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AZIMUTH-ALTITUDE DUAL AXIS SOLAR TRACKER

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Abstract*-One of the most promising renewable energy sources characterized by a huge potential of conversion into electrical power is the solar energy. Solar energy is a very prominent and inexhaustible source of energy. The variation in availability of solar energy occurs daily because sun's apparent path through the sky change throughout the year. Hence, it is impossible for the solar collector to receive constant maximum possible energy from sun from one direction. To rectify these problems the solar panel with an intelligent tracker should be developed that it always receive maximum intensity of sunlight in this paper. The solar tracker containing a sensor array which can preciously find out the exact position of sun and a two degrees freedom of the solar panel powered by motors can move the panel directly toward the sunlight to extract maximum power. A solar panel having such intelligence to track the exact location of sun proliferate the efficacy of power generation.*

Keywords: Dual-axis, Artificial Intelligence, Sensors Array, Sun Position Algorithm, Accuracy and Stability.

1. INTRODUCTION

There are several factors that affect the efficiency of the collection process of a solar cell. Major influences on overall efficiency include solar cell efficiency, intensity of source radiation and storage techniques. The materials used in solar cell manufacturing limit the efficiency of a solar cell [1]. This makes it particularly difficult to make considerable improvements in the performance of the cell and hence restricts the efficiency of the overall collection process. The radiation intensity differs from place to place according to their position (latitude) on the earth. Places with high latitude receive less radiation compared with places on the equatorial areas [2]. Therefore, the most attainable method of improving the performance of solar power collection is to increase the mean intensity of radiation received from the source. A solar tracking system can easily maximize the power generation by setting the equipment in such way to get maximum sunlight automatically. If a developed system continuously obtain the direct sunlight, it will boost up the power generation of the solar panel. Manually by human interference, keeping a solar cell facing the sun throughout the day is not a very efficient use of a person's time. Going outside to a solar cell every hour to turn it toward the sun might be possible, but this would still not be an efficient method. According to the algorithm, the sensor array compare the intensity and calculate the position of light falling upon itself and send the data to the main processing unit. For example, if the photo sensors array is not aligned with sun rays, then it could turn on the motor until it is once again aligned. If the motor is attached to the frame holding the solar cell, then the solar cell could be moved to the direction of the sun. As long as the photo sensor array is aligned with the sun, the frame won't rotate. Whenever the sun change its position across the sky, it became unaligned with the photo sensor array, then the motor moves the frame until the photo sensor array align with the sun again. So a tracking system is designed that would automatically keep the solar cell facing the sun throughout the day. An automated system of two motors, could be used for this purpose. The system includes a frame on which a solar cell could be mounted. The frame is to rotate so that it faces the sun as it travels across the sky during the day. The frame could be driven by an electric motor that turns on and off in response of sun's apparent motion. The artificial intelligence build in this system control the horizontal angle (azimuth angle) and the vertical angle (altitude angle) of the system.

2. FUNCTION EXPLANATION

The system mainly work when the sun light reached to the solar panel otherwise it remained in the standby mode. This system won't work at night or at no sun environment. The sensors detected the intensity of light and sent a corresponding the data to ARDUINO development board. The ARDUINO development board analyze the intensity of light to send a signal to servo motor. The servo motor rotates the solar panel to the desired direction based on the data ARDUINO development board was constantly receiving from ARDUINO development board. LCD shows the angle of the solar panel and displays the rate of energy absorbed by the sensors. The working procedure is sequentially limned in Figure 1.

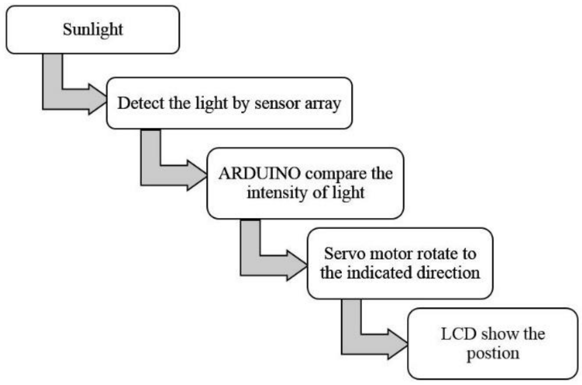


Fig.1: Working Principle of the dual axis solar tracker

3. DESIGN AND FABRICATION OF THE APPARATUS

The model of the solar tracker accommodated both degrees of freedom: azimuth and vertical. Otherwise, the solar cell did not get the full coverage of the sun.

3.1 Structure Fabrication

A plastic structure was made by joining trimmed pieces of acrylic glass, Acrylic glass pieces were drawn out and cut off by miller machine. A structure was obtained from joining those cut off pieces by screw and couple servo at the center of rotation, Figure 2.

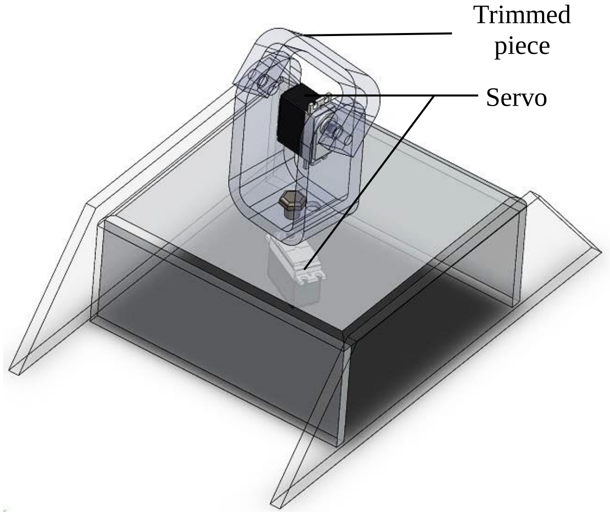


Fig. 2: Fabrication of base (SolidWorks Design)

Figure 3 represents the real view. Hence, servo motors provide the two degree freedom.

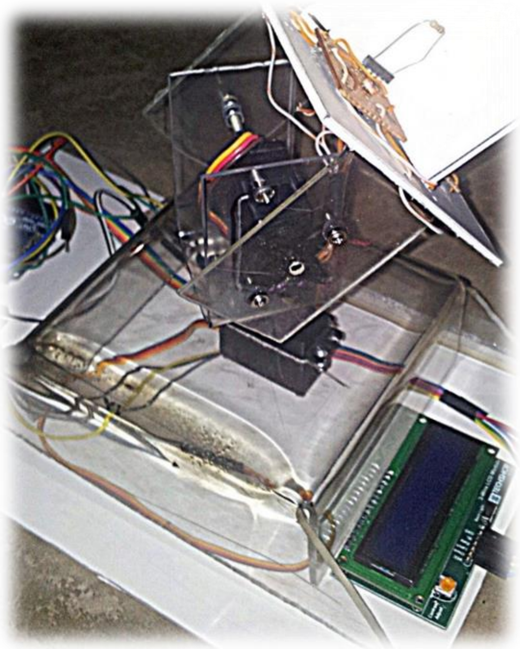


Fig.3: Two degree freedom mechanism

3.2 Sensors Array Fabrication

Sensors were placed in such a way so that the motion of sun can be easily caught by ARDUINO. Four sensors were placed in four corners separated by completely light resistive plastic, Figure 4. Sensor partition was dealt in such a way that if the sunlight is exactly perpendicular to the panel, all the sensors will get sunlight. Otherwise, some sensors will stay out of sunlight. This sensors array design provided the difference of light falling upon the panel board. It was one kind of sensor shield. All of sensors only came to light if sunlight fell exactly perpendicular at the center of the sensors array shield, Figure 5. Otherwise, one or two stayed in shadow. This caused the voltage difference to the circuit and the circuit processed the rest task positioning the sensor shield until the sunlight fall perpendicularly on the sensor array.

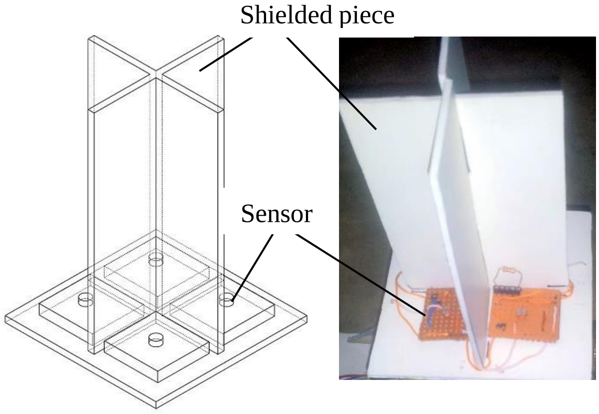


Fig. 4: Isometric View of Sensor Array
(Left-SolidWorks design, Right- Real View)

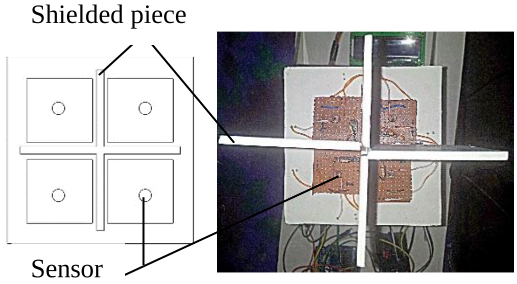


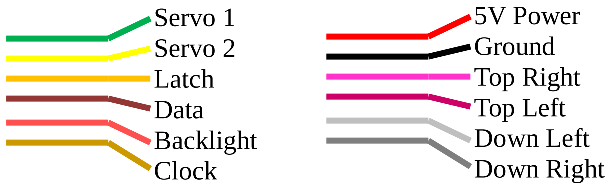
Fig.5: Top View of Sensor Array
(Left-SolidWorks design, Right- Real View)

4. CIRCUIT DESIGN, SIMULATION AND CONNECTIONS

The whole circuit connection was designed in Fritzing software, then the system was simulated in Proteus ISIS and then the circuit connections were made in breadboard.

4.1 Circuit Design

Circuit portion consisted of LDR photo-diodes, servo motors, 3-wire LCD, ARDUINO development board, voltage regulator, external 12V-2A power source, Figure 6. A phototransistor was a light-sensitive transistor. A common type of phototransistor, called a photo-bipolar transistor, was in essence a bipolar transistor encased in a transparent case so that light could reach the base–collector junction. A light-dependent resistor (LDR) or photocell was a light-sensible variable resistor [3]. The resistance of a photo resistor decreased with increasing incident light intensity which displayed the feature of photo conductivity. A Servo was a small device that incorporated a two wire DC motor, a gear train, a potentiometer, an integrated circuit, and an output shaft. Of the three wires that stuck out from the motor casing, one was for power, one was for ground, and one was a control input line. The shaft of the servo could be positioned to specific angular positions by sending a coded signal. As long as the coded signal existed on the input line, the servo would maintain the angular position of the shaft. Servomotors were rotary actuators that produced motion for precise control of angular position, velocity and acceleration [4]. A liquid-crystal display (LCD) was a flat panel display, electronic visual display, or video display that functioned the light modulating properties of liquid crystals [5]. The basic idea of 3-wire LCD represented the group the 7 pins which were involved to drive the LCD in only 3 using a shift register using 4 bits [6]. It displayed the azimuth and altitude angle. Arduino was an open-source platform used for building electronics projects. Arduino consisted of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that ran on computer, used to write and upload computer code to the physical board [7]. A voltage regulator (7805) automatically maintained constant 5 volts. But Arduino, servo motor and LCD were powered by 5V external power supply. It offered the safety and converted the power supply 12V to constant 5V.



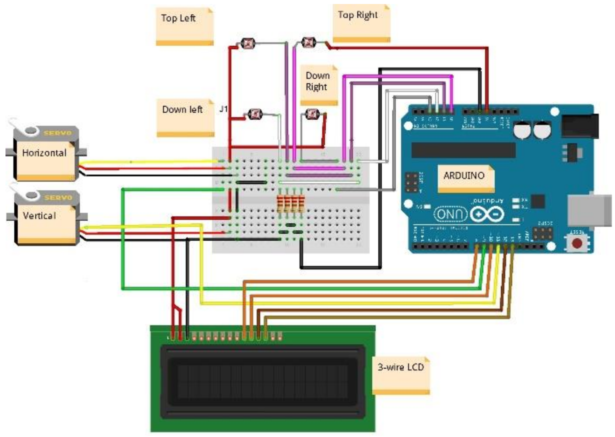


Fig. 6: Circuit Design using Fritzing

4.2 Circuit Simulation

The real time simulation was developed in Proteus ISIS professional software. This simulation rendered the imitation of the operation of a real process, Figure 7.

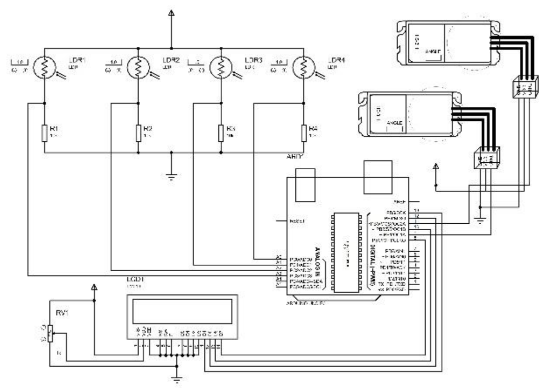


Fig.7: Circuit simulation using Proteus ISIS

4.3 Circuit Connections

Four sensors were routed as input in Arduino analog pins, the pulse pin of servo were routed as output in Arduino digital out pins and three output pin 3-wire LCD module were routed as output in Arduino digital out pins. 7805 (voltage regulator) supplied the regulated 5V voltage supply, Figure 8.

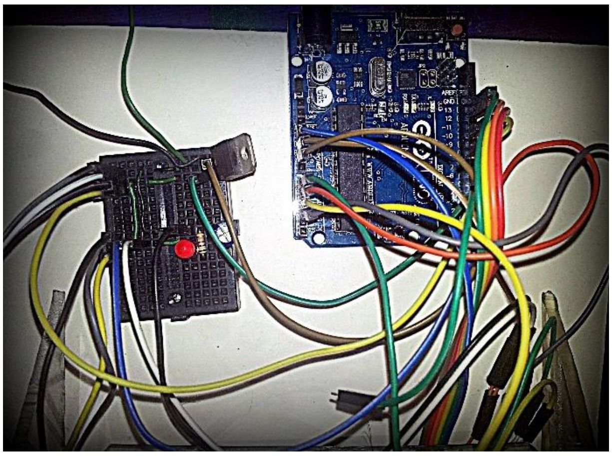


Fig.8: ARDUINO Connections

Figure 9 shows the block diagram of the circuit and their connections with each other.

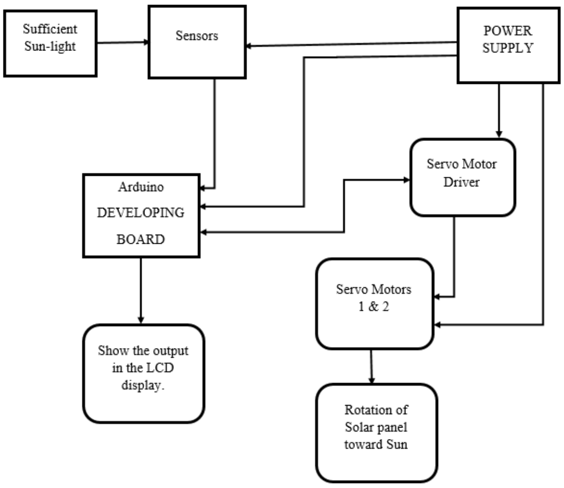


Fig. 9: Block diagram

ARDUINO input pin no. A0, A1, A2, A3 was routed to top right, top left, down left, downright sensors respectively and output digital pin no. 8, 9, 10, 11, 12 was connected latch pin of LCD, horizontal servo-1 pulse pin, backlight pin of LCD, vertical servo-2 pulse pin, data pin and clock pin of the 3-wire LCD respectively, figure 10. The 5V power was generated from 7805 voltage regulator.

Fig.10: 3-wire LCD Connections

5. PROGRAMMING

The code was developed in ARDUINO IDE from where it was debugged and uploaded in the ARDUINO development board. The flow chart 11 renders the all details of the algorithm, Figure 11.

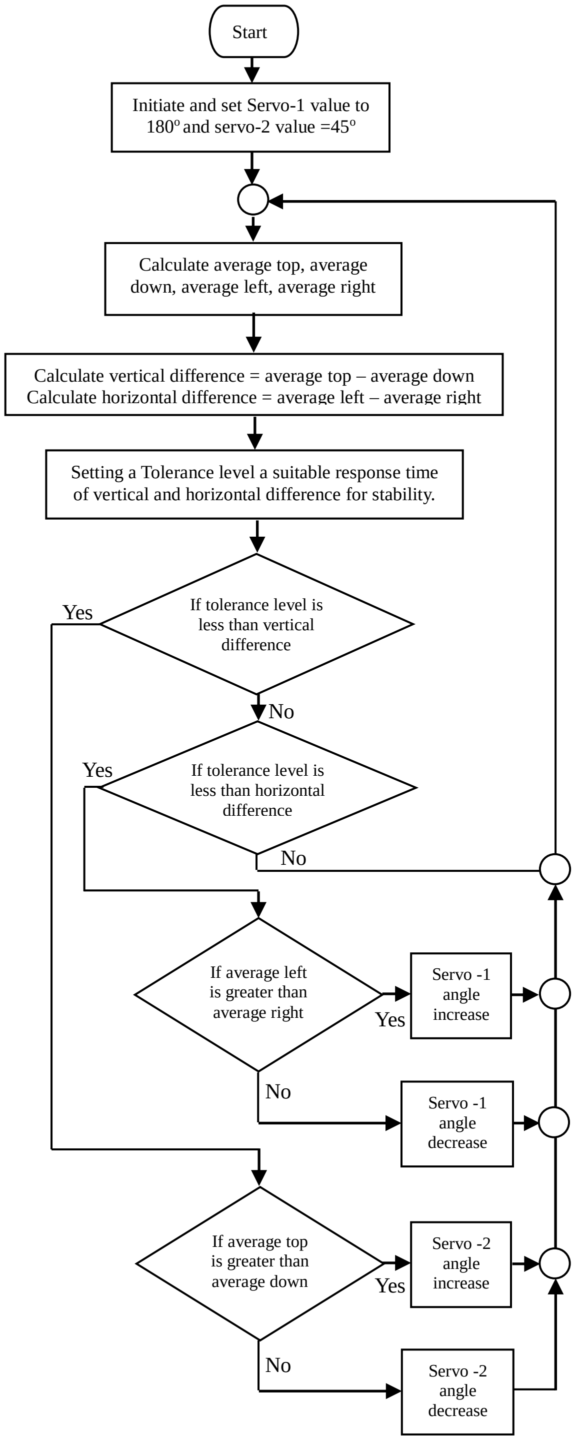


Fig.11: Flowchart of the program

6. RESULTS AND FIGURES

This solar tracking device could operate at all the sun's possible apparent position. It showed the azimuth and altitude angle of the sun. Because of its average calculating program algorithm it did not have any effect from external or sudden environment change in light intensity. Isometric View of the Solar tracking system is shown in figure 12.

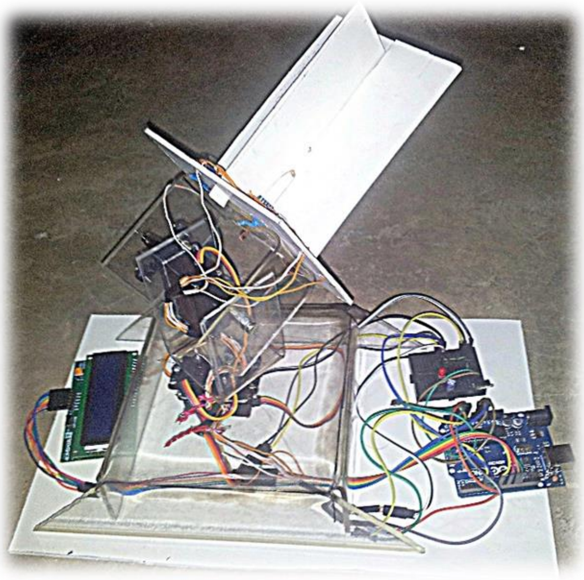


Fig.12: Isometric View of the Solar tracking system

7. OVERVIEW OF OTHER TECHNIQUES

According to the basis of the power source driving the solar tracker, there are two types of solar system. Those are self-powered and externally electricity powered solar tracker. The present system was an externally electricity powered solar tracker. Table 1 shows comparison between electricity powered solar tracking device and self-powered solar tracking system.

Table 1: Comparison between this solar tracking device and Self-Powered solar tracking system

Comparing Topic	Electricity powered solar tracking device	Self-powered solar tracker [8]
Microcontroller	ARDUINO	None
Number of sensor used	4 sensors	None
Accuracy	Track the exact position of the sun.	Not that precise.
Chemical Used	None	Methanol
Chemical Refill	No need	Need to refill possible vaporized amount of methanol.
Calibration	No need	Possible chemical calibration may be important
Type of circuit	Simple	No circuit in this system
Axis of rotation	Dual Axis	Dual Axis

According to the basis of the axis of rotation of solar tracker, there are two types solar system. Those are – 1. Single axis solar tracker and 2. Dual axis solar tracker. This system shows dual axis mechanism. Table 2 shows comparison between single axis and dual axis solar tracking system.

Table 2: single axis vs. dual axis solar tracking system

Comparing Topic	Dual Axis	Single Axis [9]
Microcontroller	ARDUINO	PIC16f73
Number of sensor used	4 sensors	5 sensors
Rotation Coverage	Horizontal and vertical both.	Single axis rotation.
Sunless weather intelligence	Yes	No
Type of circuit	Simple	Complex

8. ERROR AND LIMITATION

Placing the sensor position toward center provided the sensor array more accurate angle of exposure of sunlight, Figure 13. Hence, it was possible to get more accurate tracking that meant accurate horizontal angle (azimuth angle) and vertical angle (altitude angle).

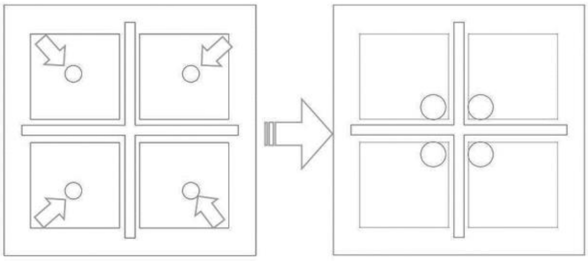


Fig.13: Modification in sensor array

It possessed all the access of the apparent position of sun. But, to get more angle of freedom, 360 degree servo can be used instead of 180 degree servo. The constant 5V provided by power supply may drop to 4.2V. Using a Lithium polymer battery instead of voltage regulator and external power source would be more appreciable in this case.

9. FUTURE WORK

Using a RTC (Real time clock) instead of sensors in the solar tracking would be easier, less costly and less power consuming. This type of tracking mechanism can be also be used in solar thermal power plant. Because RTC module calculate time, date, month and by setting every days sun's position and specific angles for specific mirror to centralize the heat.

10. REFERENCES

[1] S.Armstrong and W.G Hurley, "Investigating the Effectiveness of Maximum Power Point Tracking for a Solar System," *IEEE Conference on Power Electronics*, pp. 204-209, 2005

[2] H. P. Garg, and J. Prakash, *Solar Energy: Fundamentals and Applications*. New Delhi: Tata McGraw-Hill., 2000.

[3] T. Y. Satheeshsa, L. Hemanth, R. Ravitej and P.

Mani, "Holographic Visuals Involving Automation.", *International Journal of Engineering Research*, Volume No. 3 Issue No: Special 2, pp. 77-80, 22 March 2014 .

[4] M. Shivakumar, S. Michahail, A.Tantry H, Bhawana, C. K. Kavana, H. Kavya and V. Rao, "Robotic 2D Plotter", *International Journal of Engineering and Innovative Technology (IJEIT)* , Volume 3, Issue 10, ISSN: 2277-3754, April 2014.

[5] http://en.wikipedia.org/wiki/Liquid-crystal_display (Date of access: 29 August, 2015)

[6] Product manufactured named 3-wire LCD: http://duino4projects.com/3-wires-interface-for-lcd-display-using-arduino/ (Date of access: 29 August, 2015)

[7] Descriptions of ARDUINO development board: https://learn.sparkfun.com/tutorials/what-is-an-arduino (Date of access: 29 August, 2015)

[8] T. Billah, 'Design and Fabrication of a self-powered mechanically solar tracker', Project report, Department of Mechanical Engineering, Chittagong University of Engineering & Technology, Bangladesh, 2014.

[9] M. M. I. Barat, "Automation of a parabolic solar tracker system", Project report, Department of Mechanical Engineering, Chittagong University of Engineering & Technology, Bangladesh, 2014.

11. NOMENCLATURE

Symbol	**Meaning**	**Unit**
V	Voltage	(V)
I	Current Flow	(A)