Microcontroller based Solar Tracker system using LDRs and Stepper Motor

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ABSTRACT
The renewable sources of energy are becoming one of the utmost priorities of the present day world due to their innumerous advantages. In particular, solar energy is progressing as a potential inexhaustible and non-polluting energy source to suffice our ever-increasing energy requirements. However, the solar panels which are the fundamental solar-energy conversion components are fixed at a certain angle and are not able to track the sunlight direction with diurnal and seasonal changes. This limits the area of exposure of sunlight on solar panels and efficiency of the solar tracking system involving solar panels. We have developed a solar tracking system using a combination of micro-controller, stepper motor and light dependent resistors (LDR's) with the primary aim of improving the power efficiency of the solar panels. The main component of this tracker is AT89S52 micro-controller which is programmed to detect the sunlight with the help of LDRs and then actuate the stepper motor to position the solar panel in such a way so that it gets the maximum sunlight. Thus this system can achieve maximum illumination and can reduce the cost of electricity generation by requiring minimum number of solar panels with proper orientation with the sunlight. This work is an application development done in college project.

General Terms
Solar Tracking, Code generation, Stepping sequence

Keywords
Solar tracker, LDRs, Stepper motor, AT89S52, Solar panel.

1. INTRODUCTION
Solar energy is becoming increasingly lucrative with the increasing cost and continuous depletion of the non-renewable energy resources and the growing demand of other renewable energy sources [1] such as solar wind, geothermal and ocean tidal wave [2]. However, in spite of the multiple benefits of solar energy, solar panels which capture sunlight are stationary (solar array has a fixed orientation to the sky). These stationary as well as expensive solar panels are unable to extract the maximum solar energy as there is no stability of weather conditions [3]. The power output of solar panels is maximum when it is oriented perpendicularly to the direction of sun rays as both the area of illumination of sunlight on solar panels and intensity of sun-rays is maximum in this case. It has been found out that the efficiency of solar panels improve by 30-60 percent when we use a mobile solar tracking system instead of a stationary array of solar panels [4]. The design and implementation of a power efficient solar tracker is therefore a challenge owing to the immobility of the solar panels. The angle of inclination of sun-rays with the solar panels continuously changes due to the movement of the sun from east to west because of earth's rotation independent of the weather conditions [5]. Moreover**,** during cloudy days the situation totally goes berserk. Additionally the revolution of the earth alters the distance between earth and sun which introduces change of pattern of incoming sun rays. All these factors should be kept in mind for designing the solar tracking electricity generation system to achieve maximum efficiency.

In this paper, we have discussed about the solar tracking system that we have designed using some LDR's (light dependent resistances), micro-controller (AT89S52), comparator using OPAMP's, a crystal oscillator, stepper motor and stepper motor driver. The basic idea behind this work is that the intensity of light will be sensed by the LDR's separated by a certain angular distance, the comparators will compare the incident light intensity with the intensity of perpendicular incidence. The micro-controller will rotate the stepper motor by the desired angle depending on the output of the comparators via a stepper motor driver circuit to maximize the efficiency. Owing to the change in the location where the device is placed and weather conditions, the intensity of sunlight changes, for which we have made a provision of changing the threshold value by using variable resistances.

2. LITERATURE REVIEW
Till date, several groups have successfully reported the construction and functioning of microcontroller based solar tracking system. The autotracking of a 8051 microcontroller based solar tracker using a combinations of LDRs, optocouplers, stepper motor, relays, analog to digital converter, etc and manual tracking done by a "Sun Tracking Software" is reported in [1]. Anuraj et al reported the implementation of a solar tracking system using ATMEGA 16 which improved the power efficiency by as much as 20% [2]. Tudorache *et al.* explained the design and execution of solar tracker system for Photovoltaic (PV) power plants. The operation of the tracker is based on a DC motor controlled by an intelligent driver circuit which moves a mini PV panel sensing the difference signal from two efficient light sensors [6]. The tracking implementation of a solar tracker prototype using a PIC 16F84A microcontroller with the design of two degrees of freedom- azimuth and vertical is reported in [7]. Wang *et al.* proposed a novel design of a dual-axis solar tracking PV system utilizing a feedback control theory, a four-quadrant light dependent resistor (LDR) sensor and simple electronic circuits. Tracking is accomplished with the help of a unique dual-axis AC motor and a stand-alone PV inverter [8].

3. HARDWARE IMPLEMENTATION
The entire project work is divided into two parts:
1. Hardware Development and Implementation
2. Code Generation and Execution
In this section, we will elaborate the block diagram, circuit diagram, working principle and different components required for the implementation of our solar tracking system. Figure 1 shows the block diagram of the designed solar tracker system. The LDR output and the reference voltage are the inputs to

the comparator LM358. The comparator outputs are applied to the microcontroller AT89S52 which rotates the stepper motor to the direction of maximum solar radiation via a stepper motor driver.

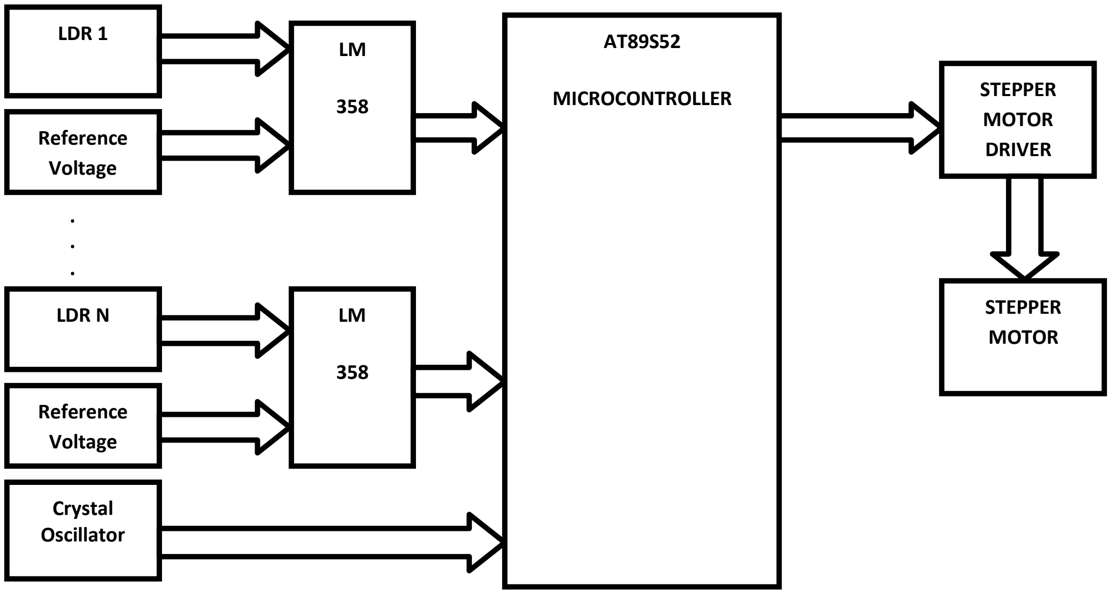

Fig 1: Block Diagram of the Solar Tracker

Figure 2 shows the schematic diagram of the solar tracker circuit. The basic component that we are using to measure the intensity of sunlight is LDR as the resistance of LDR, as the name implies, is a function of the intensity of the sunlight that falls on it. We have used five LDRs enclosed in cylindrical covering so the LDRs get activated only when light is perpendicular to the upper opening of the cylinder.

The LDRs are arranged in a semi-circular arc as shown in Figure 3. The cylindrical covering is used to prevent the stray light from being detected by the LDRs [9]. The LDRs are placed around 30 degrees apart. The purpose behind such an arrangement is that, as sun moves from East to West, at an instant, the sun rays can be perpendicular to only one LDR. Due to the cylindrical covering of the LDRs, only that LDR, to which sunlight falls perpendicularly, will get activated. And based on that the microcontroller will have the information as to how much the stepper motor is to be rotated to make the solar panel perpendicular to the direction of sunlight at that instant. We had earlier calculated the resistance of the LDR under three different situations using multimeter.

1. Under bright light (corresponding to the perpendicular sun rays), the resistance was a few ohms.

2. Under normal light condition it was approximately 2 kΩ.

3. Under dark condition, the resistance is as high as 16 kΩ.

Now, the voltage across the 2.2 kΩ resistor is given by:

$$V_{out} = \frac{2.2*5}{2.2 + LDR_{res}}$$

where LDR_{res} denotes the resistance of the LDR under different conditions. As the intensity of sunlight increases, LDR_{res} decreases and V_{out} increases. For condition 1, V_{out} will be close to 5V and under normal light condition V_{out} will be close to 2.5V. So, to differentiate between normal light condition and perpendicular light condition, we set a threshold of approximately 4V. The entire design is done keeping in mind that at an instant the output of one and only one comparator would be high. The outputs from 5 comparators (each corresponding to a LDR) is connected to PORT 1 of AT89S52 from p1.2 to p1.6. As the sun moves from east to west, the microcontroller checks the output of the comparators and once it detects a high output, the stepper motor starts rotating from its previous position to align the solar panel in the direction of maximum solar radiation. The stepping sequence of the stepper motor for 1.8 degree anticlockwise rotation is shown in Table I. Here A, B, C, D refer to the four coils of the stepper motor. ‘1’ denotes that the particular coil is energized and ‘0’ denotes negative. The

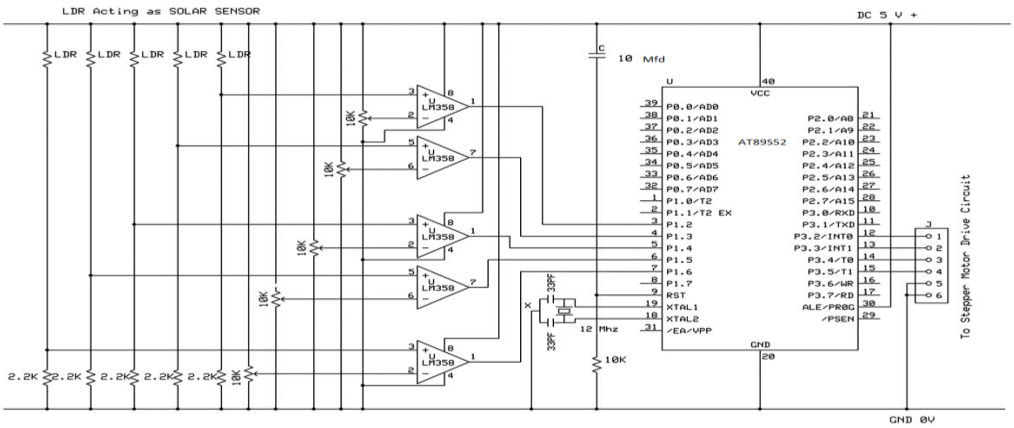

Fig 2: Schematic of Solar Tracker Circuitry

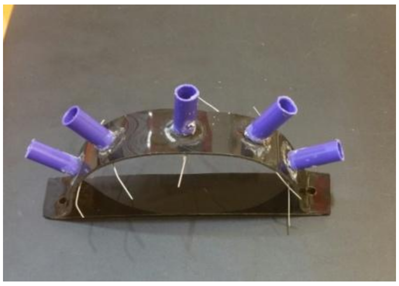

Fig 3: Light Dependent Resistors in Cylindrical Covering

black wire of the stepper motor is to be permanently grounded for its operation. This sequence has to be repeated required number of times to achieve required angular spacing. Initially the panel is so arranged that it faces downwards so that it remains dust and dirt free when there is no sunlight. When output of the comparator corresponding to the east most LDR is high for the first time in a day, the stepper motor rotates from its reset position to align the solar panel with the LDR. Thereafter when the output corresponding to the second LDR is found to be high, the stepper motor rotates 30 degrees anticlockwise to re-align the solar panel to the second LDR. This process is repeated for the rest of the LDRs.

TABLE I. STEPPING SEQUENCE OF THE STEPPER MOTOR

Winding D	Winding C	Winding B	Winding A
1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

4. PROGRAMMING METHODOLOGY

Two softwares were used for obtaining the hex code and burning the program into the microcontroller. We have written down the source code in assembly language in an interface of **EdSim51DI**. The software that we have used for burning the hex code is **UniPro.** The flowchart of the program for the operation of the tracker is given below in Figure 4. The LDRs are connected through bit 2 to 6 of Port 1. In the morning the sun rays first fall vertically on the first LDR, which is connected to P1.2 which becomes 1. After this, the stepper motor rotates the face of the solar panel to the position of the first LDR by moving 5 steps anticlockwise (using '**startangle**' subroutine). Thereafter, the microcontroller continuously checks the second sensor, connected to P1.3. When the sun rays vertically fall on it, P1.3 becomes high and the stepper motor rotates the face of the solar panel to the position of the second LDR by moving 1 step anticlockwise using '**anglechange**' subroutine. The four wires of stepper motor are connected from Port 3.2 to Port 3.5. In order to rotate the stepper motor anticlockwise or clockwise, a sequence has to be followed. Wire D of the motor will be high first followed by C, B and A. A small delay has to be applied before making any of the wires (A, B, C or D) high. This delay is under the subroutine '**dly**' whose duration is about 3 msec. This delay is used to make the sequence discrete. After following the above mentioned sequence, the stepper motor will rotate 1.8 degree. Since the LDRs are approximately 30 degrees apart, one step of the stepper motor will correspond to 30 degrees and so the aforesaid sequence has to run several times to achieve this step. Similar situation arises for the 5 steps mentioned in the '**startangle**' subroutine. Like this, as time progresses, the stepper motor rotates the solar panel from position 1 (when P1.2 is high) to position 5 (when P1.6 is high). After it reaches the fifth sensor it waits for about 10 seconds. We can increase this duration as per our requirement. This delay is programmed under '**longdly**'. Then the '**night**' subroutine is called. In this subroutine, the stepper motor rotates the solar panel five steps anticlockwise towards the rest position where the solar panel faces the ground. The program control will go to the label '**Main**'.

5. RESULTS AND DISCUSSIONS

The designed prototype is tested in the laboratory using a torch light as the light source. The comparator output connected with the east most LDR becomes high when the light is incident on the LDR and the prototype orients itself in the east most direction from its reset position. The designed tracker works successfully in a similar way to that described in Sections 3 and 4. Figure 5 shows the designed solar tracker system which is actually a working model of the main system. The components used for the tracker are Microcontroller (AT89S52), OPAMP as comparator (LM358), Stepper Motor (4SHG-050A 5IS 5V, 5Ω), Solar panel (Module type-SS3P) and Stepper Motor Driver (nifc 01 ver.3)

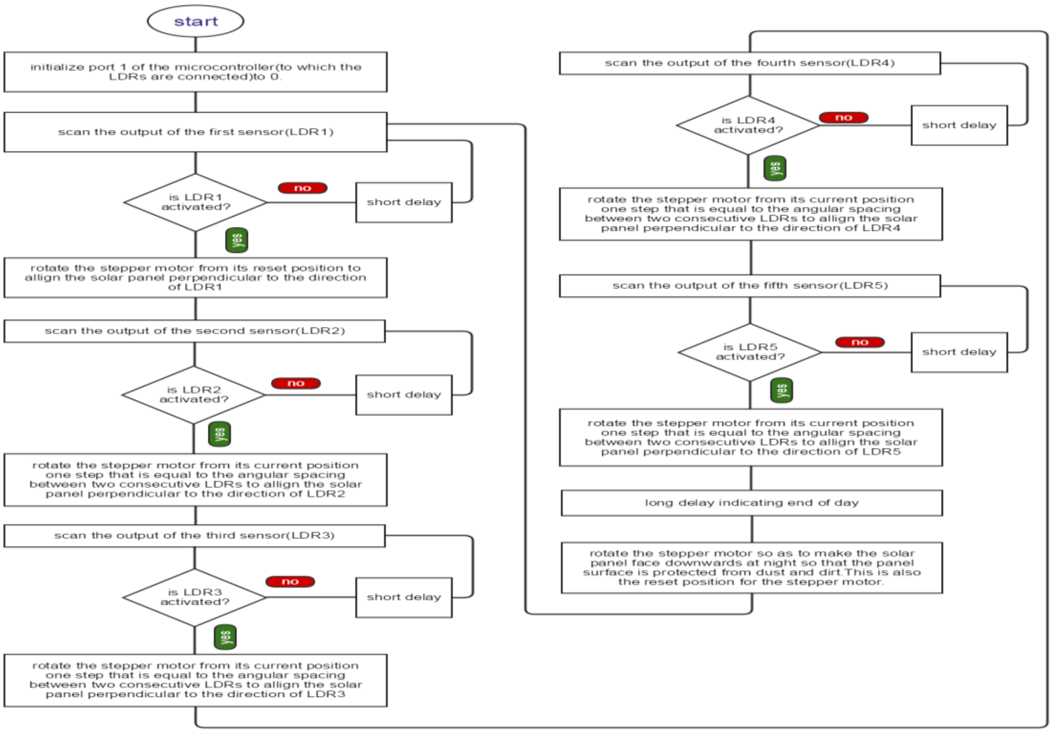

Fig 4: Flowchart of the Solar Tracker

6. CONCLUSIONS

The designed solar tracker system could track the movement of the sun with the help of microcontroller and stepper motor. This system can work properly irrespective of weather conditions and location. We can change the threshold voltage of the tracker according to our requirement. It can also initialize the starting position once the sun sets. Moreover, during night the solar panel faces the ground which in turn protects it from dust particles and increases its longevity. However, the designed prototype of the solar tracker is a miniature of the main system and so there are a number of limitations. The number of LDRs should be increased for the practical case. Moreover, we have considered one-dimensional rotation of the tracker. So we aim to increase the degrees of freedom of this tracker in future course of work.

Fig. 5: Designed Solar Tracker System

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REFERENCES

[1] Arsalan, S. 2013. Sun Tracking System with Microcontroller 8051, Intl. J. Sci & Eng. Research, Vol. 4, 2998.

[2] Anuraj, A.,and Gandhi R., 2014, Solar Tracking System Using Stepper Motor**,** Intl. J. Electronic & Electrical Eng., Vol.7 , 561

[3] Chhatwani, P. K., and Somani, J. S., 2013, Intelligent Solar Tracker System Implemented On 8051 Microcontroller, Intl. J. Eng. Trends Technol., Vol 4, 4267.

[4] Saxena, A. K., and Dutta, V., 1990, A versatile microprocessor based controller for solar tracking, Photovolt Specialists Conf., 21st IEEE Proc.

[5] Nirmal, H. B., and Naveed, S. A., 2013, Microcontroller Based Automatic Solar Power Tracking System, Intl. J. Electrical Eng. & Technol., Vol 4, 109.

[6] Tudorache, T., and Kreindler, L., 2010, Design of a Solar Tracker System for PV Power Plants, Acta Polytech. Hung., Vol 7, 23.

[7] Barsoum, N., and Vasant, P., 2010, Simplified Solar Tracking Prototype, Global J. Technol. Optim.,Vol. 1, 38.

[8] Wang., J. M., and Lu, C. L., 2013, Design and Implementation of a Sun Tracker with a Dual-Axis Single Motor for an Optical Sensor-Based Photovoltaic System, Sensors, Vol. 13, 3157.

[9] Bingoll, O., Altintas, A., and Oner, Y., 2006 Microcontroller Based Solar-tracking System and its Implementation, J. Eng. Sci., Vol. 12, 243.