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IOT Integration in Two-Axis Sun Tracking System with LDR Sensors in a Wheatstone Bridge Circuit

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Abstract- **In recent years, solar energy has gained significant attention as a clean and sustainable source of power. To maximize the efficiency of solar panels, it is crucial to track the movement of the sun and ensure optimal exposure to sunlight throughout the day. In this project, propose a two-axis sun tracking system that utilizes Light Dependent Resistors (LDR) as sensors and employs the Wheatstone Bridge Circuit for accurate sun position detection. Additionally, the system integrates Internet of Things (IoT) technology to enable remote monitoring of the solar power generation process. The two-axis sun tracking system consists of two main components: the sensor module and the control module. The sensor module consists of LDR sensors strategically placed to detect the intensity of sunlight. The Wheatstone Bridge Circuit is employed to measure the resistance changes in the LDR sensors and accurately determine the sun's position relative to the solar panels. The control module processes the sensor data and generates control signals to adjust the direction of the solar panels accordingly. Furthermore, the system incorporates IoT technology to enable real-time monitoring. The collected sensor data, including the generated voltage and the panel direction, are transmitted to a cloud platform via wireless communication protocols such as Wi-Fi or cellular networks. Moreover, the integration of IoT technology facilitates remote monitoring, enabling users to optimize energy production and identify any potential issues promptly.**

Keywords—Wheatstone bridge, LDR sensors, DAST system, PV panel, closed-loop system, Internet of Things.

I. Introduction

In recent years, modern and emerging technologies have come to assist electricity generation and distribution systems, including renewable energy based on solar photovoltaic (PV) systems, which are well known for their structure and low maintenance costs. Solar cells convert direct sunlight into direct current through the photovoltaic effect. To maximize the output power of PV panels during the day, they must be kept in a position perpendicular to the solar radiation. The geographical location and situation of the sun are constantly changing. The output power of the PV panel depends on the amount and angle of solar radiation, type and number of cells, the temperature of the cell loads, and voltage (or battery). In general, fixed solar panels do not receive maximum amounts of solar energy continuously. To solve this problem, solar tracking (ST) can be used to maximize the output power of the PV panel. The solar tracker receives the maximum amount of solar radiation during the day by positioning the PV panel perpendicular to the sun's ray.

Uniaxial tracking systems do not provide an acceptable tracking capability due to the module rotation limitation, which leads to the loss of large amounts of solar energy generated by the PV module. Hence, dual-axis tracking systems are more accurate and follow the path of the sun in all the rotation directions. Various methods have been widely used to track the sun's rays.

One of the control techniques for the solar tracking system is to use control models and optimization algorithms; optimization aims to produce maximum electrical energy by the PV system and Determining ST is considered as an optimization problem. One of the algorithms is the fuzzy logic controller (FLC) which the closest position to receiving direct sunlight is obtained from the database. A random search algorithm known as particle swarm optimization (PSO) is used as a tool for optimization. Also, a combined method based on iterative learning control (ILC) and perturb & observe (P&O) algorithm is used. There are hybrid methodologies including fuzzy particle swarm optimization (FPSO), PSO-P&O, etc.

An in-depth literature review demonstrates that optimization algorithms have high-volume equations, the solution process of which imposes a heavy computational load on the processor. Hence, an expensive microcontroller is required. Moreover, based on the initial information, including the north geographical orientation, altitude, slope, and geographical coordinates of the tracking system, a recalibration is needed in case of transfer to a new point. Thus, a sensor-based ST system is suggested, which is a closed-loop control based active tracking system. Closed-loop tracking systems based on feedback circuit use lightdependent resistance (LDRs) sensors. As a result, LDRs data are processed by a microcontroller and track the sun, independent of its geographical location. In case of solar tracker displacement, there is no need for calibration. They also have a few benefits, such as low cost, simplicity, and efficiency. For these reasons, many researchers have used this type of sensor in their systems.

A solar tracker is a generic term used to describe devices that orient various payloads toward the sun. Payloads can be photovoltaic panels, reflectors, lenses or other optical devices. This is a power generating method from sunlight. This method of power generation is simple and is taken from natural resource. This need only maximum sunlight to generate power. This project helps for power generation by setting the equipment to get maximum sunlight automatically. This system is tracking for maximum intensity of light. When there is decrease in intensity of light, this system automatically changes its direction to get maximum intensity of light.

Solar energy is rapidly advancing as an important means of renewable energy resource. More energy is produced by tracking the solar panel to remain aligned to the sun at a right angle to the rays of light. This paper describes in detail the design and construction of a prototype for solar tracking system with two degrees of freedom, which detects the sunlight using photocells. The control circuit for the solar tracker is based on aAT89s52Micro controller. This is programmed to detect the sunlight through the photocells and then actuate the motor to position the solar panel where it can receive maximum sunlight. Sunlight's angle of incidence needs to be constantly perpendicular to the solar panel. This requires constant tracking of the sun's apparent daytime motion, and hence develops an automated sun tracking system which carries the solar panel and positions it in such a way that direct sunlight is always focused on the PV cells Many different methods have been proposed and used to track the position of the sun. The simplest of all uses an LDR a Light Dependent Resistor to detect light intensity changes on the surface of the resistor.

In this project, designing and implementing a dual-axis solar tracking system are suggested, which simultaneously adjusts the PV panel toward solar radiation in two x and y axes. The proposed tracking system is a simple, low-cost, and active system based on closed-loop control, in which solar sensors (LDRs) are the system inputs. The tracking strategy is presented, without using a microcontroller, a simple logic circuit designer, and a Wheatstone bridge with the participation of LDRs sensors. Wheatstone bridge circuit has been used to achieve higher sensitivity, measurement, and comparison between LDRs in the control circuit. Results of experiments demonstrated the feasibility of the DAST system.

II. LITERATURE SURVEY

For working in different weather conditions use of different strategies by which the tracking error of the normal tracking strategy is 0.15, so it could provide high tracking accuracy for the solar systems.[1] One of the advantages of a dual axis solar tracker how solar energy can be collected more effectively at unfavorable locations and weather conditions in comparison with single axis solar system.[2] With an automated two axis solar tracker the average gain in the maximum power and efficiency obtained with two-axis PV tracking system is 5.0423 W per hour and 28.87 % respectively compared to the fixed PV system.[3]-[6]A report provided the information on using data logging in an automated solar tracker for storing data as solar radiation, voltage, temperature on board, its design and implementation.[7] For working under different conditions construction of a solar tracker following direct and indirect sensing system.

A study which shows implementation of a dual axis solar tracking system using a 555 timer to construct a simple solar tracker with a rear sensor circuit incorporated to aid in the repositioning the solar panels for the next sunrise.[13] Solar tracking system that consists of a combination of open loop tracking strategies based on solar movement models and closed loop strategies using a dynamic feedback controller was presented.[8] Using a systemic approach to capacity development for solar PV, it also addresses other domains, such as economic development and gender equality, which can impact on capacity for solar PV lighting. By providing knowledge and educating and employing people in rural areas.[9]-[12].

The Earth's surface receives around 1.2*105 TW of solar energy. Solar radiation offers the most promise for green technology since it is a plentiful, clean, cost-free, and infinite source of energy. From 2014 to 2018, the capacity of solar energy in India expanded eightfold, from 2.63 GW to 22 GW. India will achieve 227 GW of non-conventional energy. However, solar energy can only be utilized during the daytime. Fixed or static solar systems have been in use recently, but with the development of technology, solar system efficiency is rising thanks to the use of single- and dual-axis solar tracking systems that can follow the sun's location according to the day and season. Although tracking is a more complicated system that needs more site preparations and fixed racking can easily withstand harsher environmental conditions, additional trenching for wiring and some additional grading systems are being widely used because they have increased the efficiency of energy extraction [14]. About 90% of the solar energy is carried by direct beam radiation on a bright sunny day, whereas only 10% is carried by diffuse radiation [15]. Utilizing a solar concentrator in tandem with a solar tracker is another possible method for utilizing the majority of this incoming energy. The installation space can be decreased by using solar concentrators to boost solar energy density, and solar trackers in general increase system efficiency by 30–40% compared to stationary systems [16]. With the help of photovoltaic effects, solar cells transform straight sunlight into direct current panels must be kept in a position perpendicular to the sun's rays in order to produce their maximum amount of electricity during the day. The Sun's position and geographical location are both dynamic. The PV panel's output power is influenced by the solar radiation level and angle, the kind and quantity of cells, the temperature of the cell loads, and the voltage (or battery). Fixed solar panels often don't continually get the most sun energy. Solar Tracking (ST), which increases the PV panel's output power, can be utilized to address this issue. By putting the PV panel perpendicular to the sun's beams during the day, the solar tracker can capture the most solar radiation [17].

An active single-axis solar tracker may be installed on a wall due to its small size. Two Light-Dependent Resistor (LDR) sensors that are mounted on the Photo-Voltaic (PV) panel's surface measure solar irradiation. The smart tracker system functions in a variety of settings to provide consumers flexibility to suit their tastes and diverse climatic situations. While the system is in the "sleep" mode at night to save energy, during the day the PV panel rotates automatically dependent on the sun's irradiance. PV cells, a charge controller, and a lead acid battery make up the solar tracker [18]. In addition, LDR sensors, a voltage regulator, and a target board with a microcontroller called the PIC18F4520 were employed. The microcontroller receives a signal from the LDR sensors telling it to spin the PV panel using the servo motor. A lead-acid battery is then utilized to store the electrical energy before being used to power the corresponding components. [19] It is simpler to maintain and more affordable because just single-axis tracking is used. A time-based tracking technology has been integrated with light-sensor tracking technology in the tracker system. However, it requires the generation of Pulse Width Modulated (PWM) waves to be provided as input to the microcontroller, and the tracking is inefficient compared to dual-axis tracking.

A novel control method that enhances distributed maximum power point tracking systems' dynamic performance. The new control algorithm presented in this paper exploits the benefits of vectorial multi-variable perturb observe logic and acts on the control sequence under varying irradiance conditions, reducing the voltage stresses at the DC/DC converter output terminals [20]. Additionally, the topic of matching with the DC-bus voltage control is covered, giving the entire system centralized control, which hasn't been covered very often. A simple way to coordinate the operation of distributed and central MPPT functions and avoid the simultaneous change of reference for the various variables is to include VDC control in the MV control sequence. Additionally, DMPPT systems with various converter topologies in their modules can use H-MV control. The MV algorithms may operate inefficiently and each PV panel's MPPT may be off, while non-homogeneous irradiance fluctuations across modules might cause these issues. Additionally, the system becomes more expensive and sophisticated due to components like TMS320F28069M DSP converters [21].

III. Proposed Methodology

In this project proposed a two-axis sun tracking system with LDR sensors using the Wheatstone bridge circuit and IoT integration. The Wheatstone Bridge Circuit is employed to measure the resistance changes in the LDR sensors and accurately determine the sun's position relative to the solar panels.Furthermore, the system incorporates IoT technology to enable real-time monitoring. The collected sensor data, including the generated voltage and the panel direction, are transmitted to a cloud platform via wireless communication protocols such as Wi-Fi or cellular networks.

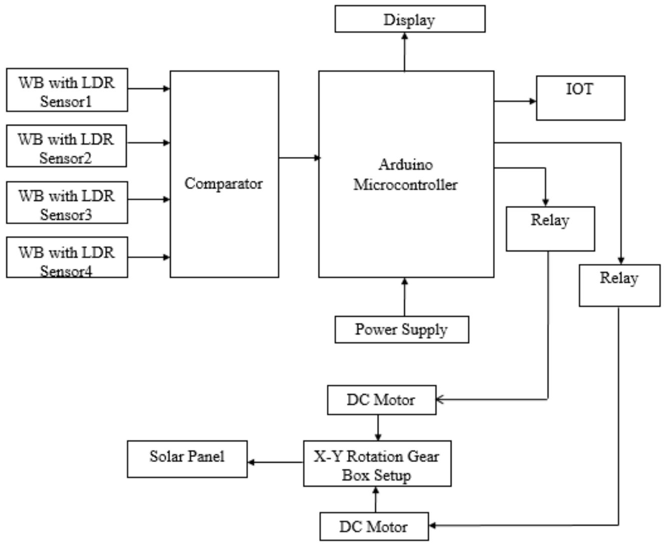

Fig.1 Proposed Block Diagram

1) Wheatstone bridge with LDR Sensor

The LDR sensors are placed on the four sides of the PV panel at a distance of 1 cm from the panel surface. The angle of the sun changes, the LDR sensor remains in the shadow. DAST system is more sensitive and faster due to the use of the Wheatstone bridge circuit. Sensors LDR1 and LDR2 are used to calibrate the PV panel relative to the horizontal axis and sensors LDR3 and LDR4 are employed to calibrate the PV panel relative to the vertical axis.

The Wheatstone bridge was first used to measure very low values of resistance. It is more precise compared to many other techniques and simply operates by dividing the voltage. One of the most important and well-known applications of the Wheatstone bridge circuit is measuring the variations of the sensor resistance

Fig. 2 (a) it is fully illustrated how to connect and use the resistance sensor in the quadratic Wheatstone bridge circuit. The half-bridge structure shown in Fig. 2 (b) is used to measure two elements with the same type to achieve higher sensitivity. This method is used to provide a signal in the output of resistance sensors such as light-dependent resistance sensors and LDRs . The resistance R_x of a linear resistance sensor can be as follows:

$$R_x = R_0(1 \pm kx)$$

Where k is the conversion constant of the sensor, x depends on the measured quantity, and R_0 is the nominal resistance of sensor element (x = 0). When the resistance in other parts of the bridge is equal to R_0 , the output bridge V_{oB} is equal to

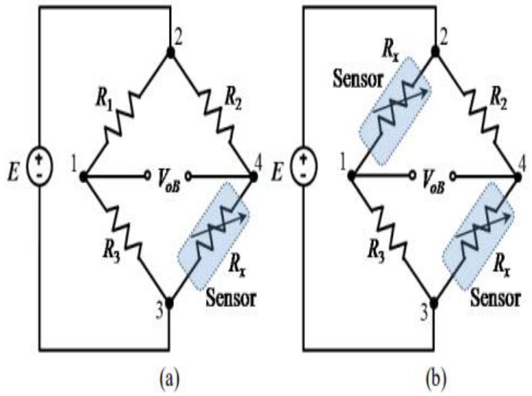

Fig. 2. The structure of the Wheatstone bridge. (a) full bridge; (b) half bridge

$$V_{oB} = \frac{E.kx}{k_B(1+\frac{kx}{2})}$$

In Equation, E is the voltage of the power supply of the bridge, and B_k is the bridge constant (full bridge B_k = 4 and a half bridge B_k = 2). Equation clearly shows that the output voltage of the bridge V_{oB} will be the nonlinear function. Since the percentage of change in the resistance element is very low (k_x<<1), the nonlinearity is also low. In contrast, as it increases, it'sk$_x$ also increases. Nonlinearity with respect to the operating range can be increased up to %8. Given these points, it provides the advantage of a bridge-based measure

2) Control Unit

An Arduino microcontroller is used for its control system. Control system is a closed-loop system that uses Wheatstone bridge circuit function along with LDRs. LDRs data are processed by a microcontroller and track the sun, independent of its geographical location. The control unit handles the controlling task and coordinates all parts of the DAST system and also the PV panel's movement in all directions. The DAST system function is automatically performed by the control unit and LDR sensors

The DAST system has two circuits for controlling the rotary motion of the PV panel in both horizontal and vertical axes and each axis operates in two directions. Each hardware circuit consists of three parts including a Wheatstone bridge with an LDR sensor, op-amps, and control circuits. To achieve maximum power for the PV panel, the astronomical tracking processes proceed simultaneously to make the PV panel perpendicular to sunlight. Then, the voltage generated at the output of the Wheatstone bridge is transmitted to the op-amps and amplified as well. The output voltage of the op-amps by the control circuits activates the relay. The relay rotates the engine of the tracking system in the desired direction, and the PV panel will rotate around its axis so that the ST system automatically places the PV panel perpendicular to the direction of the sun rays. Accordingly, the control system continuously monitors the solar radiation angle and PV panel by LDRs and sends a differential control signal to the relay of the tracker motor until the voltage difference in the bridge branches becomes less than a threshold value

3) X-Y Rotation

The main axis of the horizontal rotation of the PV panel allows the rotation of the PV panel to track the angle of the solar radiation from the east to the west. The ball bearings facilitate the rotation of the PV panel on the structure. The vertical rotational axis of the PV panel allows the PV panel to rotate in order to track the angle of the solar radiation from the north to the south. The upper gearing mechanism (DC motor with gear mechanisms) is connected to the horizontal shaft to bear the axle load along with the gear mechanisms situated in a suitable box on the moving part.

4) Solar Panel

Solar panel c (3.2) number of solar cells arranged in specified manner. Solar cells are the device which directly converts the solar energy into electrical energy through photovoltaic effect. Solar cells are primarily photovoltaic devices.

Fig 3. Solar Panel

Solar panel systems work by converting the suns energy into electricity, which is stored in a battery/ batteries. A regulator lies between the battery and the solar panel which protects the battery from over-charging. The regulator may also have discharging protection as draining the battery excessively will cause it long term damage. Energy can be taken out of the battery as required (12 or 24 Volts DC) using a transformer to convert to 220/240V if required. Control systems may shut down power draining equipment automatically to preserve the battery. Display units are available so that vital working of the solar panels and batteries can be monitored.

5) Integrated Design of IoT Gateway

The design of IoT gateway is based on the purpose of solving the need for data transmission using two different protocols, namely, WiFi and GPRS. The gateway nodes transmit the data to the remote server in the packet format of Wi-Fi. Wi-Fi provide the underlying communication of the IoT architecture to enable the integration and interconnection of physical and virtual things. Every gateway is given a unique user ID, which is randomly generated after sign up in the designed Website portal.

6)Arduino UNO

The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc.The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits.The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered by a USB cable or by an external 9 volt battery, though it accepts voltages between 7 and 20 volts. It is also similar to the ArduinoNano and Leonardo. The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0.The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform. The ATmega328 on the Arduino Uno comes preprogrammed with a bootloader that allows uploading new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol. The Uno also differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it uses the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

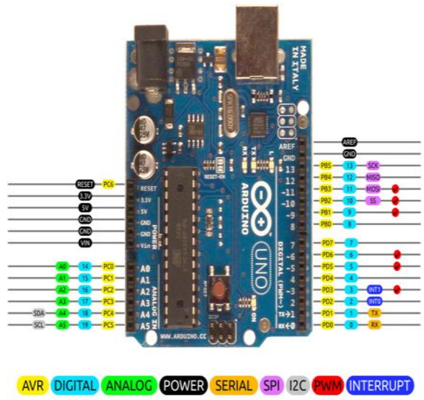

Fig .4.Arduino UNO

IV. RESULTS AND DISCUSSION

To maximize power, the PV panel should be placed perpendicular to the sun radiation angle. The PV panel is positioned at different angles depending on the angle of solar radiation. The sun moves from east to west during the day. By the movement of the sun, the DAST system simultaneously moves in all directions and locates the PV panel in the direction of solar radiation. The performance of the DAST system is examined in two modes as follows:

1) The motion of the panels to the west
2) The motion of the panels to the east

As the sun radiates on the surface of the light sensors, their ohmic resistance decreases. The higher the radiation intensity, the lower the sensor resistance. As the sun radiates on the surface of the sensors (LDRs) in different modes of the DAST system, their ohmic resistance changes. Furthermore, the system incorporates IoT technology to enable real-time monitoring. The collected sensor data, including the generated voltage and the panel direction, are transmitted to a cloud platform via wireless communication protocols such as Wi-Fi or cellular networks.

CONCLUSION

The solar tracking system detects the astronomical position of the sun during the day and increases the output power of the PV panel by placing it in a suitable position relative to the angle of the sun's rays. Many solar tracking systems have been developed so far that either has been not able to move on two axes or have been based on geometric and astronomical equations and artificial intelligence, which are expensive. This study presented a new DAST based on LDRs, which adjusts the PV panel relative to the angle of the sun's rays by moving simultaneously on two axes. DAST is a very simple and cost-effective control system that utilizes Wheatstone bridge circuit function and LDRs. If this controller is used, it is possible to control PV panels on the metal structure both individually and in an integrated manner. Therefore, the experimental findings of this solar tracking system can help develop solar energy applications. The IoT integration allows the system to be monitored and controlled remotely. This can be done by logging into the web-based interface or mobile app and viewing the current position of the solar panel. The system can also be programmed to track the sun's position automatically, based on the time of day and the location of the solar panel. This system can be used to increase the efficiency of a solar panel by tracking the sun's position and adjusting the position of the panel accordingly. This can lead to a significant increase in the amount of energy generated by the solar panel.

In future, using high powerful motors to tracking the solar radiation with maximum capability and also lifespan shall be improved, but comparatively at higher cost. Dual-axis solar trackers will helpful to accomplish the optimum solar energy level for implementing this technique. In forthcoming this twin axis solar collector tilting techniques can also be implemented in the huge solar plants and it can be functioned spontaneously. Efforts should be taken to implement this on a large scale for future purpose so as to meet increasing energy requirements.

References

1. Yingxue Yao, Yeguang Hu, ShengdongGao, Gang Yang b, Jinguang Du. “A multipurpose dual-axis solar tracker with two tracking strategies”. Elsevier.
2. Aditya Sawant, Deepak Bondre, Apurav Joshi, Prasad Tambavekar. “Design and Analysis of Automated Dual Axis Solar Tracker Based on Light Sensors”. IEEE.
3. PrabodhBajpai, Subhash Kumar. “Design, Development and Performance Test of an Automatic Two-Axis Solar Tracker System”. IIT Kharagpur.
4. Tung-Sheng Zhan, Whei-Min Lin, Ming-Huang Tsai, Guo-Shiang Wang. “Design and Implementation of the Dual-axis Solar Tracking System.” IEEE 37th Annual Computer Software and Applications Conference.
5. A. Yazidil, F. Betin, G. Notton, G.A. Capolinol. “Low cost twoaxis solar tracker with high precision positioning.” IEEE.
6. Hassan Fathabadi. “Novel high accurate sensorless dual-axis solar tracking system controlled by maximum power point tracking unit of photovoltaic systems.” Elsevier.
7. Dr. M. Mani Roja, SidharthMakhija, AishwaryaKhatwani, Mohd. Faisal Khan, VrindaGoel. “Design & Implementation of an Automated Dual-Axis Solar Tracker with Data-Logging.” International Conference on Inventive Systems and Control (ICISC-2017).
8. F.R. Rubio, M.G. Ortega, F. Gordillo, M. Lo´pez-Martı´nez. “Application of new control strategy for sun tracking.” Elsevier.
9. Long Seng To, Alex Zahnd. “Enhancing Capacity For Solar Photovoltaics in Rural Nepal.” Murdoch University.
10. MasoumehAbdollahpoura, Mahmood Reza Golzariana, Abbas Rohania, HosseinAbootorabiZarchib. “Development of a machine vision dual-axis solar tracking system.” Elsevier.
11. J. Rizk, and Y. Chaiko. “Solar Tracking System: More Efficient Use of Solar Panels.” WORLD ACADEMY OF SCIENCE ENGINEERING AND TECH.
12. BouzianeKhadidjaa, KorichiDrisa, AzouiBoubekerb ,SettouNoureddinec. “Optimisation of a Solar Tracker System for Photovoltaic Power Plants in Saharian region, Example of Ouargla.” EUMISD
13. ShrishtiRana. “A STUDY ON AUTOMATIC DUAL AXIS SOLAR TRACKER SYSTEM USING 555 TIMER.” IJTRA.
14. J. P. Bijarniya, K. Sudhakar, and P. Baredar, “Concentrated solar power technology inindia: A review,” Renewable and Sustainable Energy Reviews, vol. 63, pp. 593–603, 2016.
15. H. Ayoub, “Improving the energy capture of solar collectors,” Department of Mechanical and Aerospace Engineering, University of Strathclyde engineering, pp. 1–54, 2012.
16. S. J. Oh, M. Burhan, K. C. Ng, Y. Kim, and W. Chun, “Development and performanceanalysis of a twoaxis solar tracker for concentrated photovoltaics,” International Journal of Energy Research, vol. 39, no. 7, pp. 965– 976, 2015.
17. A. Awasthi, A. K. Shukla, M. M. SR, C. Dondariya, K. Shukla, D. Porwal, and G. Richhariya, “Review on sun tracking technology in solar pv system,” Energy Reports,vol. 6, pp. 392–405, 2020.
18. C. Chin, A. Babu, and W. McBride, “Design, modeling and testing of a standalone single axis active solar tracker using matlab/simulink,” Renewable Energy, vol. 36, no. 11, pp. 3075–3090, 2011.
19. K. S. Karimov, M. Saqib, P. Akhter, M. Ahmed, J. Chattha, and S. Yousafzai, “A simple photo-voltaic tracking system,” Solar energy materials and solar cells, vol. 87, no. 1-4,pp. 49–59, 2005.
20. Karthikeyan K, Anitha P, Karthik Kumar K, &Kamaraja A S. (2023). Smart Emergency Charging of Electric Vehicle with Solar PV-based Backstepping Model-Free and critic RL Control Structure. CONTROL ENGINEERING AND APPLIED INFORMATICS, 25(1), 69–78.

21. R. Lo´pez-Erauskin, A. Gonza´lez, G. Petrone, G. Spagnuolo, and J. Gyselinck, “Multi-variable perturb and observe algorithm for grid-tied pv systems with joint central and distributed mppt configuration,” IEEE Transactions on Sustainable Energy, vol. 12,no. 1, pp. 360–367, 2020.

22. MasoumehAbdollahpoura, Mahmood Reza Golzariana, Abbas Rohania, HosseinAbootorabiZarchib. “Development of a machine vision dual-axis solar tracking system.” Elsevier.

23. J. Rizk, and Y. Chaiko. “Solar Tracking System: More Efficient Use of Solar Panels.” WORLD ACADEMY OF SCIENCE ENGINEERING AND TECH.

24. BouzianeKhadidjaa, KorichiDrisa, AzouiBoubekerb ,SettouNoureddinec. “Optimisation of a Solar Tracker System for Photovoltaic Power Plants in Saharian region, Example of Ouargla.” EUMISD

25. ShrishtiRana. “A STUDY ON AUTOMATIC DUAL AXIS SOLAR TRACKER SYSTEM USING 555 TIMER.” IJTRA. 26. HosseinMousazadeh, AlirezaKeyhani, ArzhangJavadi , HosseinMobli, Karen Abrinia, Ahmad Sharifi. “A review of principle and sun-tracking methods for maximizing solar systems output.” Elsevier.

27. Zolkapli, M. 1; AI-Junid S. A. M.; Othman Z.; Manut, A.; MohdZulkifli M. A. “High-Efficiency Dual-Axis Solar Tracking Developement using Arduino.” IEEE.

28. B. J. Huang and F. S. Sun, “Feasibility study of one axis three positions tracking solar PV with low concentration ratio reflector,” Energy Convers. Manag., vol. 48, pp. 1273–1280, 2007.

29. I. Visa, D. V. Diaconescu, A. Duta, and V. Popa, “PV tracking data needed in the optimal design of the azimuthal tracker’s control program,” in Int. Conf. Optimization Electr. Equipment (OPTIM), Romania, 2008, pp. 449– 454.

30. C. Alexandru, Software Platform for Analyzing and Optimizing the Mechanical System (SYROM 2009). New York: Springer, 2009, pp. 665– 677.

31. C. Alexandru and C. Pozna, “Simulation of a dual-axis solar tracker for improving the performance of a photovoltaic panel,” in Proc. Ins. Mech. Eng., Part A: J. Power Energy, vol. 224, no. 6, pp. 797–811, 2010.