Performance Analysis of Dual-Axis Solar Tracking System using DC Motor

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Abstract: *This journal presents the performance analysis of dual-axis solar tracking system using DC motor. The main objective of this research is to present development of an automatic solar tracking system in which solar panel will keep aligned with the sunlight in order to maximize in harvesting solar power generation from the solar panel and to show for the output power with solar tracking system is higher than without tracking system in the sunny day condition. The system focus on the controller design is simple structure and saving cost by using LM 324 (op-amp) IC. Light Dependent Resistor acts as a sensor is used to trace the coordinate of the sunlight by detecting brightness level of the sunlight and DC motor is used to control the appropriate position of the panel. From the hardware testing, the system is able to track and follow the sunlight intensity in order to get maximum solar power of the output. The design details and experimental results are shown.*

Key Words: *Light Dependent Resistor, Tracking, Dual-axis Control System, Solar Panel.*

1. INTRODUCTION:

Due to the energy crisis and environmental problems such as pollution and global warming, solar energy is becoming a very attractive solution for places with solar density. However the cost of solar panels is still high and the conversion factor of solar energy into electrical energy is very low. Therefore, increasing energy efficiency for solar energy conversion system has been the focus of much research to date.

Solar tracker is a device used to orient a solar panel towards the sun. Since the sun position in the sky changes with the time of day, solar tracker is used to track the maximum amount of light produced by the sun. It is discovered that the instantaneous solar radiation collected by the photovoltaic modules, assembled in a tracking system, is higher than the critical irradiance level for longer hours than in fixed system.

Nowadays, there are many types of solar trackers invented but the two basic categories of trackers that are widely-used are single-axis and dual-axis tracker. Single-axis tracker can either has a horizontal or a vertical axis, while dual-axis tracker have both horizontal and vertical axis, thus making them able to track the sun's apparent motion almost anywhere in the world. In recent years, there has been growing volume research concerned with dual-axis solar tracking systems. However, in the existing design, most of them used two DC motors to perform dual axis solar tracking. With two tracking motors designs, two motors were mounted on perpendicular axes, and even aligned them in certain directions. In some cases, both motors could not move at the same times.

In this research, the performance of the dual- axis solar tracker was analyzed. It was separated into three parts which were input, controller and output. The input was form the LDRs, LM 324 (op-amp) IC as the controller and the DC motor as the output. Finally, the solar panel is a 20W panel which is being used as a prototype.

2. LITERATURE REVIEW:

To track the sun in two directions that is elevation and azimuth, a dual-axis tracking prototype is developed to capture the maximum sun rays by tracking the movement of the sun in four different directions. One axis is azimuth which allows the solar panel to move left and right. The other axis is elevation and allows the panel to turn up and down. The result of this new development provides the solar panels with extensive freedom of movement. This process makes use of the Light Depending Resistor (LDR) which is important to detect the sun light by following the source of the sun light location.

To implement the solar tracking control system of solar panel, the controller circuit is used. The DC motor is used to control the direction of the solar panel with respect to the sunlight. The solar panel is moved in dual axis. The LDR sensor is used to sense the sunlight. The charge controller circuit is used to control the charge for the battery and the load. Two DC motors are applied to rotate the solar panel. One DC motor is used to rotate the solar panel in vertical rotation and another motor is used to rotate the solar panel in Horizontal rotation.

DC motors were the first type of motor widely used and the systems (motors and drive) initial costs tend to be typically less than AC systems for low power units, but with higher power the overall maintenance costs increase and would need to be taken into consideration. The DC Motors speed can be controlled by varying the supply voltage and are available in a wide range of voltages, however the most popular type are 12 & 24V, with some of the advantages being • Easy installation

- Speed control over a wide range
- Quick Starting, Stopping, Reversing and Acceleration
- High Starting Torque
- Linear speed-torque curve

DC motors are widely used and can be used from small tools and appliances, through to electric vehicles, lifts & hoists.

3. MATERIALS: This research can also be divided into two parts which are hardware and simulation software.

A. Hardware

Light dependent resistor, Window comparator, H-bridge, DC motor and Solar panel are components of the hardware.

1) Light Dependent Resistor (LDR)

Photo resistors, also known as light dependent resistors (LDR) are light sensitive devices most often used to indicate the presence or absence of light or to measure the light intensity. This used as a sensor in the detention of light level in a variety of applications. The use of this type of sensor is a relatively simple task which relies on the linear reduction of the resistance of a LDR with the increase in the intensity of the light. If the light intensity is lower than the setting, the resistor of the LDR is high. The result is a logic low signal on the output of the comparator. When the light intensity exceeds the require level, the output of the comparator changes to a logic high state. In this research, the intensity of light sensed by the LDR becomes an input to the comparator.

2) Window Comparator

The op-amp comparator compares one analogue voltage level with another analogue voltage level, or some preset reference voltage Vref and produces an output signal based on this voltage comparison. In other words, the op-amp voltage comparator compares the magnitudes of two voltages inputs and determines is the larger of the two. In the proposed solar tracker design, the voltage sensing module is required sense the voltage from sensing device. So, LM 324 (op-amp) IC is chosen as the voltage comparator. It is used as the window comparator. Window comparator is combined with inverting and non-inverting comparator into a single comparator.

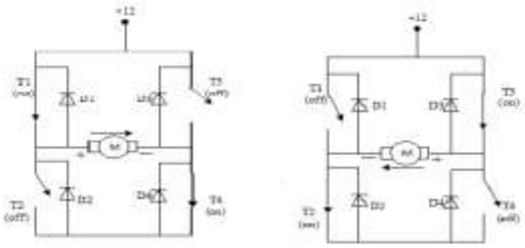

Figure 1. Window Comparator

3) H-bridge

H-bridge is an electronic circuit, containing four switching element, with the load at the center, in an H like configuration. H-bridge enables a voltage to be applied across a load in opposite direction. These circuit applications allow DC motor to run forwards and backwards. In this research design, there are two functions which need for two motors. Driver for main vertical motor and horizontal motor are needed. Both direct and H-bridge driver can control speed. But direct motor driver cannot get required direction control. So, we choose H-bridge driver system design. Solar tracking control system needs a precise position. Solar panel needs to have the correct position and stop exactly at right angle to track the sun. This function is also done by H- bridge.

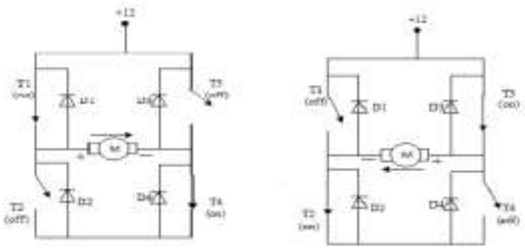

Figure 2. Process of H-Bridge (a) Forward Direction (b) Reverse Direction

4) DC Motor

There are many different electrical motor types, all with their good and bad sides. Motion control is the art and science of precisely controlling the position, velocity and torque of a mechanical drive. Motion-control systems comprise a numerical controller that performs path generation, such as DSP, an amplifier and a motor [3]. For many motion engineers, motor selection plays a central part in getting good devices performance. Knowing which motor to use in a given application improves the cost, performance, and simplicity of machine-design process. DC motors are widely in practice, particularly in applications where accurate control of speed or position of the load required. The DC motor can provide high starting torque for applications requiring quick stoppage or reversals [4]. Speed control over a wide range is relatively easy to achieve in comparison with all other electro-mechanical energy-conversion devices; in fact, this has traditionally been the DC motor’s strength.

Figure 3. Wiper Motor-Model 258

5) Solar Panel

Solar panel which is also called photovoltaic (PV) panels are devices that cleanly convert sunlight into electricity and offer a practical solution to the problem of power generation in remote areas. They are especially useful in solutions where the demand for electrical power is relatively low and can be catered for using a low number of panels. There are many types of solar panel distinguished by their efficiency, price and temperature coefficient that are available in the market. Some of them are mono-crystalline, poly-crystalline and amorphous silicon module. The poly-crystalline type of solar panel was selected for this research because the process used to make poly-crystalline silicon is simpler and cost less. They are easily recognized by its color (usually blue), but there are other colors also and this is the most common panels available from a range of manufacturers.

Figure 4. Poly-crystalline Solar Panel

B. Simulation Software

In this solar tracking system, LDRs sense the light intensity and then sent input signals to the comparator IC. The comparator is operated with the appropriate input signal and displayed the result as LED diode. At the same time, the comparator sends an output signal to the motor via motor driver. The motor driver controls the rotation of the motor to rotate either forward or reverse. The solar panel which is attached to the motor reacts to the control signal from controller accordingly. Fig. 6 shows the complete circuit for motor driver diagram. Simulation test is implemented with Proteus Version 8 software.

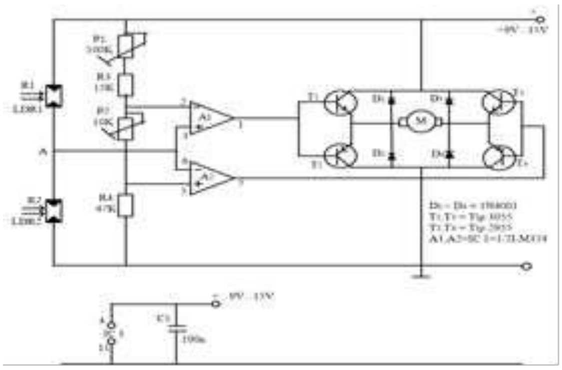

Figure 5. Motor Driver Circuit Diagram

4. METHOD:

As stated before, the aim of this research is to analyze the performance of dual axis solar tracking system. It consists of three main structures which are the inputs, the controller and the output. The inputs are from the LDRs, LM 324 (op-amp) IC as the controller and the DC motor as the output. The overall system is presented in Fig 1. In this research, the main controller is the LM 324(op-amp) IC used as the voltage comparator, receives input voltage data from LDRs. Then the controller sends the signal to the DC motor in order to determine the movement of the solar panel.

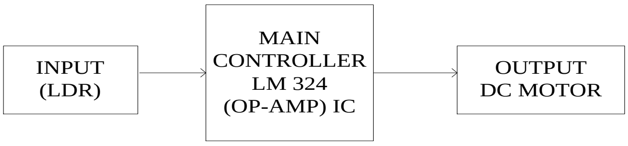

Figure 6. Block diagram of overall system

5. DISCUSSION:

The main aim of the system is to analyze the performance of dual-axis solar tracking system by motor control method. And, it intends to generate the maximum power from solar panel by continuously tracking the sun rays. Moreover, this solar tracking system is very useful for the people who live in rural areas which cannot give any source of energy. In this research, LM 324 (op-amp) IC is used as the heart of the control system, and light sensing is implemented with LDR sensor. The solar tracking system can produce more power because the solar array is able to remain aligned to the sun vertically and horizontally during the day. In this tracking system, the power losses due to the electronic control circuit but it is not significant compared to the power gained from the tracking system. The electricity output power from the solar panel can be increased by 32% by using the tracking system instead of the stationary system. This experiment is testing in Pyay Technological University, Pyay Township, Bago Division,Myanmar. Thus, the proposed dual-axis solar tracking system is a feasible method of maximizing the energy received from solar radiation.

6. ANALYSIS:

The solar light tracking control system will be analyzed by sensor unit, calculation for motor rotation angle and motor driver circuit. In sensor units, the analog voltages of the LDRs are sent to the window comparator amplifier to get the linear response. The outputs of the window comparator control the circuit if the motor rotation is clockwise or anti-clockwise. In calculation for motor rotation angle, desired gear ratio is used according to the speed of the motor that we used. Rotation time is also calculated for each rotation angle of the solar panel. In main process control, according to the voltage difference of the sensors, determine the direction of the motor and rotation time of the motor. H-bridge arrangement is used for motor drive system. Although there are many types of H-bridge drive modes, this research used lock anti-phase drive method. Fig. 7 shows the prototype for dual-axis solar tracker.

T1	T2	T3	T4	Mapping 1
1	0	0	1	On time state
0	1	1	0	Off time state
T1	T2	T3	T4	Mapping 2
0	1	1	0	On time state
1	0	0	1	Off time state

Table 1 shows the motor drive system by using lock anti-phase drive method

7. FINDINGS:

The optimum tilt angle of a south-facing photovoltaic module for fixed system in Pyay Technological University, Pyay Township, Bago Division (Latitude 18.82˚) is calculated at solar noon on March 1. March 1 is the 60 days of the year, so the solar declination can be calculated in Equation (1);

$$\delta = 23.45^{o} \sin\left[\frac{360}{365}(n-81)\right]$$

$$= -8.3^{o}$$

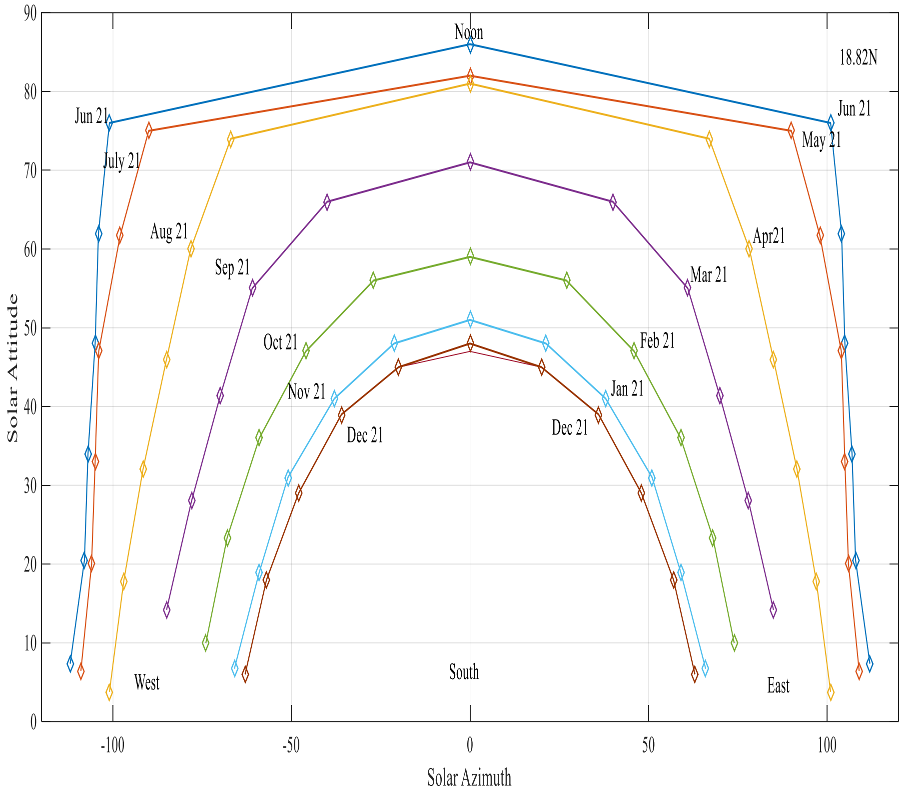

Figure 7 . Sun Path Diagram Showing Azimuth and Altitude Angles for 18.82º Latitude (at Pyay)

It is clearly seen that maximum power is very near to 20W in the whole day with tracking system.

Table 2 Solar Panel Data Sheet

Module	SM 20
Rated Power P_{max} (W)	20W
Maximum Power Current, I_{mp}(A)	1.14A
Maximum Power Voltage, V_{mp}(V)	17.5V
Open-circuit Voltage, V_{oc} (V)	21V
Short-circuit Current, I_{sc} (A)	1.4A

8. RESULT:

The results revealed that the location of the solar panel was one of the important things in collection its output power. The total output power of the without tracking system and tracking system throughout the day is 108 W and 143 W, respectively. So the average power efficiency of the tracking system over the without tracking system is 32 %. Fig. 8 shows the comparison charts of output power versus time for the without tracking system and tracking system. Blue line represents for power without tracking and red line also shows in power with tracking system. It is proved that tracking system can absorb solar energy more than without tracking system. It illustrates improvement in efficiency of the solar tracking system.

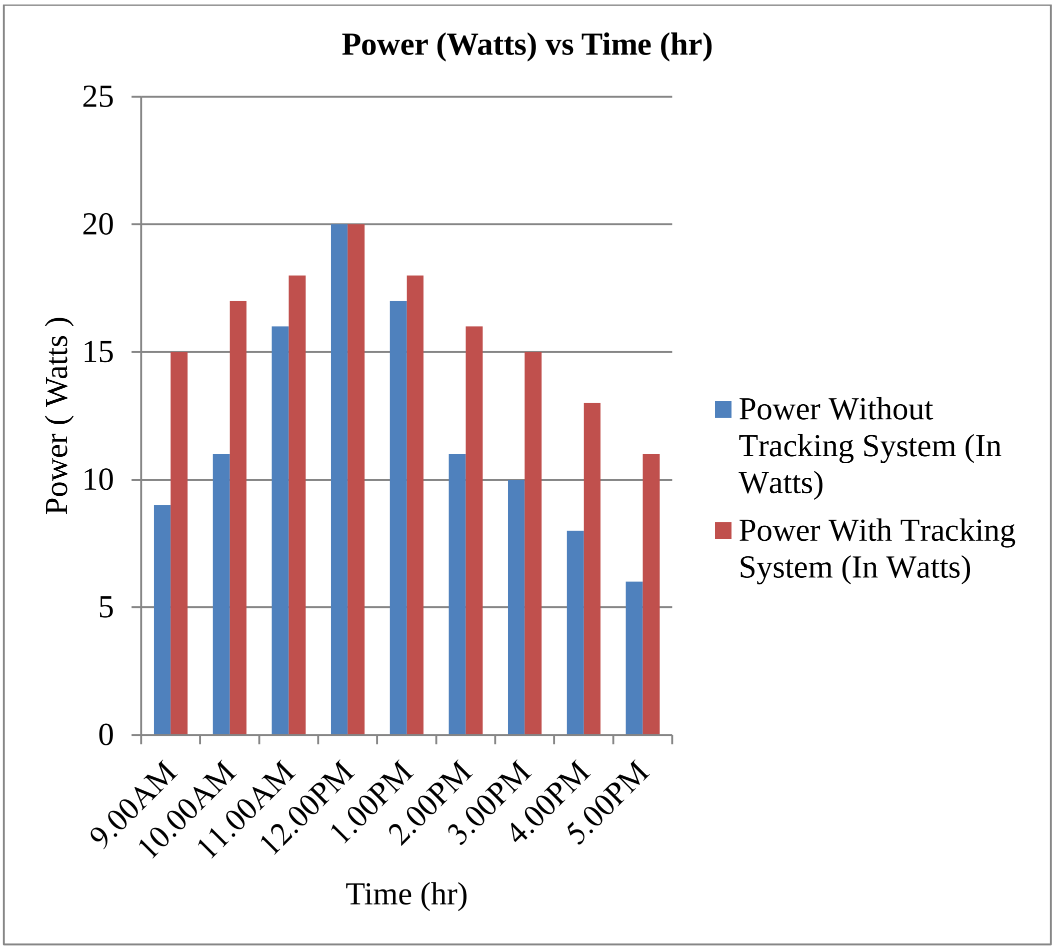

Figure 8.Output Power Comparison between Without Tracking System and Tracking System on 21/08/2018 at Pyay

This experiment testing session is conducted two days from 8.00AM to 5.00PM on August 21st and August 22nd, 2018. Figure 9 illustrates the timely motion of sun position and tracker position for August 21st at Pyay. Moreover, Figure 10 shows the timely motion of sun position and tracker position for August 22nd at Pyay. These movements also describe the differences between the sun position and tracker position.

In this experiment, the least error is 2° and the most error is approximately 6° for altitude angle and the minimum error is 7° and the maximum error is 15° for azimuth angle have obtained.

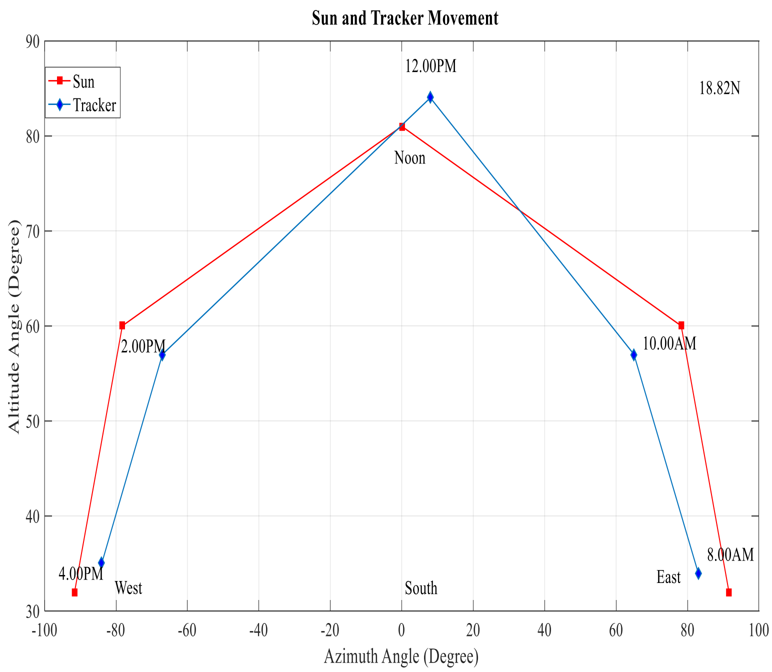

Figure 9.Tracker Movement for Dual-Axis Solar Tracking System in August 21st at Pyay

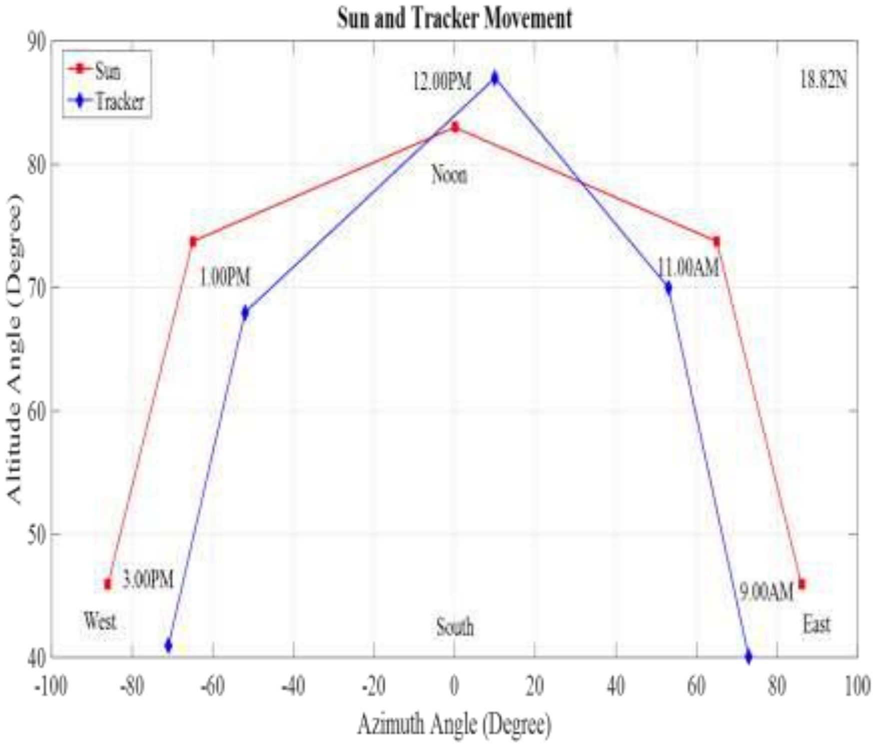

Figure 10. Tracker Movement for Dual-Axis Solar Tracking System in August 22nd at Pyay

In the solar tracking control system, window comparator LM 324 (op-amp) IC is used to compare the LDR voltage and reference voltage.

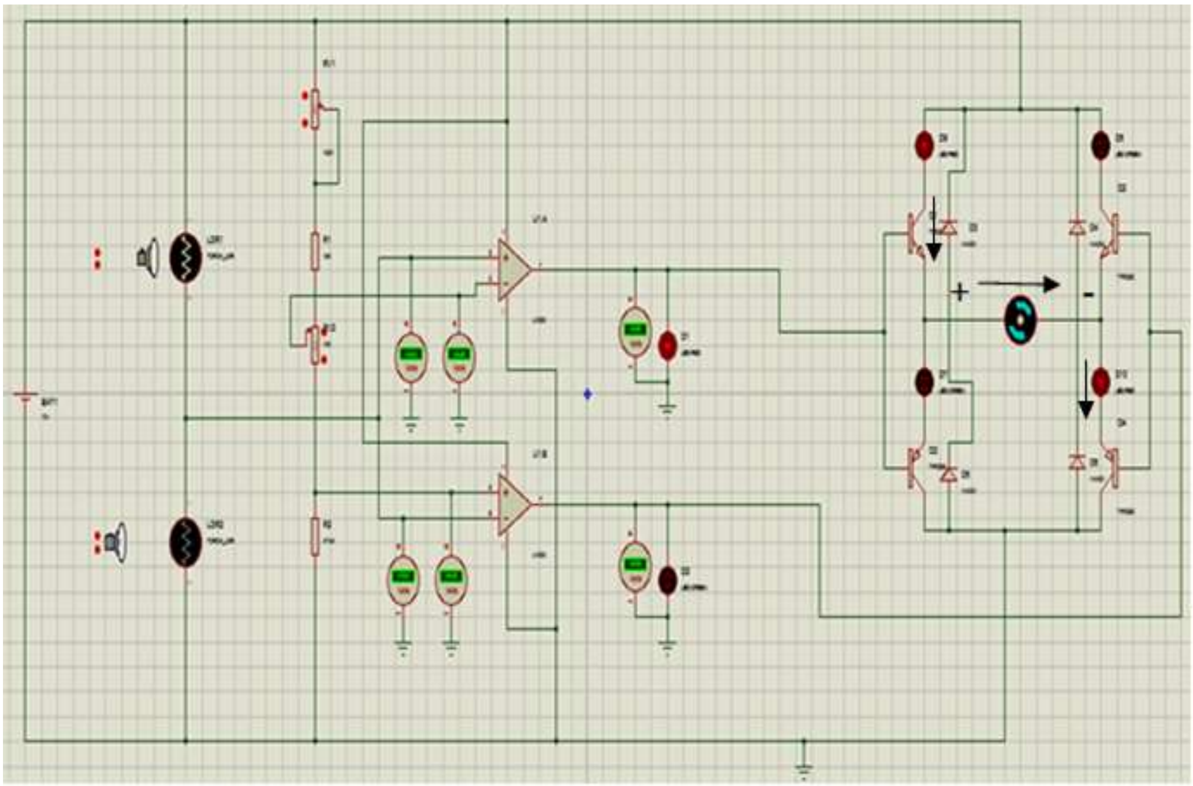

Figure 11. Simulation Result of Motor when the Light is upon LDR1 (Forward Direction)

In Fig 12, it can be seen as an anti-phase state in which T1and T4 are ON state and T2 and T3 are OFF state. Simulation result for lock anti-phase drive method in mapping1 at ON time state is shown in Fig 12.

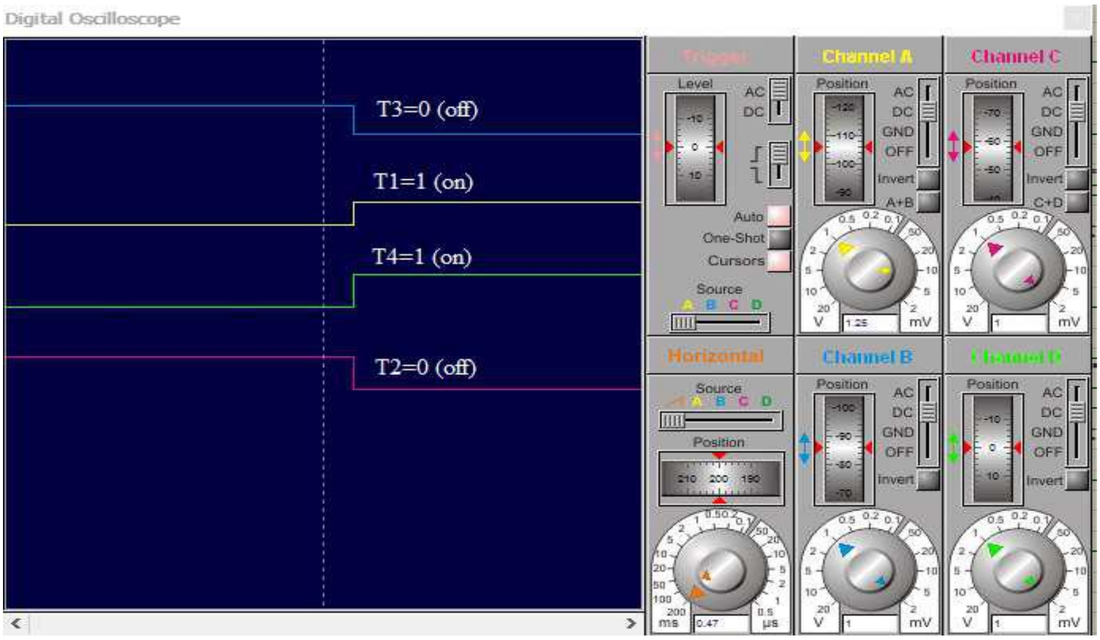

Figure 12.Simulation Result for Lock Anti-phase Drive Method in Mapping1 at ON Time State

9. RECOMMENDATIONS:

There are certain limitations of the system and additional extensions to advance the system. Further extending to avoid the limitations of the system needs more sophisticated circuit diagram, software and construction. But, it can get precise control and angle for solar tracker.

If stepper motor was used, precise step angle would be rotated. In this case, stepper motor driver and appropriate software should be also added in this system as further extensions. And also, if phototransistor were used in sensor circuit instead of LDRs, it would be better sensitive and precise changing point for various voltage levels. If there are also limit switches, there can be precised position for motors to rotate the solar panel.

10. CONCLUSION :

The proposed solar tracking system has been successfully constructed. The combination of hardware and simulation results has been described. The circuit diagram of this solar tracking system design is very simple and there is no complication. The detail design and explanations of sensor circuit and DC motor driver circuit are included.

Solar tracking systems are widely used to enhance and maximize the energy production of photovoltaic plants. Solar trackers are beneficial and dependent on various factors including weather, location, obstruction and cost. This is a more cost effective solution than purchasing additional solar panels when dealing with large panel arrays. Moreover, another benefit is the space saved rather than adding extra panels. The equipments in this solar tracking system are very cheap, so this system provides that the total cost for tracking is low. To sum up, this research states that the benefits of using solar system are suitable for the weather of Myanmar.

REFERENCES:

1. Swe Swe Mar, Zarchi San, Thuzar Mon(Set-Oct 2018): Performance Analysis of Dual-Axis Solar Tracking System by Using Lock Anti-Phase Drive Method, International Journal of Trend in Scientific Research and Development (IJTSRD), India, Vol-2, Issue - 6, , ISSN: 2456-6470.
2. Dante Johnson-Hoyte(2013): Dual-Axis Solar Tracker,
3. Gilbert M. Master(2004): Renewable and Efficient Electric Power System
4. (A.E. Fitzgerald): Electric Machinery.
5. (Bill Drury, 2009): The Control Techniques Drives and Controls Handbooks.
6. Edvard(2015): 4 Types of DC Motors and Their Characteristics.
7. (Bill Drury, 2009): The Control Techniques Drives and Controls Handbooks.