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Design and implementation of Sun Tracking Solar Panel and Smart Wiping Mechanism using Tinkercad

¹Keyur Patel, ¹Sanket Borole*, ²Ketan Ramaneti, ¹Atharv Hejib, ¹R. Raja Singh

¹School of Electrical Engineering, VIT Vellore, India

²School of Electronics Engineering, VIT Vellore, India

*Corresponding author's email: sanketsubhash.borole2017@vitstudent.ac.in

Abstract. In today's times, electricity has become very essential for mankind. Increasing demand for electricity leads to the depletion of the coal and fossil fuel available to humans. As fossil fuels are bound to get exhausted and also not being a clean source of energy is another added disadvantage. In this era of enormous energy demand, wide research and development of renewable sources of energy is mandatory. The use of solar energy can be advantageous to great extent. To make most of the power from photovoltaic cells, development should focus on getting greater efficiencies using Solar panel arrays. Dust on the surface of the panel and varying intensity of the sunlight contributes to a significant amount for reduction in efficiency. In this paper, an integrated solution for both the dust accumulation problem and the sun's continuous movement has been proposed, which leads to an increase in the efficiency of the panel. The consequences of dust and intensity of sunshine on the efficiencies of the Photo-voltaic panels are highlighted. The paper gives a brief description of the planning and construction of microcontroller-based cleaning and tracking system. The solution proposed is visualized in Tinkercad, which is an online simulator to design CAD models and electronic circuits. The designed model is practically implemented as a hardware prototype for validation.

1. Introduction

Energy is inheriting a crucial role in the world of development and urbanization. The primary source through which power can be harnessed has always been the nature itself. Non-renewable sources of electricity such as coal, oil, and natural gas, are commonly used to operate the base load which is majority of the power usage. However, these resources are non-replenishable. These resources account for majority of the climate change problems faced by the humanity. There is a way out through this. Using renewable energy resources such as solar, wind, hydropower, etc can drastically reduce the affects that the power needs have on the environment. Solar energy has risen as a potential and efficient way to generate electricity in the future. There's nothing wrong in saying that renewable energy will occupy more than 80% of the total energy and nearly 60% will be comprised of solar energy [1]. Amidst the rush of finding sustainable solutions, Solar energy generation is flourishing with great potential. With the development and research in mind, India has promised to achieve 100 GW of solar energy by the year 2022.



Photovoltaic systems are on the rise and also the investments and risks related to these systems are increasing [2]. Solar energy stands for generating energy using the energy of the sun such as heat and light. A photovoltaic cell converts the sunlight into electrical energy through the process of photovoltaic effect. Solar power plants use solar panels which have hundreds of photovoltaic cells in it. The solar panel's array efficiency has to be maximized to make solar energy a largely and widely used source of energy [3]. The generation of electricity using photovoltaic cells has few drawbacks. To get the most out of the solar panels, the panels must be facing perpendicular to the sunlight that is incident on them and also the surface of the panel must have any dust on it. The automatic sun tracking system is a solution for this issue [4]. If the incident light is not perpendicular to the surface, the panel will not give its maximum power output. Real time sun tracking has to be done to get maximum possible efficiency [5]. There is drastic decrease in the power output of the panel, if there is sand accumulated on the surface of the panel [6].

A solution has been proposed in this paper to effectively harness the solar radiation for the majority part of the day and convert it into electricity. An additional feature has been incorporated to clean the surface of the solar panel and solve the dust accumulation problem. Solar panels are placed on house roofs to give more exposure to sunlight. Dust gets accumulated very quickly on the surface. As a result, the intensity of the solar radiation is reduced, and hence the panel's efficiency drops. In [7], the authors predict system soiling losses of up to 27%. Solving these problems will give enhanced efficiency for the panel and hence, lower payback periods.

A variety of solutions are proposed by researchers in the field of solar photovoltaic generation. Passive tracker solutions have been developed which are dependent on thermal expansion of materials or on the principle of a pressure difference between two points. They are used to having no gears, motors, or sensors in their tracking process. Solar tracker solutions are also classified on the base of the rotational axes/degree-of-freedom. Broadly, they are classified into a single axis and dual axis, out of which dual axis is found to be more efficient [8]. Single-axis trackers have a single axis of rotation and they give 15% to 30% more efficiency compared to the static solar cells. The next classification in the field of solar trackers comes in the form of dual-axis solar tracking. As they have two axes of rotation, they can track the sun throughout the day [9]. They aren't affected by the varying seasons or the movement of the sun. As they have a greater degree of freedom, these types of systems are able to have 40% more efficiency compared to their static counterparts. In [10], the authors have expected to have an increase of 65% in their efficiency using the helianthus model. Though, tracking helps in increasing the efficiency of the system, if dust cleaning and sun tracking is incorporated in one system, a much better efficiency can be extracted [11]. The author presented an automatic solar tracking system in which the author designed a solar panel tracking system based on microcontroller and observed that single axis tracker increases efficiency by 30% compared to the static panel system. In [12] a solar tracker has been made which uses Programmable Logic Controller (PLC) as the controller to track the sun.

To get the peak efficiency of the solar panels, researchers have also explored a few methods to get rid of the dust accumulation on the surface of the panel. Self-cleaning nano-films have been developed which have anti-soiling properties [13]. Nano-film solutions are very useful in regions with water scarcity as they need very minimal water or often no water to clean the surfaces. Another breakthrough in the technology of cleaning PV Panels has been observed using Electrostatic methods [14]. A piece of detachable cleaning equipment is employed for the removal of dust that accumulates on PV panels. It is performed using electrostatic standing waves which were generated using negligible power [15].

In this paper the proposed solution has been implemented on Tinkercad. Tinkercad has a very user-friendly interface for designing circuits and CAD models. It also has a wide range of components such as Arduino UNO, Integrated circuits, and various other electronic components. Along with the software implementation of the model, a hardware model has also been made. The hardware model is aimed to the increase in efficiency of a solar panel by employing Sun-tracking and smart dust wiping Mechanism. Model establishes a proof of concept for the model which can enhance

the efficiency. Overall organization of the paper is given as follows. Section 2 discusses about the design and implementation strategies of sun tracking and smart cleaning mechanism. In section 3, the prototype development of the proposed sun tracking and smart cleaning mechanism is discussed. Followed by it, the results and discussion with different cases are given in section 4 and finally concluded with future scope in section 7.

2. Design of Sun tracking and smart wiping mechanism

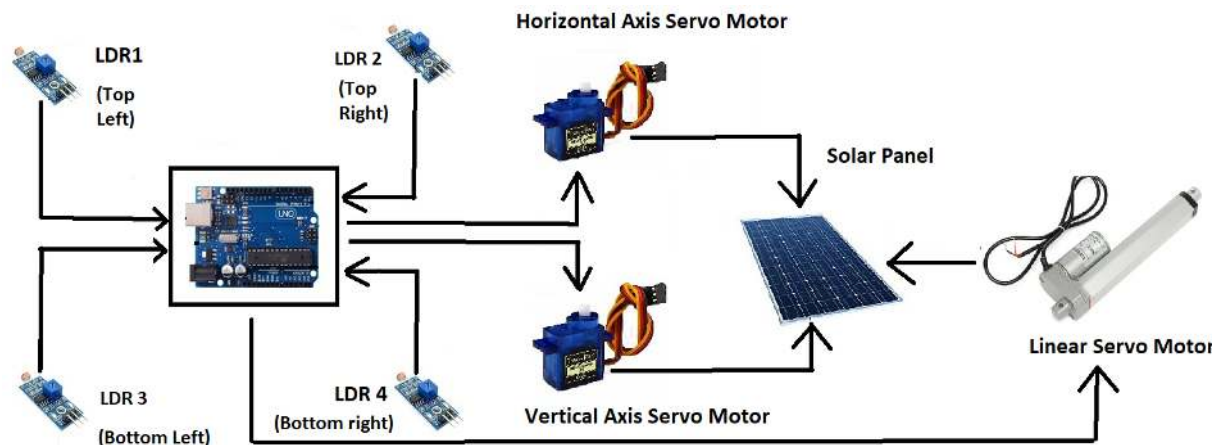


Figure 1. Pictorial representation of sun tracking system with smart wiping mechanism

Pictorial representation of sun tracking system with smart wiping mechanism is shown in Figure 1. As it is evident from Figure 1 a total of four LDR's are present which sense the light falling on them from four different directions. The intensity values are given to the controller. The controller analyses those values and gives the output to the corresponding servo motors to move in the respective direction for the required angle. These actuators then turn the solar panel to maximize the sunlight falling on it. For smart cleaning mechanism a linear servo motor is connected which would be programmed such that after a duration of four hours the wiper connected would wipe the panel.

The sun tracking system with smart wiping system is designed in Tinkercad online environment which is shown in Figure 2. Each of the components used has been specified in the table above. In the circuit above, 4 LDRs have been connected to take the intensity of the sunlight from all the directions. The LDRs pin are connected to the analog pins of Arduino UNO control board. A better resolution of the values of the intensities can be received by using the analog pins. Two servo motors namely, horizontal servo motor and vertical servo motor is connected to the Pulse Width Modulation pins of the microcontroller. Along with the tracking actuators, the cleaning actuator is connected to the DC output of the microcontroller to get constant motion.

2.1 Sun tracking and wiping mechanism

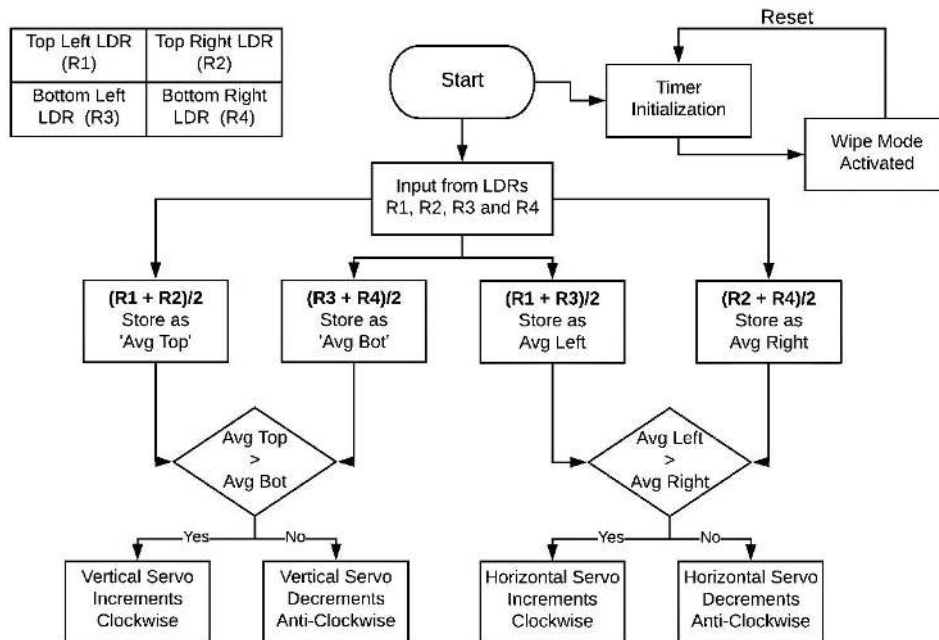


Figure 2. Flowchart for sun tracking mechanism

The algorithm is made to sustain autonomously. The sun tracking algorithm works by comparing the average value of sunlight falling on the 4 LDRs. The flowchart shown above is a clear depiction of the algorithm coded on the controller. The terminology of the LDRs based on the location. Four distinct LDRs are named as follows: top left, top right, bottom left, and bottom right.

Initially the algorithm calculates the average of the intensity of light falling on top, bottom, right, and left, respectively which gives a sense of orientation of Sun. The algorithm starts with comparing the average intensity of top and bottom LDR, i.e., comparing the average of top left and top right LDRs with the average of the bottom left and bottom right LDRs. If the average intensity of the top LDRs is less than the average intensity of the bottom LDRs, the vertical servo rotates anti-clockwise. The vertical servo rotates clockwise when the average intensity of light on the top is more than the average intensity of sunlight at the bottom.

Similarly, If the average intensity of the left LDRs is less than the average intensity of the right LDRs, the horizontal servo rotates anti-clockwise. The horizontal servo rotates clockwise when the average intensity of light on the left is more than the average intensity of sunlight at the right.

Here the linear motor is attached on the edge of the panel. The wiper is arranged in such a way that it can clean the panel's surface in a single swipe. The controller has been programmed such that after an interval, of 4 hours in this case, the controller would power the linear servo motor to perform a certain number of wipes.

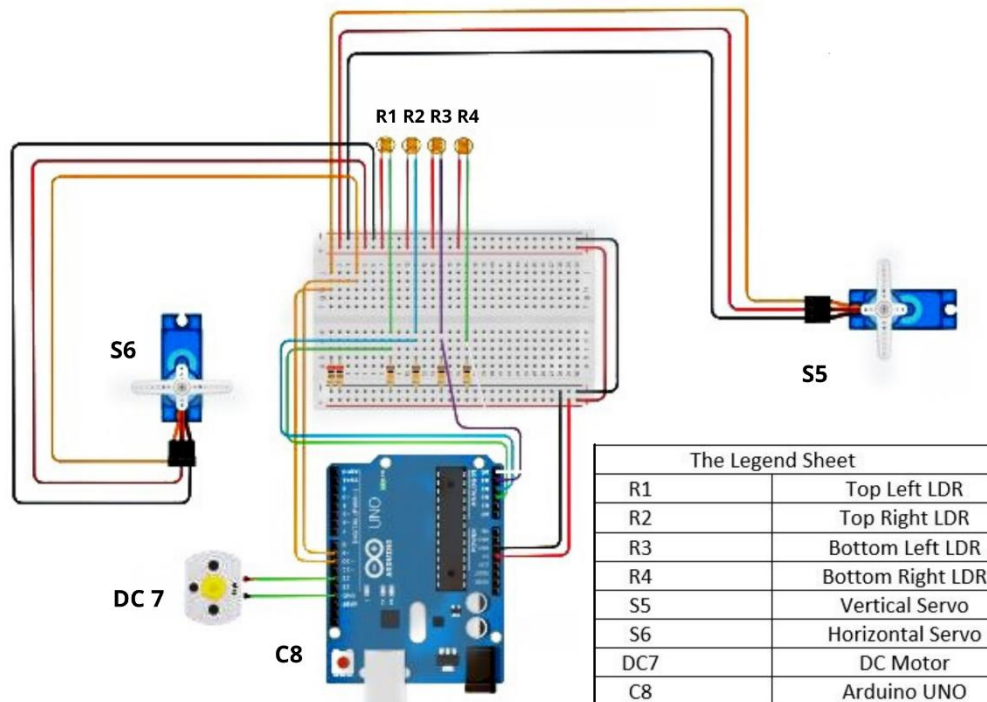


Figure 3. Design of sun tracking system with smart wiping mechanism

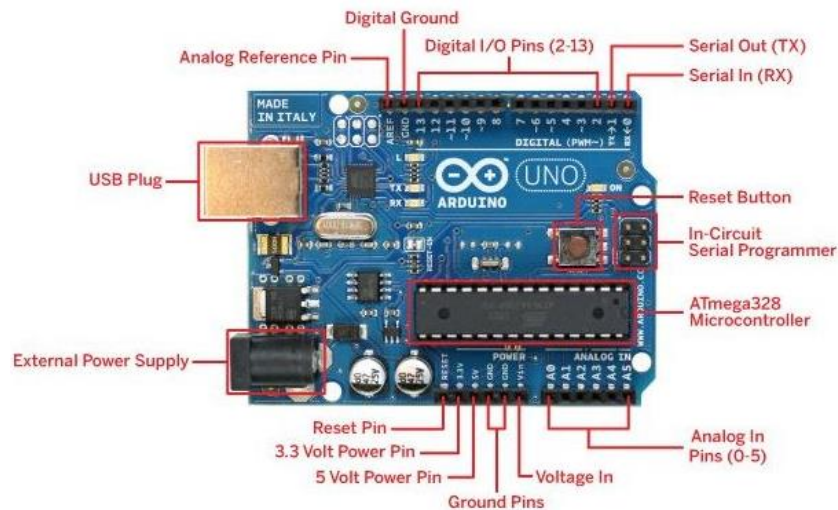


Figure 4. Pin diagram of Ardiuno UNO

3. Implementation of sun tracking and wiping mechanism

The prototype is built using two dc servo motors for tracking and a linear servo motor used for the cleaning mechanism. The servo motors are separately powered by the controller itself due to the low power output of the solar panel. But, for practical purposes, the servo motors cannot be directly powered by the controller because the motors (~5 to 6 Watts) can damage the controller. The wiper is placed on the edge of the panel. The wiper wrapped with a piece of fabric acts as a mop to draw the

dust out of the panel's surface. These dc motors controlled are using the microcontroller through sophisticated control algorithms. The angular servo motor used for the sun-tracking mechanism is employed to act as a robotic arm. One servo motor is used for the Yaw movement, and the other servo is used for the Pitch movement of the panel.

The prototype of the sun tracking solar panel with smart wiping is implemented with various hardware components. *The description and detailed function of each component are as follows.*

3.1. Arduino UNO Controller

Arduino UNO microcontroller has been used to control the overall process. It has fourteen input/output pins. Among them six pins are dedicated to PWM or Pulse Width Modulation. Because of the ease of use, Arduino UNO has been considered the ideal controller for the prototype. The function of the controller is to track the Sun's movements and send the signal to the actuators to rotate accordingly. Along with sun tracking, the controller also performs the self-cleaning task through the movement of an external actuator.

3.2. Solar Panel

The rating of the prototype solar panel is 6V, 100 mA. The panel is attached to the rotary actuator. A solar panel has numerous photovoltaic (solar) cells arranged in an order. When the sunlight is incident on the surface of the photovoltaic cell, the energy is transformed by this cell into electrical potential across the terminals, i.e., electrical power. The absorbed energy makes the electrons jump from one energy level, i.e., orbit to another energy level inside the atom, thus releasing energy. For residential purposes, panels with ratings of 24V/330 W are normally used.

3.3. LDR

Light Dependent Resistors are the critical element in the prototype. LDR is a type of resistor whose resistivity is inversely proportional to intensity of sunlight incident on the surface. That means, in the dark when the intensity of light is negligible the LDRs show high amount of resistance, whereas when the intensity of light is higher in the day the LDRs present low resistance. The LDRs are placed on the edge of the panel and move along with the panels to track the sun. While using LDRs, the value is taken as an analog input to get an accurate value when the reading values are combined.

3.4. Actuator – Servo Motor

Servo motor-based actuator is used in this prototype. The role of servo motor in the prototype is to rotate the panel as per the control signals. Rotating the servo motor is done using a PWM signal provided to the motor's control pin. The controller generates the PWM signal. The control system used to operate the servo motor implies an error-sensing feedback control, which helps the servo motor to precisely land on the desired angle. It usually requires a sophisticated controller. Servo motors are classified in 2 variants, which are DC Servo motors and AC servo motors. In this sun-tracking mechanism, the type of motors used is the DC Servo motor as massive torque is not required. The servo motors used have a range of 0-180°. For the cleaning mechanism, a linear servo motor has been used, which has a precise linear movement that can be calculated and precisely controlled using the microcontroller. Adapting the hardware components, the prototype model has been built to track the solar radiations to extract the maximum power.

In the prototype, a dual-axis sun tracker is being made. For the dual-axis tracker, 4 LDRs have been incorporated. Each LDR is placed on four different corners of the panel. One set of LDRs used is to give pitch movement signals, and the other is for the yaw movement signal. As two sets of sensors are present, two different function blocks have been used to compare the intensity of light falling on LDRs. In the morning, the set of LDRs measuring the intensity of sunlight for the East-west arc gets low resistance from the LDR facing east. The LDR facing the west shows a high value of resistance. The signal compared is in the function block, and it depicts that solar radiation is more on the east.

Hence, the panel inclines itself towards the east using the servo motors. Here, the tracking is done in fixed intervals of 1 hour only. Instantaneous tracking using the actuators would lead to more power consumed. Hence, including instantaneous tracking would lead to reduction in net efficiency of the system. Doing this will reduce the power usage for the Servo motor.

Table 1 consists of the technical specifications of the components used and their cost has been shown below to give an overall idea of the cost of the prototype. The hardware prototype is shown below in the Fig 5.

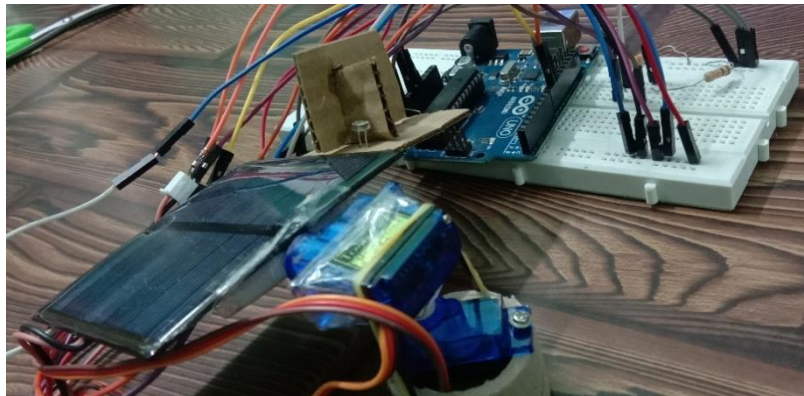


Figure 5. Sun tracking and wiping prototype model

Table 1: Technical Specification with cost description

Components	Specifications	Quantity	Total Cost
Solar Panel (70x70x3mm)	(6V/100mA)	1	160 INR
Light Dependent Resistor (LDR)	N/A	4	40 INR
Servo Motor SG90	Operating Vol:3.0V - 7.2V Stall Torque: 1.2 kg-cm	2	200 INR
Arduino UNO	ATmega328P – 8-bit AVR family Operating Voltage: 5V	1	350 INR
Linear Servo Motor	Voltage: DC 3-6 V Current: 100 mA-120mA	1	250 INR

4. Results and Discussion

The implementation of the Sun tracking solar panel was successfully carried out. The initial position of the solar tracker is depicted in Figure 3. For demonstration purpose it is considered that the servo motors to be along two axis which are horizontal and vertical. The horizontal servo would give the panel an east-west direction motion and on the other hand the vertical servo would give it a north-south direction motion as and when required. The vertical axis comes into picture in the higher latitude regions.

4.1. Case 1:

On increasing the intensity falling on the top right and bottom right LDRs the sunrise situation has been simulated. The horizontal and vertical servo motors are at the initial position. Considering that the Sun's position is on the right side of the panel; the average value of the right LDRs is greater than the average values of the Left LDRs. The average top, average bottom, average left and average right is calculated. There is no incident light falling on the Top left and bottom left LDRs. The difference between average top and average bottom is very small and hence there is an anti-clockwise drift in the vertical servo, whereas the average right value is greater than average left. Hence, the angle of the servo motor is incremented until the difference between average right and average left doesn't become zero. The direction of rotation of servo motor is also shown with the help of arrows.

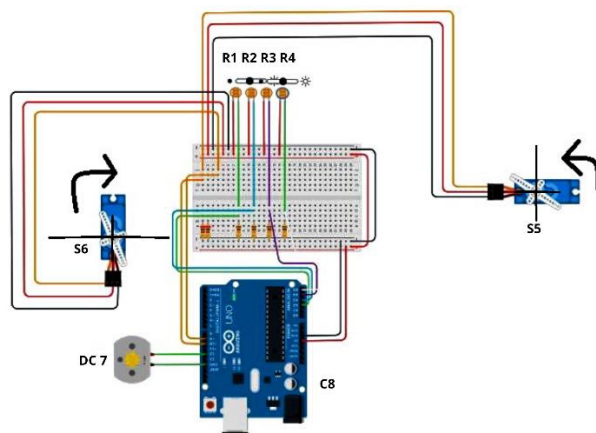


Figure 6. Case 1

(Top right and bottom right)

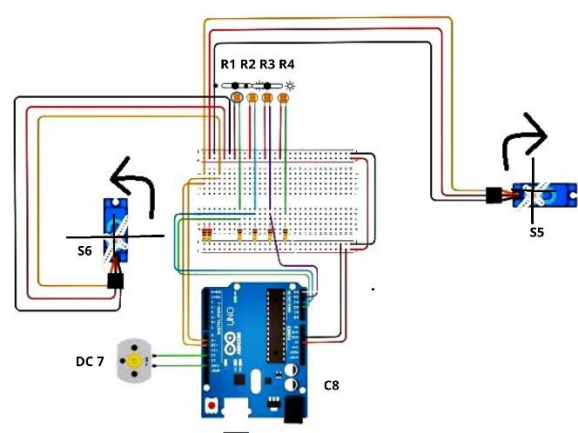


Figure 7. Case 2

(Top left and bottom left)

4.2. Case 2:

On increasing the intensity falling on the top left and bottom left LDRs the sunset situation has been simulated. The horizontal and vertical servo motors are at the initial position. Considering that the sun's position is on the left side of the panel; the average value of the left LDRs is greater than the average values of the right LDRs. The Average top, average bottom, average left and average right is calculated. There is no incident falling on the Top right and bottom right LDRs. The difference between average top and average bottom is very small and hence a clockwise drift is seen in the vertical servo, whereas the average left value is greater than average right. Hence, the angle of the servo motor is decremented until the difference between average right and average left doesn't become zero.

4.3. Case 3:

On increasing the intensity falling on the top right, top left, and bottom right LDRs 'Sun at the North-east' situation has been simulated. The horizontal and vertical servo motors are at initial positions; considering that the sun's position is on the top-right side of the panel; the average value of the right LDRs is greater than the average values of the Left LDRs and the average value of the top LDRs is greater than the average values of the bottom LDRs. The Average top, average bottom, average left and average right variables are calculated. There is very little light falling on the bottom LDRs and the left LDRs. Hence, average top is greater than average bottom, and the average right value is greater than average left. Hence, the angle of the horizontal servo motor is incremented until the difference

between average right and average left doesn't become zero. And, the angle of vertical servo motor is incremented until the difference between them doesn't become zero.

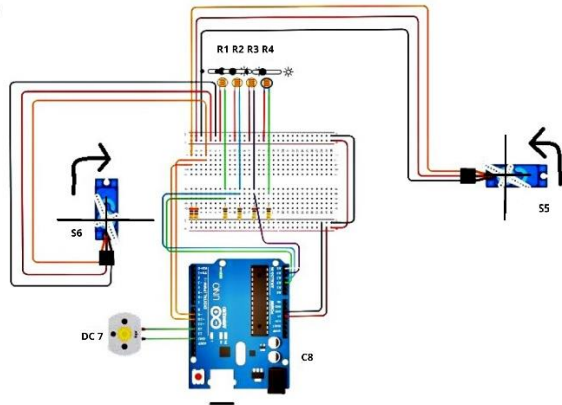


Figure 8. Case 3

(Top right, bottom right and top left)

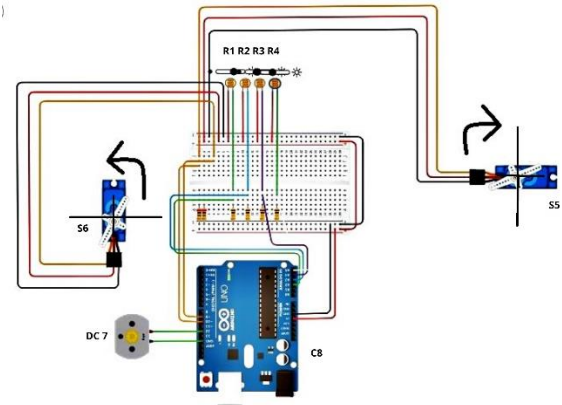


Figure 9. Case 4

(Bottom right, bottom left and top left)

4.4. Case 4:

On increasing the intensity falling on the bottom right, Bottom Left, and Top Left LDRs ‘Sun at the South-west’ situation has been simulated. The horizontal and vertical servo motors are at initial positions; considering that the sun’s position is on the bottom-left side of the panel; the average value of the left LDRs is greater than the average values of the right LDRs and the average value of the bottom LDRs is greater than the average values of the top LDRs. The Average top, average bottom, average left and average right variables are calculated. There is very little light falling on the top LDRs and the right LDRs. Hence, Average bottom is greater than average top, and the average left value is greater than average right. Hence, the angle of the horizontal servo motor is decremented until the difference between average right and average left doesn't become zero. And, the angle of vertical servo motor is decremented until the difference between them doesn't become zero.

5. Tabulation

Table 2: Output comparison between proposed and conventional systems

Time	Uncleaned w/o tracking (Volts)	Cleaned w/o tracking (Volts)	Uncleaned with tracking (Volts)	Cleaned with tracking (Volts)
6:00	1.29	2.39	1.78	2.71
7:00	1.41	2.51	2.00	3.03
8:00	1.66	2.63	2.07	3.10
9:00	1.83	2.78	2.17	3.22
10:00	2.10	3.18	2.34	3.37
11:00	2.22	3.25	2.54	3.47
12:00	2.40	3.50	2.59	3.54
13:00	2.24	3.32	2.49	3.49
14:00	2.17	3.10	2.32	3.42
15:00	1.90	2.83	2.05	3.25
16:00	1.63	2.59	2.02	3.17
17:00	1.46	2.54	1.85	3.05

18:00	1.24	2.41	1.73	2.78
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The hardware prototype which was built according to the concept mentioned was used to take the readings of the voltages given above in Table 2. Readings are taken for a cleaned panel with and without tracking and also for an unclean panel with and without tracking. The results were noted down for an entire day from 6AM to 6PM. By observing the output values, it can be seen that there is a notable difference when sun tracking and cleaning mechanism is applied as shown in Fig 10. There is a 64.3% increase in voltage compared to a dusty and non-solar tracking system. Also, it was observed that the sun tracking system does not show a significant difference for <10% of sun's movement. The increase of voltage is very small and thus for rotating the servo motor for small angles, there is a loss of energy in running them. Hence, the motor is considered to operate after 1 hour, to get significant change in movement and voltage values.

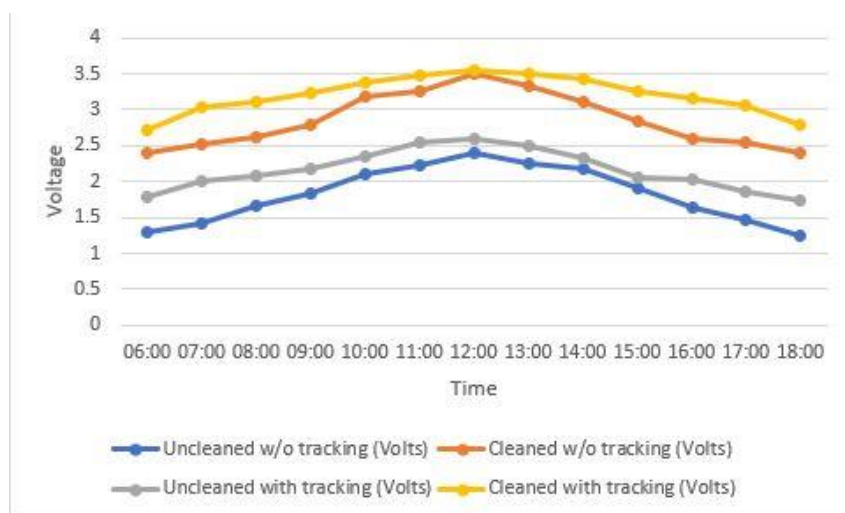


Figure 10. Output comparison between proposed and conventional systems

6. Conclusion

Solar energy is one of the most promising energy sources for the future. The challenge now is to maximize the utilization of this solar energy by absorbing it. Utilizing the Sun tracking solar panel, the results have shown that the efficiency of the system can be increased considerably. The system with the design and algorithm has been presented in the paper. The implementation was successfully carried out using Tinkercad software and the servo motor angles were also presented in the tabulation column. The motion of the servo motor was successfully visualized and controlled using the intensity values on the LDR. The automatic cleaning mechanism was visualized using the DC motor in the Tinkercad software.

7. Future Scope

Optimised by using Fuzzy Logic algorithm to increase the precision of the actuator movement. The proposed model in this paper uses external power to actuate the circuit, hence using its own power for the servo movement can make it a more reliable and increase monitoring and control. The cleaning mechanism can be improved by comparing the solar PV output with the predicted values to increase the efficiency.

8. References

- [1] International Energy Agency (IEA). *Technology Roadmap: Solar Photovoltaic Energy*. 2010
- [2] M. Catelani, L. Ciani, L. Cristaldi, M. Faifer, M. Lazzaroni, and M. Rossi *Characterization of photovoltaic panels: the effects of dust* in Energy Conference and Exhibition (ENERGYCON), 2012 IEEE International, 2012, pp. 45-50.
- [3] I. Nayshevsky, Q. Xu, G. Barahman and A. Lyons *Anti-reflective and anti-soiling properties of a KleanBoost, a superhydrophobic nano-textured coating for solar glass* 2017 IEEE 44th Photovoltaic Specialist Conference (PVSC), Washington, DC, 2017, pp. 2285-2290, doi: 10.1109/PVSC.2017.8366777
- [4] Mo Yibo, Yang Liang, Huang Liuyan, Xu Qiongying, Chen Haifeng *Review of various solar power generation technologies* Dongfang Electric Review, 2018, 32(125):78- 82.
- [5] Mayank Kumar Lokhande (2014) *Automatic Solar Tracking System* Journal of Core Engineering & Management, Volume 1
- [6] N. Bose, Arindam & Sarkar, Sounak & Das, Sayan. (2012). *Helianthus – A Low Cost High Efficient Solar Tracking System Using AVR Microcontroller* International Journal of Scientific and Engineering Research. 3..
- [7] Maghami, Mohammad Reza & Hizam, Hashim & Gomes, Chandima & MohdRadzi, MohdAmran & Reza, Sina & Hajighorbani, Shahrooz. (2016) *Power Loss Due to Soiling on Solar Panel: A review. Renewable & Sustainable Energy Reviews* 59. 1307-1316. 10.1016/j.rser.2016.01.044.
- [8] A. Kimber, L. Mitchell, S. Nogradi and H. Wenger *The Effect of Soiling on Large Grid-Connected Photovoltaic Systems in California and the Southwest Region of the United States* 2006 IEEE 4th World Conference on Photovoltaic Energy Conference, Waikoloa, HI, 2006, pp. 2391-2395, doi: 10.1109/WCPEC.2006.279690.
- [9] B. K. S. Vastav, S. Nema, P. Swarnkar, and D. Rajesh *Automatic Solar Tracking System using DELTA PLC* Conference 2016 International Conference on Electrical Power and Energy Systems (ICEPES), 2016.
- [10] B. Abhilash and A. K. Panchal *Self-cleaning and tracking solar photovoltaic panel for improving efficiency* 2016 2nd International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB), Chennai, 2016, pp. 1-4, doi: 10.1109/AEEICB.2016.7538291.
- [11] Ma Huihui, Bai Lianping *Dual-axis tracking of solar energy panels for maximum power* Journal of Beijing Information Science and Technology University, 2011, 26(5):93-96.
- [12] V.R. Sushma, V. M. Sneha *PLC Based Solar Tracking Panel Assembly* International Journal of Engineering Trends and Technology (IJETT) – Volume 18 Number 5, pp 230-234, 2014.
- [13] N. Barsoum and P. Vasant *Simplified solar tracking prototype* Global Journal of Technology and Optimization GJTO, vol. 1, pp. 38-45, 2010

[14] P. Rani, O. Singh and S. Pandey *An Analysis on Arduino based Single Axis Solar Tracker* 2018 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), Gorakhpur, 2018, pp. 1-5, doi: 10.1109/UPCON.2018.8596874

[15] H. Kawamoto and M. Kato *Electrostatic Cleaning Equipment for Dust Removal from Solar Panels of Mega Solar Power Generation Plants* 2018 IEEE 7th World Conference on Photovoltaic Energy Conversion (WCPEC) (A Joint Conference of 45th IEEE PVSC, 28th PVSEC & 34th EU PVSEC), Waikoloa Village, HI, 2018, pp. 3648-3652, doi: 10.1109/PVSC.2018.8547468.