Dual-Axis Solar Tracking System with SimpleLogic Control Circuit

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***Abstract*- One of the most promising sources of renewableenergy is solar energy. A photovoltaic (PV) system's ability to produce power can be significantly enhanced with sun trackers. In order to increase the amount of solar energy that strikes the photovoltaic (PV) panel, this article introduces a revolutionary dual axis solar tracking system. Throughout the day, the sun moves from east to west, and with the changing seasons, so does its radiation angle with respect to the Earth. Consequently, PV panel output power also varies. When PV panels are positioned perpendicular to the angle of the sun's beams, their output powerincreases. The goal of this study is to create and use a dual-axis solar tracker (DAST) to boost the PV panel's output power. This simple device has a high efficiency and simultaneously moves twoaxes to adjust the PV panel based on solar radiation. The closed- loop DAST control system employs a simple control circuit using logic gates and make use of light-dependent resistors (LDRs).To test the suggested system, a small DAST was created and its performance was confirmed.**

***Index Terms*- DAST, LDR Sensors, Closed loop control, Feed-back system, Logic gates**

I. INTRODUCTION

One of the most significant sources of clean and sustainableenergy at the moment is solar energy. As a result, numerous studies have been conducted in an effort to enhance the performance of sun trackers employing efficient mechanical drives and control systems. Modern and emerging technolo- gies have recently been used to support the production and distribution of electricity, including renewable energy basedon solar photovoltaic (PV) systems, which are renowned for their robust design and minimal maintenance requirements. Due to the photovoltaic effect, solar cells convert straight sunlight into direct current. The sun's position and geographiclocation are always shifting. The PV panel's output powercan be influenced by various factors. Such as the quantityand direction of solar radiation, the kind and quantity of cells, the temperature of the cell loads, and the voltage (or battery). Fixed solar panels typically don't consistently receive the greatest quantity of sun energy. Solar tracking(ST), which increases the PV panel's output power, can be applied to this issue. By placing the PV panel parallel to the sun's rays, the solar tracker captures the most solar radiation possible during the day. Due to the module rotation restriction,uniaxial tracking systems cannot provide an adequate trackingcapability, which results in a significant loss of generatedsolar energy utilising a PV module [8]. Dual-axis tracking devices are therefore more precise and track the sun's motion in all directions of rotation [7], [9]. The tracking of the sun's beams has been done using a variety of techniques [2], [10]. Utilising control models and optimisation algorithmsis one of the control strategies for solar tracking systems;optimisation seeks to maximise the amount of electrical energyproduced by the PV system, and ST determination is viewedas an optimisation problem [10]–[12]. Due to the module rotation restriction, uniaxial tracking systems cannot provide an adequate tracking capability, which results in a significant loss of generated solar energy utilising a PV module [8]. Dual-axis tracking devices are therefore more precise and track the sun's motion in all directions of rotation [7], [9]. Particle swarm optimisation (PSO), perturb & observe (P&O) algorithm and iterative learning control (ILC) are different techniques utilized for solar tracking. Fuzzy particle swarm optimisation (FPSO), PSO-P&O, and other hybrid techniques are also available in the industry.

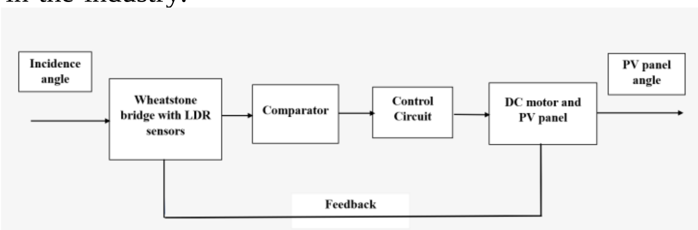

Fig. 1. Block diagram

Additionally, a recalibration is required in the tracking system based on the initial data, which includes the north geographical orientation, altitude, slope, and geographic co- ordinates transfer to a new point scenario. As a result, a sensor-based ST system is recommended, which is an active tracking system based on closed-loop control. Light-dependentresistance (LDR) sensors are used in closed-loop tracking sys-tems based on feedback circuits. As a result, a microcontrollerprocesses the LDRs' data and tracks the sun regardless of where it is in the sky. There is no requirement for calibration when there is a shift in the solar tracker. Additionally, they offer a few advantages like affordability, ease of use, andeffectiveness. These factors have led to the use of this sortof sensor by numerous researchers in their systems [4],[5].The design and implementation of a dual-axis solar tracking system that concurrently moves the PV panel in two x and y axes towards solar radiation are suggested in this article. The suggested tracking system is a accurate, inexpensive, active system that relies on closed-loop control and uses solar sensors(LDRs) as its inputs . Without a microcontroller, a simplelogic circuit designer, and the involvement of LDR sensors,the tracking approach is provided. Higher sensitivity [6], measurement, and comparison between LDRs in the control circuit have been accomplished using a simple logic control circuit.

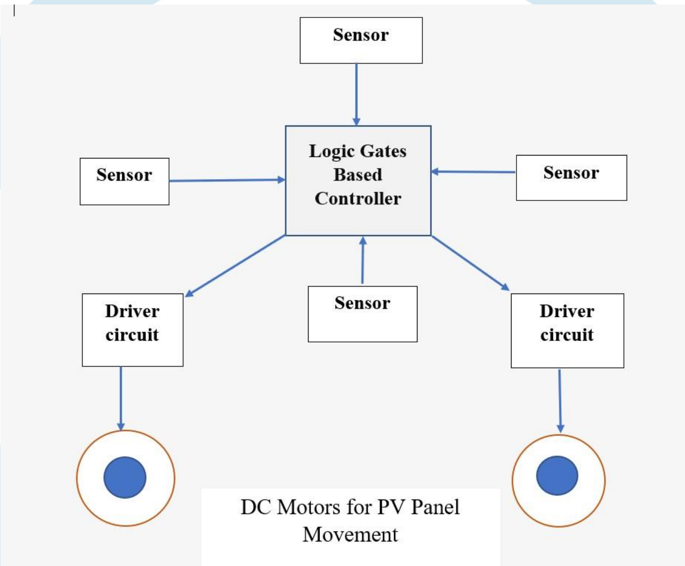

Fig. 2. Block diagram

II. SOLAR TRACKING SYSTEM

A. Mechanical Design

The market for solar systems is expanding, which has increased interest in ST systems. The DAST system's design, which comprises of logic gates based controller and driver circuit is depicted in Fig. 1. The planning of the ST systems' architecture is crucial for performance, durability, and price. The purpose of this paper is that a lab prototype of the DAST system is created and implemented at a reduced scale. The design of this DAST system can be utilised to support a single or a number of PV panels on a structure in biggerdimensions (for example, 10). To support the weight of the panel, frame, actuators, shafts, gear mechanisms, and solar measuring equipment, the mechanical structure of the tracker must be adaptable [8], [9].

Additionally, the DAST system's structure may be impacted by the flow of destructive forces (wind power). Consequently,thought of wind energy is seen to be crucial when designing the system. Low wind speeds (about 20 m/s) are suitablefor the suggested system. It will be more wind-resistant ifa larger tracking system is constructed and a more powerful drive system (electric jacks) is used. To do this, the armsare thought of in various directions to endure wind force.For better performance we need to maintain the PV panel perpendicular to the sun's rays by controlling the ST systemin all directions (East, West, North, and South).

a) *S:* tatic part The base frame structure, lower gearing mechanism, control panel, control unit, charge controller, battery, vertical shaft, etc are all components of the DAST system's static component. The DAST system's components are all anchored and secured to the ground by the base frame structure. All joints are integrally connected, and the arms are thought of in various orientations to support the DAST systemagainst wind forces. With the gear mechanisms housed in an appropriate box on the structure, the lower gearing mechanism(DC motor with gear mechanisms) is connected to the vertical shaft to support the axle load. The control unit coordinates all components of the DAST system as well as the PV and conducts the controlling task of all directions of the panel movement. The control panel aims to modify both manualand automatic DAST system control. The charge controlleris a tool used in DAST systems to control energy flow. Its duties include system power management, deep discharge andovercharge protection. In solar systems, batteries are utilisedas a means of storing solar energy. The PV panel's main axis of horizontal revolution (vertical shaft) enables it to monitor the angle of the sun's rays as they move from east to west.The PV panel on the structure may rotate more easily because of the ball bearings.

b) Moving part: The PV panel, the sunlight measurement system (LDRs), upper gearing mechanism, the horizontal shaft, and the PV are all part of the moving component thatis attached to the upper end of the vertical shaft. PV panelsuse solar cell modules to produce electricity. The PV panelcan revolve to follow the angle of the sun's rays as they move from north to south thanks to its horizontal shaft and vertical revolving axis. Along with the gear mechanisms located in an appropriate box on the moving component, the upper gearing mechanism (DC motor with gear mechanisms) is connectedto the horizontal shaft to support the axle load. It is supported on the shaft by the PV holder.To measure sunlight, LDRs are placed around the PV panel in each of the four orientations.

III. CONTROL METHOD

The designed DAST system is a developed closed-loopsystem in who operates based on the input provided by the LDR sesnsors and the feedback by itself The amount of sunlight is taken into account as a reference input signal inthe closed-loop DAST system . The position of the sun must be determined using optical sensors in order to perform solar tracking. The PV panel is adjusted by the suggested tracking system according to the angle of the sun using optical sensors.

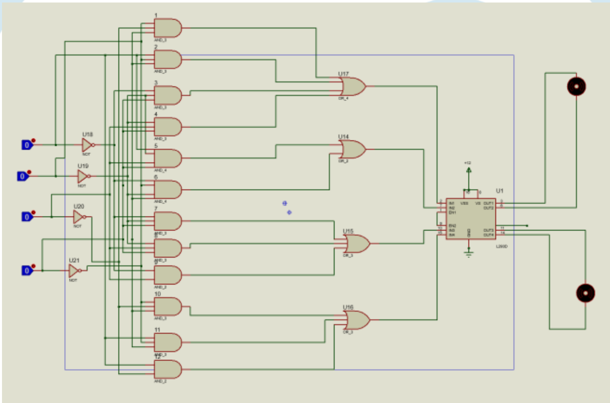

Fig. 3. Circuit Diagram

As the light intensity increases, the electrical resistance of LDR sensors reduces, and this resistance is varied. The discrepancy between the angle of the solar radiation and the location of the PV panel results in an imbalance in the voltagesproduced in the Wheatstone bridge branches by the LDR sensor. The voltage produced at the control circuit outputis then sent to the motor driver and amplified. The control circuits' use of the logic gates output voltage to activate the motor driver. The PV panel will revolve around its axis when the relay turns the tracking system's engine in the appropriate direction, positioning the PV panel automatically so that it is perpendicular to the direction of the sun's rays.As a result, until the voltage difference between the bridge branches drops below a threshold value, the control system continuously monitors the solar radiation angle and PV panel using LDRs and provides a differential control signal to the relay of the tracker motor. A comparator with a four-quadrant LDR has been utilised in various DAST systemsto determine the sun's position. However, in this study, the LDR sensors are positioned on each of the PV panel's four sides, 1 cm away from the panel's surface, such that even when the sun's angle changes, the LDR sensor will alwaysbe in the shade. The usage of this simple control circuit also makes the proposed DAST system faster and more responsive.The PV panel is calibrated with respect to the horizontal axis using sensors LDR1 and LDR2, and with respect to the vertical axis using sensors LDR3 and LDR4. The DAST system uses two circuits to regulate the PV panel's rotating motion in both the horizontal and vertical axes, with eachaxis having two directions of motion. Each hardware circuitis made up of the components: an LDR sensors, motor driver and control circuits. The astronomical tracking operations run simultaneously to align the PV panel perpendicular to the sun'srays in order to maximise power for the PV panel. A DAST system hardware circuit is shown in Figure 4.

A. Hardware Circuit of Horizontal Motion Control

Whenever the sun's radiation changes, the DAST automat- ically moves. The PV panel's rotating motion in the east (E) and west (W) is managed by the horizontal control hardware circuit (Fig. 4).

The LDR sensor circuit determines the brightness of thesun. The VE and VW voltages are regarded as the generated voltages in the east and west, respectively, if there is an imbalance in the voltages generated in the bridge branches by LDR sensors, that will affect the next rotation of the PV panel. LEDs, also turn on to confirm the relays' activation. The PV panel will spin along its axis to set it perpendicularto the direction of the sun's beams as relays turn the M EW tracker engine in the desired direction. The PV panel stops at this point because the LDRs are receiving even and uniform solar energy . A controlled path for the PV panel is takeninto consideration at night during the dark hours to bring it back to its initial state as the sun rises (sun radiation fromthe east). By reaching the end of the journey and collidingwith the microswitch SW1, the PV panel moves eastward and positions itself in the beginning state early in the morning.

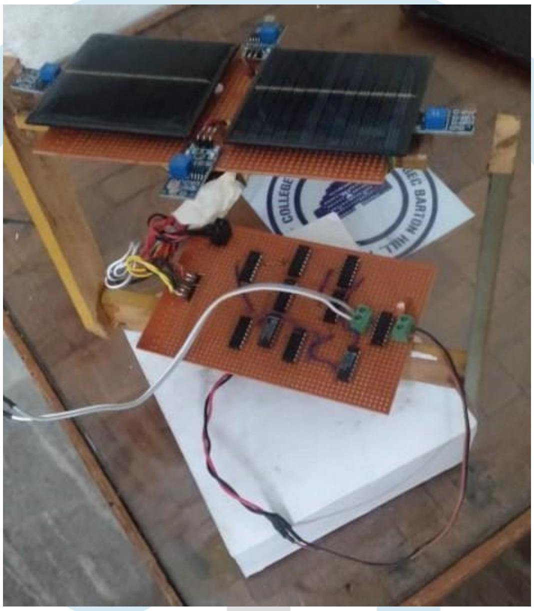

Fig. 4. Hardware model

B. Hardware Circuit of Vertical Motion Control

The PV panel's rotating motion in the north (N) and south (S) is managed by the vertical control hardware circuit (Fig.6). The LDR sensor circuit determines the brightness of the sun. The VN and VS voltages are taken into account as the generated voltages in the north and south, respectively,if there is an imbalance in the voltages generated in the bridge branches by LDR sensors. The motor driver get the voltage created in the bridge output after that. The outputvoltage, which triggers the motor driver enables the rotationof the panel. LEDs, DN, and DS then turn on and activate,respectively. In order to position the PV panel perpendicular tothe direction of the sun's rays, relays turn the M NS tracker engine in the desired direction. The PV panel stops at that point because the LDRs are receiving even and uniform solar light at that time.

IV. SYSTEM TESTING AND RESULTS

A prototype of the above model was created and evaluated in order to evaluate the performance of the DAST system and its control. The PV panel should be positioned perpendicular tothe sun's radiation angle to generate the maximum amount of power. The light sensors ohmic resistance reduces as sunlight passes through their surface. The sensor resistance decreasesas radiation intensity rises. The sensors (LDRs) in the DAST system's many modes change in ohmic resistance as a resultof solar radiation reaching their surfaces. The angle of solar radiation on the PV panel surface changes in the first mode as the sun advances towards the west. The LDR1 is consequentlygradually positioned in the shade, and its ohmic resistance rises. As a result, the PV panel begins to move towards the west, and stops when the VW and VE voltages are equal. The PV panel is rotates westward because the radiation hitting the surface of the LDR1 and LDR2 sensors is not uniform. After the PV panel has moved, the DAST system stops when it is perpendicular to the angle of solar radiation. In the second mode, the angle at which the sun's radiation strikes the earth steadily increases in the morning as it advances towards the west. Similar to the first mode, the LDR4 gradually movesinto the shade when the angle of solar radiation hitting thePV panel's surface changes, increasing the ohmic resistance. Fig. 5 shows that the LDR4's increased ohmic resistance has caused the VN and VS voltages at the circuit to be out of balance. When the VN voltage is greater than the VS voltage,a result, the PV panel begins to move towards the north.

Whenthe VN and VS voltages are equal, the PV panel comes to a stop.

In Fig.5, the DAST system comes to an end when it is perpendicular to the solar radiation angle (VN=VS) following the movement of the PV panel to the west. In the third mode, the angle at which solar radiation strikes the earth steadily narrows as the sun advances westward in the late afternoon. The LDR3 is somewhat positioned in the shade as a result of changes in the angle of solar radiation, increasing its ohmic resistance. According to Fig. 6, the VN and VS voltages are out of balance and the VS voltage value is larger than theVN voltage because of the rise in the ohmic resistance ofthe LDR3. As a result, the PV panel begins to move in the direction of the south, and stops when the VN and VS voltagesare equal . The ohmic resistance of the LDR1 and LDR2increases significantly in the fourth mode, which occurs after sunset and when there is no solar radiation. As a result, the voltages of VE and VW drop. The PV panel is subsequently shifted by the DAST system to face east, where it will be whendaybreak arrives. The PV panel spins eastward and stops, and there is no radiation on the surface of the LDR1 and LDR2 sensors.

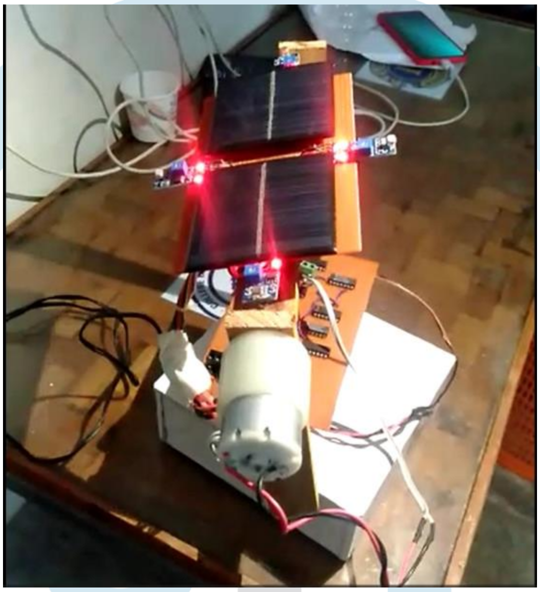

Fig. 5. Hardware model

V. CONCLUSION

The solar tracking system determines the sun's astronomicallocation during the day and positions the PV panel in a way that maximises its output power in relation to the sun's rays. Numerous expensive sun tracking systems based on artificial intelligence and geometric and astronomical equations or incapable of moving in two axes have been created thus far. This study introduced a new DAST based on LDRs that concurrently moves on two dimensions to change the PV panel's tilt in relation to the sun's rays. DAST is a relatively straightforward and economical control system that makes useof simple logic control circuit and LDRs.If this controller is employed, it is feasible to individually and collectively controlthe PV panels on the metal structure. The experimental resultsof this solar tracking device can therefore be used to create solar energy applications.

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