationary counterparts due to an increased direct exposure to solar rays.

- There are many different kinds of solar tracker, such as single-axis and dual-axis trackers, which can help you find the perfect fit for your unique jobsite. Installation size, local weather, degree of latitude, and electrical requirements are all important considerations that can influence the type of solar tracker that’s best for the required output.

- Solar trackers generate more electricity in roughly the same amount of space needed for fixed tilt systems, making them ideal optimizing land usage.

Conclusion and Future Work

Solar trackers are rising in popularity, but not everyone understands the complete benefits and potential drawbacks of the system. Solar panel tracking solutions are a type of device that host mounted photovoltaic panels, which use the sun to generate electricity. It's a fantastic system for energy output, but there are a few considerations to bear in mind before pursuing one for your jobsite.

So through the above described technique, it is easier to meet the requirements and can be developed on a large scale.

The whole working explains the focussed use of ADC0809 and 8051 Microcontroller with proper setup construction so as to enhance the system's output power. The efficiency of this solar tracking technique can be increased by enhancing some resolution parameters on which the main outcome depends on.
Therefore, it can be one of the good procedures for tracking the sun at the approximate coordinates and even during the cloudy days.

Developing a prototype was not made properly as the stay at IIITM Gwalior was time bounded . We ensure to continue the work on this project to further develop and make it as a productive machine which could be introduced in to the market.

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