Cost Effective System Modeling of Active Micro-Module Solar Tracker

Md. Faisal Shuvo
Dept. of ECE,
Khulna University of Eng. & Tech.,
Khulna-9203, Bangladesh

Md. Abu Saleh Ovi
Dept. of ECE,
Khulna University of Eng. & Tech.,
Khulna-9203, Bangladesh

Md. Mehedi Hasan
Dept. of ECE,
Khulna University of Eng. & Tech.,
Khulna-9203, Bangladesh

Arifur Rahman
Dept. of ECE,
Khulna University of Eng. & Tech.,
Khulna-9203, Bangladesh

Mirza Md. Shahriar Maswood
Dept. of ECE,
Khulna University of Eng. & Tech.,
Khulna-9203, Bangladesh

***Abstract*— The increasing interests in using renewable energies are coming from solar thermal energy and solar photovoltaic systems to the micro production of electricity. Usually we already have considered the solar tracking topology in large scale applications like power plants and satellite but most of small scale applications don't have any solar tracker system, mainly because of its high cost and complex circuit design. From that aspect, this paper confab microcontroller based one dimensional active micro-module solar tracking system, in which inexpensive LDR is used to generate reference voltage to operate microcontroller for functioning the tracking system. This system provides a fast response of tracking system to the parameters like change of light intensity as well as temperature variations. This micro-module model of tracking system can be used for small scale applications like portable electronic devices and running vehicles.**

Keyword— micro-module, active solar tracker, LDR sensor, microcontroller.

I. Introduction

Renewable energies can technically contribute to practically all sectors of energy demand, that is, fuel for transportation, electricity, and low temperature heat for space heating and hot water and, to a limited degree, to high temperature process heat. As other sources of energy are finite and someday will be depleted but renewable energy will not run out ever. Most renewable energy investments are spent on materials and workmanship to build and maintain the facilities, rather than on costly energy imports. Solar energy is one of the best ways to reduce the problem of energy deficiency and environment pollution in modern society. In the actuality a lot of research works have been conducted to improve the use of the solar energy. Tracking technologies can also be applied to rural and remote areas for small scale applications, where energy is often crucial in human development because photovoltaic power generation is clean and pollution less with respect to other available resources [1] having wide range of applications [2]. Different kinds of single axis or two axis solar `s and programs were presented in the previous year's [3], [4]. Some optimization of solar trackers concentrated on shading, cost, and sizing for photovoltaic systems and mass-flow rate for thermal systems were discussed [5-8]. While many solar energy tracking projects are large-scaled [9] having complex design with maximum power point calculation [10], [11] as well as solar panels are body mounted and fuzzy based [12], the tracking system is controlled by the photovoltaic sensors and its accuracy is determined by the accuracy of mechanical model [13], [14] and combination of integrated circuit as well as large array sensor system [15]. Single axis or one dimensional solar tracker is a device having one degree of freedom that orients the solar panel to the direction of incident rays of sunlight for particularly in one dimensional rotation for obtaining maximum power for longer duration. It will be effective more than dual axis tracker if we consider some other criteria like circuital power consumption, sensor accuracy, mechanical simplicity, wind loading and tolerance to misalignment. There are two types of tracker according to their functional properties like active tracker and passive tracker. Active solar tracker uses external sources of energies to power blowers, pumps and other types of equipment to collect, store and convert solar energy. Once energy is received it stored for later appliances. Small systems are used to furnish electricity for heating and cooling system in homes and other sections, where large system can furnish power for entire communities. As the installation cost and complexity of dual axis tracker is very much larger than single axis or one dimensional tracker corresponds to its efficiency as well as the mechanical module. On the other hand single axis tracker offers lower cost and higher reliability. The possible horizontal rotation can be possible manually if needed if we consider one dimensional tracker vertically for small scale applications. This active one dimensional tracker will provide the best power output relevant to less installation cost than any other tracking system.

This paper proposes an active micro-module solar tracking system focusing on cost effective circuital setup with less complexity based on LDR sensor with its maximum accuracy as well as microcontroller as function of ADC converter and comparator to attain maximum energy storage with less power consumption and having fast tracking response for small scale applications as well as portable devices witsih maximum performance corresponding to different parameters. Besides these we also consider about the power consumption of motor as well as motor driver for maximum output response as well.

The rest of the paper organized as follows. Section II briefly overviews of our proposed micro-module model. Section III describes the proposed algorithm of our method. Software simulation as well as experiments and result analysis are described in Section IV and V. The overall discussion is represented in Section VI. We conclude the paper and future research directions in Section VII.

II. Our Proposed Model

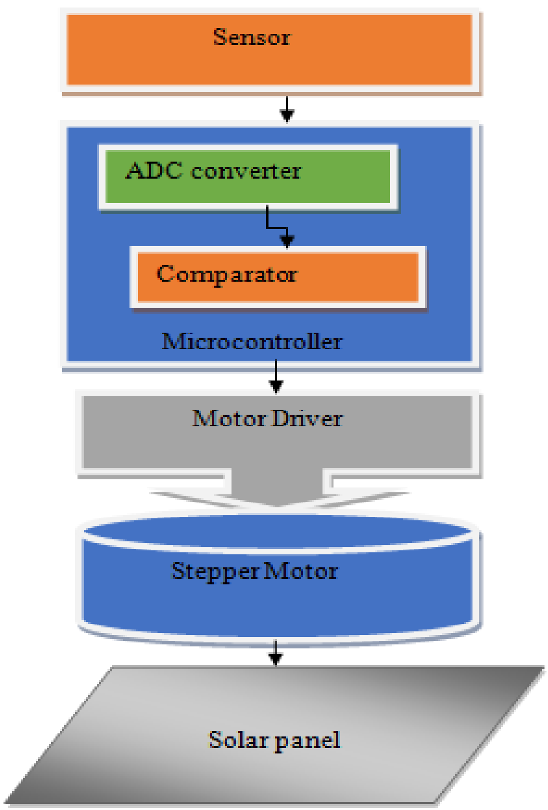

Fig.1. Our proposed micro module tracking model

Fig.1 shows our improved solar tracker model in which we have tried to implement a complexion free tracking setup of vertical single axis or one dimensional module tracker using LDR (Light Dependent Resistors), microcontroller, a motor driver chip and a stepper motor which will control the tracking system of solar panel from east to west with necessary programs included in microcontroller as well.

A. Sensing Protocol

Photo sensors are used in many projects involving sensing of light and shadow. In case of making an efficient project we must consider of choosing reasonable sensor from wide variety among different types of sensors.

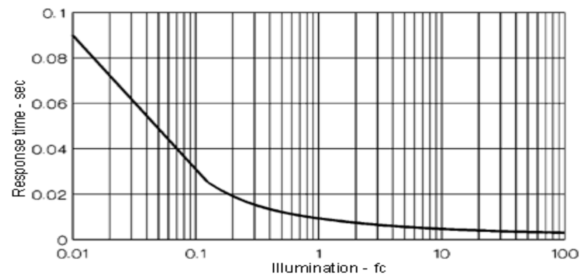

Fig.2. Response time vs. illumination-decay time

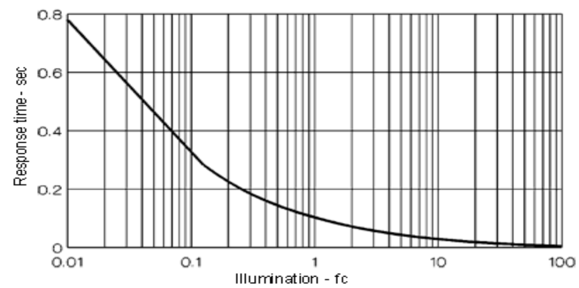

Fig.3. Response time vs. illumination-rise time

We have used LDR as photo sensor that is cheap and rugged in nature which is suitable for external uses. They are basically resistors whose resistance depends on the intensity of light**.** By considering the properties of LDR which is suitable for applications where many different levels of light intensity are to be measured with its moderate response time. In here we have used the properties of changing resistance and voltage drop across the LDR. Fig.2 & Fig.3 shows speed of response at which a photocell responds to a change from light-to-dark or from dark-to-light. The rise time is defined as the time necessary for the light conductance of the photocell to reach 1-1/e or about 63% of its final value. The decay or fall time is defined as the time necessary for the light conductance of the photocell to decay to 1/e or about 73% of its illuminated state.

B. Processing of Sensor Output with Microcontroller

As light signal or illumination is continuous analog signal so it is practically difficult to compare the output of two sensors we have used in east and west direction with real time to track sun's position without comparing it. For this comparison we need to convert analog voltage to discrete voltage using ADC conversion which is built in function of microcontroller we have used Atmega8L which reduces the external implementation ADC circuit. In it receives analog signal directly from the LDR sensor's voltage drop and then convert it to discrete value which can be determined numerically then compare the voltage difference of these sensors. This is done by small program loaded in it. This reduces addition of circuital arrangement of reference voltages. The program loaded in microcontroller have a small algorithm to check, compare and give necessary commands as output for taking the decision of rotation of tracker. To drive the motor we have used a motor driver L293D that will help to gear up the stepper motor of 12v.

C. Reason of Using Stepper Motor for Maximum Efficiency

The power consumption of the motor depends on the moment of inertia which relates to the output torque of the motor and the moment of inertia relates to the factor of width and length of the solar panel as well as the tilt angle of the panel related to the step-angle of the motor and the basic equation of moment of inertia is given by the following equation.

$$I = \frac{\frac{1}{12}m(l^2 + w^2)}{cos\theta} \qquad (1)$$

Where the mass $'m'$, length $'l'$ and width $'w'$ of the solar panel is fixed and the only way to reduce the inertia by reducing the tilt angle of the solar panel which is similar to the step-angle of the motor.

$$I \propto \frac{1}{cos\theta} \qquad (2)$$

$$cos\theta \propto \frac{1}{\theta} \qquad (3)$$

If the step-angle θ decreases, $cos\theta$ increases and similarly inertia decreases. So, the stepper motor is used to reduce the inertia because its step-angle is 1.8° and the reason to reduce the inertia is to reduce the output torque of the motor because the torque is directly proportional to the inertia and it determines the power consumption of the motor.

$$\tau = I\alpha \qquad (4)$$

Where, $'\tau'$ is the output torque of the motor and $'\alpha'$ is the angular acceleration of the motor. The reduced inertia reduces the output torque and the reduced torque reduces the power consumption of the motor to achieve the maximum efficiency.

III. TRACKING ALGORITHM

We use a simply modified algorithm based on LDR sensing and microcontroller processing.Fig.4 represents this algorithm provides the automatic tracking system from east to west in a day and for the other day it will adjust it position again automatically.

According to Fig.4 firstly we determine light intensity incident from the sunlight of East and West sensors. From the difference of two sensors we will decide the stepper motor will rotate or not. If the difference exceeds 0.3 volt which is defined in program the motor starts to move on. Then according to given instruction it compare and check statements for the East and West light intensity and step on to desired position to hold the panel in order to attain maximum solar energy.

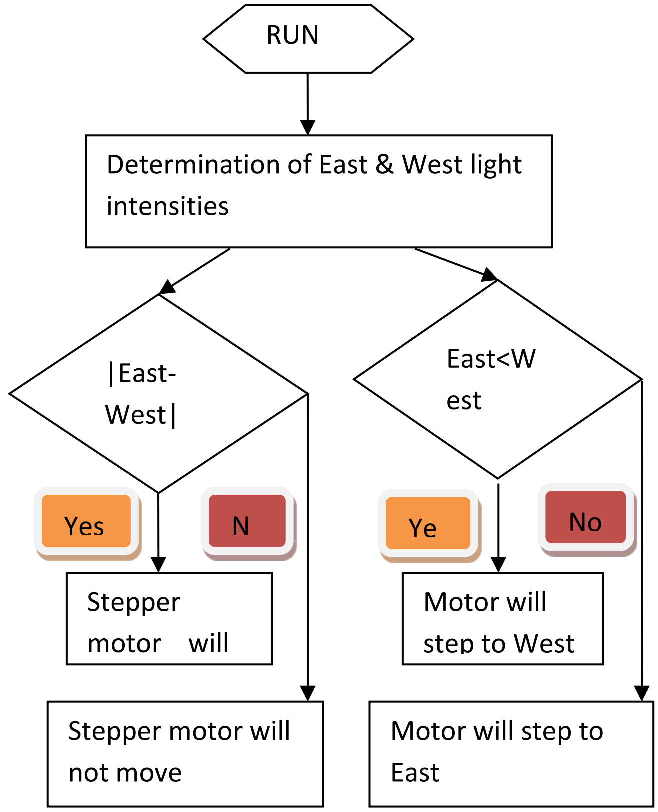

Fig.4. Flowchart of micro module tracking algorithm

IV. SOFTWARE SIMULATION

Fig.5 shows our ISIS professional simulated circuit. We have developed a program for AVR on the basis of an algorithm. First of all we implemented two sensor circuits to take input from the outer environment like radiation intensity of sunlight. Two LDR are used to take input of light intensity. Those are connected in ADC0 and ADC1 pin. By using ADC pin of Atmega8L we took that input then compare both input data.

Then it will convert into binary data with respect its logical unit. Then we send binary input to output pin for corresponding logical program. The PD0-PD3 is set to output port. These output ports are connected to stepper motor through driver L293D.

This driver drive and rotate the stepper motor in both direction according to the program generated in the microcontroller. The program is simulated in Micro C AVR studio & converted into a hex file to load in microcontroller as well.

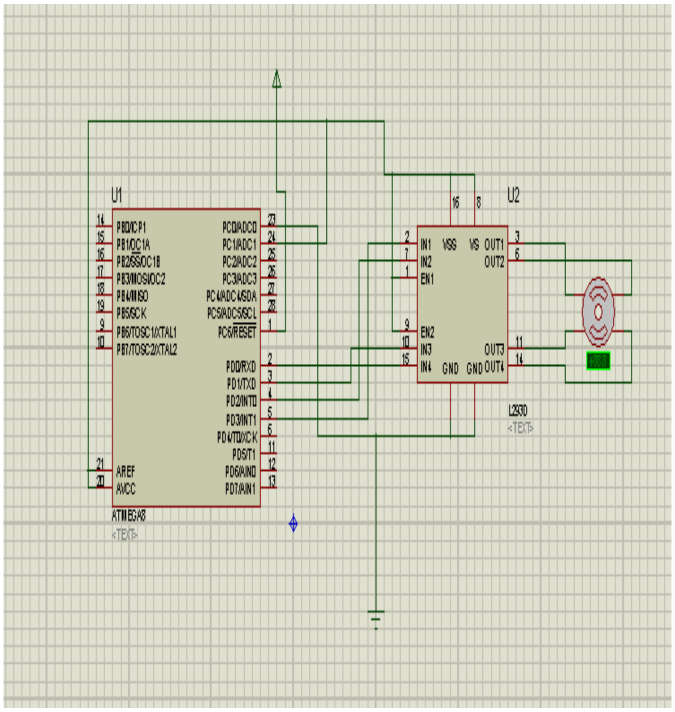

Fig.5. ISIS professional simulated circuit

V. EXPERIMENTAL EVALUATION

TABLE I. PERFORMANCE ANALYSIS OF TRACKING RESPONSE OVER A DAY.

Initial time	**Final time**	**Resistance of LDR 1 (Ω)**	**Resistance of LDR 2 (Ω)**	**Volt. Drop of Sensor 1 (V)**	**Volt. Drop of Sensor 2 (V)**
8:00 Am	8:10 am	512	500	3.30	3.34
9:05 Am	9:13 am	178.5	166.5	4.24	4.29
10:30 am	10:40 am	112	100	4.49	4.55
11:45 am	11:53 am	83.4	71.5	4.61	4.66
12:53 pm	12:58 pm	64.6	52.6	4.69	4.75
1:30 Pm	1:35 pm	62	50	4.70	4.76
2:53 Pm	2:58 pm	74.5	62.6	4.65	4.71
3:55 Pm	4:00 pm	112	100.5	4.50	4.55
4:55 Pm	5:00 pm	262	250	3.96	4.00

As the light intensity increases, the resistance of two LDR decreases and for this reason the voltage drop across two LDR also decreases and the light resistance as well as voltage drop of LDR is determined from the following equation which is closest to our experimented value.

$$\text{Light resistance, } R_L = \frac{500}{lux} K\Omega \qquad (5)$$

Voltage drop across LDR,

$$V_{LDR} = \frac{5 * R_L}{(R_L + 10)} volt \qquad (6)$$

As the voltage drop decreases with the increasing of light intensity, the current flow increases which causes the power consumption.

$$P_c = I^2 R \; watt \qquad (7)$$

For this reason, we use a 10K resistor in the sensor circuit to reduce this consumption and the sensor circuit is shown in the following figure.

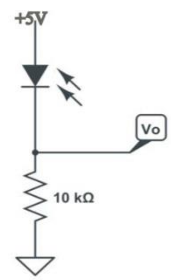

Fig.6. Sensor circuit

10K is preferred to 100Ω or 1KΩ because of its lower power consumption but if we use 25KΩ power consumption can be reduced whether the sensitivity also decreases.

The output voltage of sensor circuit,

$$V_o = 5 - V_{LDR} \; volt \qquad (8)$$

As the voltage drop across LDR decreases, the output voltage drop of sensor circuit increases and this output voltage is used as the input of micro-controller for analog to digital conversion which reduces the power consumption. The data Table.1 shows the relationship between resistance of LDR-1 as well as LDR-2 and light intensity across day time from 8:00 am to 5:00 pm and Fig.7 shows the resistance characteristic curve of LDR-1 and LDR-2.

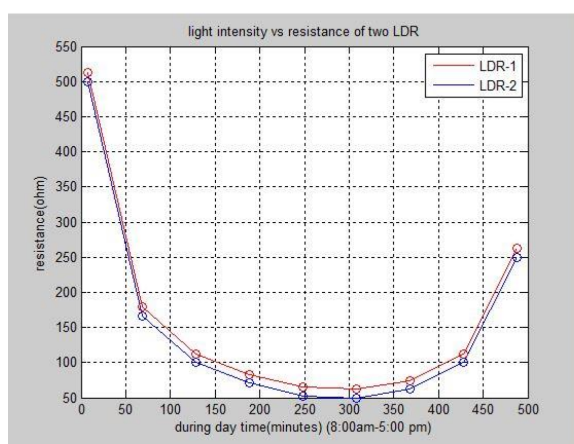

Fig.7. Matlab simulated resistance variation curve of LDR-1 &LDR-2

In Fig.8, we have also observed that the voltage drop of Sensor-2 (West) is always greater than Sensor-1 (East) during day time and for this reason the solar panel rotates from East to West during day time and at night it stays at the West direction and in the morning it moves to the East direction because at that time we place an another additional LDR-3 as switch at East which sense the raising sunlight and automatically hold the panel to the East direction by an additional program loaded in microcontroller.

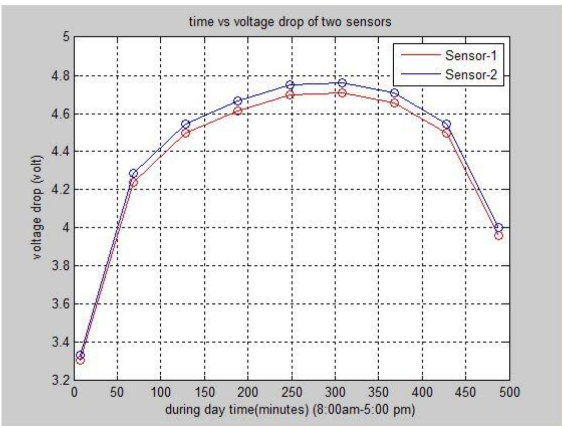

Fig.8. Voltage drop of two sensors across time

VI. Discussion

Now-a-days research on renewable energy for compensating our loss of resources of energy has been becoming more and more popular. Among different types of energy options the best and easiest option is solar energy is virtually inexhaustible than other natural resources. With economic consideration here we have implemented a new tracking scheme for covering wide range of uses of small applicable sections. We have observed different types of tracking system and their performance relevant to their installation cost and started our work on the basis of that with aiming at reduction of cost, complexion corresponding with maximum performance. We have modified our sensing part, replace large complicated control circuits in a single chip and evaluated it. We have also observed device response through over a long day and compared our experimental data as well as performance.

VII. Conclusion

This paper is proposed focusing on an improved version of tracking system in order to provide faster response and suitable size for obtaining maximum power for small scale applications. The circuit is implemented in such a way to reduce power consumption of tracker. Here we have included much additional circuit like comparator and voltage regulator in a single chip in order to minimize complexion as well as increase efficiency with possible lower cost. System performance has been evaluated through the simulation. Above all to provide constant performance, replacement of chip in case of damage with less installation cost for wide variety of appliances can be provided by this micro-module solar tracking system.

In future we are interested to work on designing of solar panel for small objects in order to minimize the power consumption of motor as well as driver for higher degree of accuracy.

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AUTHORS PROFILE

Md. Faisal Shuvo is currently pursuing B.Sc degree program in electronics and Communication Engineering in Khulna University of Engineering and Technology, Khulna-9203, Bangladesh. His research interest includes antenna design, machine learning, pattern recognition, neural networks, image processing, and telecommunication and feature selection.

Md. Abu Saleh Ovi is currently pursuing B.Sc degree program in electronics and Communication Engineering in Khulna University of Engineering and Technology, Khulna-9203, Bangladesh. His research interest includes antenna design, machine learning, pattern recognition, neural networks, image processing, and telecommunication and feature selection.

Md. Mehedi Hasan received the B.Sc degree in Electronics and Communication Engineering from Khulna University of Engineering and Technology, Khulna-9203, Bangladesh, 2013. His research interest includes antenna design, biomedical image processing, machine learning, pattern recognition, neural networks, image processing, and telecommunication and feature selection.

Arifur Rahaman received the B.Sc degree in Electronics and Communication Engineering from Khulna University of Engineering and Technology, Khulna-9203, Bangladesh, 2013. His research interest includes antenna design, machine learning, pattern recognition, neural networks, image processing, and telecommunication and feature selection.

Mirza Md. Shahriar Maswood received his B. Sc degree in Electrical and Electronic Engineering from Khulna University of Engineering and Technology. He received M. Sc degree in ECE from Khulna University of Engineering .He is accomplishing my Ph.D. degree beginning at fall 2013 semester from UMKC (University of Missouri, Kansas City) which is located at the state of Missouri. . His research interest includes Network security: Enhancing security in wireless sensor network, ad-hoc network, Image Processing, Machine Learning etc.