JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Automatic Water and Dust Detector Based Solar Panel Cleaning System

Km Saba Khan[1], Thanuku Hemanth Kumar[2], Sanapala Sri Naveen[3], Kottiyada Sai Yochan[4], Thripuram Balarama Krishna Murthi[5], and Mandeep Singh[6]
[1 2 3 4 & 5] Undergraduate Student; Department of Mechatronics Engineering; Lovely Professional University, [6] Assitant Professor; Department of Robotics and Automation

Abstract:

As the requirement for sustainable energy increases, solar (PV) innovation is a subject of concern. Various research projects have been developed to extract the highest advantage from sun rays, but dust collection on solar panels and air pollution are two major impediments. The Indian government has set a great achievement of installing a grid-connected residential photovoltaic solar capacity of producing 40GW. Although, dirt amassing on sun-oriented photovoltaic modules decreases light transmission from the outer surfaces to the sun-powered cells, diminishing photon assimilation and therefore contributing to PV framework execution decrease thus it is necessary to clean the panel to urge high amount of voltage supply. This research presents automatic water and dust detector cleaning system for the solar panel. The functional PV system can work automatically and can deliver input of occurrence of detecting water and dust. we will address the technique, approach, and framework design of the cleaning and tracking system. The system is divided into two subsystems; In the cleaning system, the dust sensor detects the intensity of the dust and the microcontroller will command the motor's rotation direction accordingly. An adequate amount of water will be spread all over the PV surface and a wiper, powered by a stepper motor, moves back and forth over the PV panel to clean the surface. And in the tracking system, the sun's rays will be detected by the LDR module, and the panel will be adjusted correspondingly.

Keywords:

Sun rays, PV solar panels, Arduino, stepper Motor, Dust sensor, LDR module, water.

Introduction:

Renewable energy is a non-polluting, environmentally friendly source of energy that is expected to become more cost-effective in the next years, as well as a better technology in terms of cost and uses. Solar rooftop panels capacity has grown and is being embraced at a faster rate these days. Solar panels comprised of polycrystalline silicon, that responds to sunlight by producing a modest electrical charge, are erected on a roof or open land facing towards the sun [1]. The DC generated by the conversion of sunlight to energy is transmitted to an inverter, which transforms it into AC power. This alternating current (AC) is applied to your main electrical service panel, where it is used to power all of your home's appliances. However, only 13-16% effective solar irradiance is harnessed to generate electricity in a mono-crystalline solar Module using typical lab conditions [2].

The efficiency of a solar panel is determined by various factors and it is based on how much sun rays can transform into useful power. Due to various advancements in cell efficiency, system balance, and overall management and control, the total efficiency of solar photovoltaics (PV) has increased. External circumstances, such as the deposition of foreign particles on the module surfaces of a solar PV array, are, however, beyond the scope of such increases. Sand, salt, bird droppings, snow, or something else completely could be present. Photon transmission through the array's glass cover is diminished as a result of these deposits, limiting photon absorption by the solar cells. Conversion efficiency diminishes as deposition increases, resulting in decreased energy yields from the modules and the array as a whole. If dust collects on the surface of a photovoltaic (PV) solar panel, its efficiency can be lowered by up to 50%. It stated that the particle deposition densities range from 0.50 mg/m2 to 0.80 mg/m2 and the PV module with the lowest particle deposition density has the highest surface temperature as the surface temperature increases [3]. According to an experiment conducted for two separate arrangements: indoor and outdoor, the efficiency was reduced by roughly 30-40%, while lichen deposition might lower the throughput power by up to 86% [4].

Considering the inspected realities and measurements related to effectiveness decay, and suitable way of cleaning can lead to a tremendous upgrade in the yield of the sun-powered boards. There have been various photovoltaic board cleaning arrangements created, but exceptionally few, if any, of them, coordinated condition-based sun-powered board upkeep. Hand cleaning photovoltaic panels is time-consuming and costly since they are regularly found in blocked-off districts such as rooftops or deserts. Since cleaning solar panels during daytime comes about in non-uniform power outages and a diminished inefficiency, subsequently are generally wiped out in the twilight hours [5]. The primary purpose of this research is to build and implement a system capable of monitoring the state of a solar power plant and deciding whether or not to instruct the microcontroller to perform the set of loops.

Literature Review :

Different electrostatic cleaning methods and with or without water-based methods are now available and widely used as solar panel cleaners. In the paper [6], the exhaust fan, which works as an air blower, and wiper are used to power it with a dc motor to avoid water wastage and are effective in desert areas. Maximum efficiency of 87-96% is achieved using a two-step mechanism, 1st exhaust fan removes dust, then a wiper swipe it. To set the limit of the cleaning shaft, such a button is used. The system begins the operation every morning between 10 and 11.

Based on Semi-automatic wiper control mechanism is shown in paper [7] with maximum efficiency of 56.0%, 79.1%, and 86.7% when the wiper swept repetition 10, 20, and 30 times respectively. The battery is wired to supply power to the system and as the amount of water is sprayed, using a DC motor, the wiper moves back and forth and its speed is controlled through the PWM module, and direction is controlled by using two manual push buttons. Due to wasted water spray flow, circulated water is partially flowing back to the water tank.

An automatic self-cleaning method is proposed in paper [8] for pole mounted. It starts cleaning every 24hours for a period of 20 sec at noon as the microcontroller has been programmed and restricts the SCM to continue cleaning during rain or when the battery voltage level is low. Experiments were done on PV panels tilted at a 33° angle for 6 weeks, results show fairly a consistent performance due to regular cleaning. The cleaning time, cleaning period, and cleaning interval can be adjusted anytime through re-programming.

In the paper [9] The cleaning mechanism was created to clean the module by utilizing Arduino programming. To improve power efficiency, dust must be removed from PV modules. The frame containing the cleaning brush is moved along the length of the solar panel in a vertical direction of 11ft and vice versa, resulting in a mopping motion on the solar panel cleaning the panels. This frame is similarly made up of DC motors that generate rotational motion that is transformed into linear motion via a rack system. This operation is also governed by an Arduino signal. Gear motors are also used to move the frame from one solar panel array to another. All of these cleaning procedures will take 300 seconds for the mopping action for both cleaning system movements. Rooftop solar panels can be placed with this system. It was unable to scrub the dust because it was sticky in nature.

An automated solar panel cleaning system using IoT is presented in the paper [10]. It provides about 32% more energy output compared to the dust accumulated on the solar panel. The cleaning system is controlled via an android application and is powered by a rechargeable battery. While the cleaning tool moves horizontally, water pumps and spray water are activated by pressing a button in the mobile application, which sends an output signal to the gear motors through Wi-Fi. The rubber wiper is moved by a gear motor that is connected to a rack and pinion mechanism. By pressing the reverse button in the application wiper moves backward direction, this cleaning tool moves horizontally forward. The pinion drives the complete wiper movement mechanism. The pinion is guided by a rack and it is guided by a gear motor.

In paper [11], an automated cleaning robot is presented, its design utilizes an Arduino controller system to control the robot's movement during the cleaning process. Also equipped with two rough sponges and a water pump system to clean dust. The efficiency of the panel has been observed, it shows that it can clean the panel effectively and increase back the output current as well as the max power of the panel by 50%. When the switch is turned on, the robot moves forward at a speed of 100 revolutions per minute. The ultrasonic sensor is also activated and begins to measure the robot's movement distance. If the robot's movement distance is less than 5 cm, the robot continues to move forward, if the distance is greater than 5cm, the robot begins to move backward. When the time delay set in the microcontroller reaches 1000ms, the robot stops moving backward. Then it returns to moving in a straight line. This procedure is repeated until the robot is switched off.

The development of a Smart Solar Panel Cleaning System with a primary focus on the use of Internet of Things (IoT) technology in paper [12]. This allows dust monitoring, advanced analysis, and system control, all of which contribute to increased overall efficiency. A dust monitoring system detects dust particles in the environment and activates the water motor pump by a microcontroller and driver module. To clean, a raindrop sensor detects rainfall and communicates with the Arduino and a wiping system. The Arduino board is connected to the internet via the ESP8266 chip, which means that this data can be accessed at any time by the user via a mobile application. The user can remotely turn the sprinkler and wiper on and off using the mobile application from anywhere within its range.

In paper [13] for cleaning the PV panel, using the developed water system that minimizes the amount of water needed for cleaning. The cleaning wiper moves on the solar panel in a forward and backward motion. When the switch is ON the Arduino circuit output is given thought driver circuit to the motor which runs in a forward direction as soon as the motor starts moving, The pump activates and the spraying motion begins. A wiper is mounted with a belt which is guided by a timing pulley for the entire time of moving forward path, water spread on the solar panel and forces to dust move in the direction of wiper motion, and the wiper cleans the panel after reaching the edge of the panel, according to coding, motor start to rotate in the anti-clockwise direction, the water pump gets off, the action of water spray stops and wiper comes to the initial position and complete to one cycle and process to stop.

The project intends to increase the efficiency of a solar panel by removing all kinds of dust particles which is presented in [14]. The Locomotion and cleaning units were assembled with the mainframe and system tests were conducted. The current apparatus utilizes a nylon spiral brush and two wipers cleaning system that cleans on set cleaning cycles. The brush rotates to clean as it horizontally translates across an array of panels. The device is mounted on a set of battery powered-motorized wheels. At the end of the panel, there would be a docking station. It also has a solar panel to charge the battery.

The presented idea in the paper [15] is about the designed automatic cleaning mechanism consisting of IR LED, Photodiode arrangement to sense the dust accumulated. The efficiency is determined by taking the readings of voltage and current of the particular panel with and without dust for various days, weeks, and months. The result proved that the average efficiency of solar panels increases by about 1.6% to 2.2% with regular cleaning. If there is any dust on the panel, IR rays continuously falling on the panel reflect the photodiode is less thus the output of the sensor goes high and these signals are fed to the microcontroller. Depending upon the input signal the controller compares those signals with preprogrammed data for motor movement and drives the motor driving circuit to rotate the motor in a clockwise, anti-clockwise direction accordingly. The wiper is connected to the motor which results in cleaning the panel.

They developed a solution for a mechanical low power controller specifically designed for operating cleaning robots for entirely automated cleaning processes of solar PV module-based power plants in this cited work [16]. The controller runs a Linux Debian-based circulation, controls the drives of the built robot, monitors the position and all framework parameters, allows configuration through a web interface, and can connect to the internet over LAN or WLAN. Furthermore, for deployed solar plants, the controller can be coordinated with SCADA frameworks by using Modbus TCP for information transmission and control through Arduino UNO and L293D with geared motor, conveyor belt, pulley, and wiper.

With the use of IoT systems, an elegant strategy for increasing the performance of solar power systems was devised [17]. The system's goal here is to monitor the sunlight angle to tilt the solar panel angle to get the most radiation from the sun. The technology also intends to identify the dust present in the solar panels to analyze the efficiency of electricity generation. The technology was created to compute energy loss based on the presence of dust particles. The dust particle readings will also generate a signal to clear up the dust in the solar panels.

They discovered that conventional cleaning of solar panels wastes a lot of water, and especially in tropical regions where there is a lot of dust collection on the solar panels, the consumption of water is high when it is cleaned using conventional techniques. As a result, there is a need for a technique that employs a brush or wiper to clean the system while saving or eliminating the usage of water. Also, in areas where water is critical, such as the desert region of the UAE, the constant need for water is met with the help of cleaning the ocean water, and that region has the potential to produce a large amount of electricity from solar radiation, so when both are important, water must be eliminated. Also, in the usual approach, human strength is required, however in this method, human force is abolished, and so there is no damage or threat to the human being. The robot is used to clean the panels as the cleaning material, such as a bush or a wiper, is inserted, and it cleans the panel automatically at the predetermined interval. Also, because the robot is self-charging, it will draw power from the produced electricity, eliminating the need for an additional power source to charge the robot [18].

Proposed Methodology :

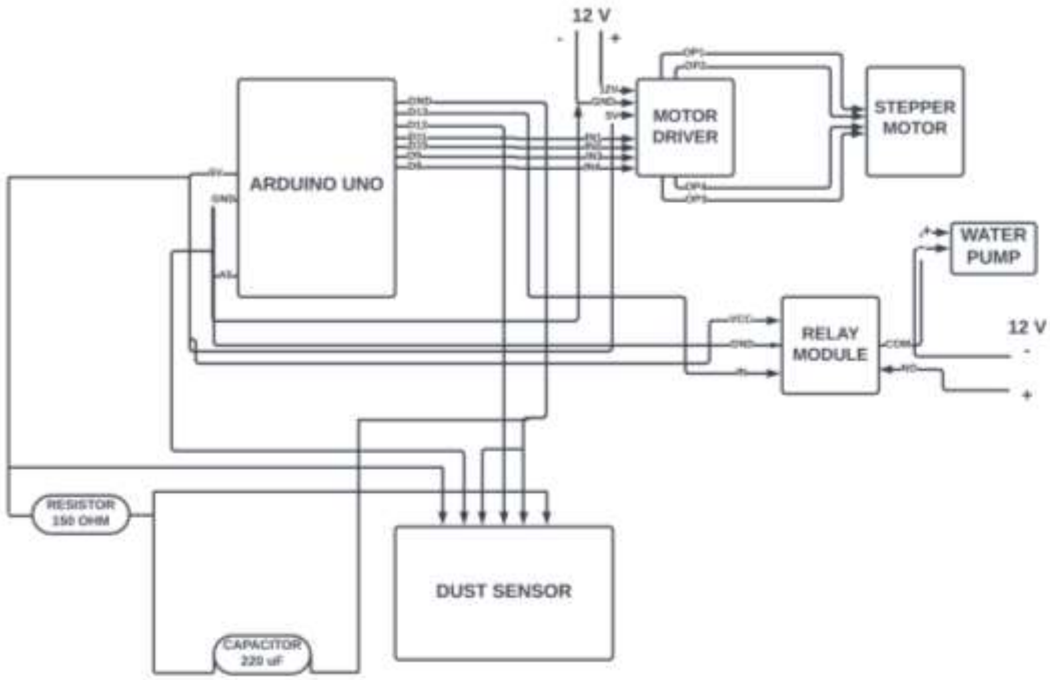
The mechanism of the proposed idea is a combination of two subsystems to accomplish the objective of this research.

Cleaning system:

Cleaning solar panels by removing the dust particles from the PV surface is achieved. The accumulation of dust on the PV panel decreases the solar radiation which results in lowering output voltage. To prevent the stated cause, the dust sensor will use to detect the presence of debris impacting power generation and which will proceed with turning ON the water pump. The dust sensor detects the reflected light of dust in the air. It consists of an IR (Infrared) LED and a Phototransistor when the sensor is turned ON the IR light illuminates the dust particles present in the air. A scattered light signal is created as a result. The light detector phototransistor detects this scattered light signal. The multiple signal amplifier circuit amplifies the output of the light detector circuit. The concentration of dust particles in the air is then determined using an amplified light signal. The optical dust sensor generates an analog voltage signal on the Vo pin based on the concentration of dust particles or smoke in the air. The magnitude of the output voltage is determined by the amount of dispersed light measured by the light detector circuits. Furthermore, the intensity of scattering light is proportional to the concentration of dust particles in the air. The higher the presence of dust particles, the lesser the power output and vice versa.

Design of the system:

The Arduino processes the information (Analog voltage reading) and if the reading provided by the Dust sensor is



greater than the threshold voltage value (as specified in the code), it sends

CIRCUIT DIAGRAM OF THE CLEANING SYSTEM

the instruction to the L293d module via Arduino 8,9,10,11 pins to the int1, int2, int3, and int4 pins of the L293d to start the stepper motor to move clockwise and anti-clockwise at 90 degrees as specified in the code. The outputs of the l293d are linked to a bipolar stepper motor. A motor controller with two H-bridges is always used to operate a bipolar stepper motor. An H-bridge is made up of four switches, S1, S2, S3, and S4. When switches S1 and S4 are closed, a positive (+) voltage is applied to the motor's left terminal and a negative (-) voltage is applied to the motor's right terminal. As a result, in this scenario, the motor begins to rotate in a clockwise direction. When the S2 and S3 switches are closed, the right motor terminal receives a positive (+) voltage and the left motor terminal receives a negative (-) voltage, and the motor begins to rotate in an anti-clockwise direction.

Tracking system:

To track the sun's rays using a Light-dependent resistor (LDR). Here, the water level indicator system is attached to this system, which is to notify the amount of water present in the tank to prevent dry cleaning. Therefore, this system has two partitions.

Light detecting system:

Light Dependent Resistors (LDR), are resistors whose resistance values vary with light intensity. The resistance value decreases whenever the intensity of light on the LDR increases and the resistance value increases as the intensity of light on the LDR decreases. Thus, it will have the most resistance in the dark. The LDR will produce an analog value that must be converted to digital. A microcontroller-based automated solar tracker that is simple and easy to the program is implemented. It is based on an Arduino Uno, which receives data from the LDR sensors and rotates the solar panel accordingly using the motor driver and the dc motor. This is intended to detect sunlight through the LDRs and afterward, the DC motor adjusts the solar panel to receive the most sunlight. Arduino UNO is used as an analog to digital converter that can be used to change the value. It contains six ADC channels numbered ADC0 through ADC5. Individual 10K resistors are used to link the two LDRs to ADC pins A0 and A5 in a voltage divider, it is used to read the voltage of the LDR arrangement. The successive approximation approach is used for ADC conversion. The sun tracking system is supposed to rotate in direction of clockwise (CW) and counterclockwise (CCW) of the LDRs which is compared. The battery is used to store the energy from the solar panel and distribute it to the loads.

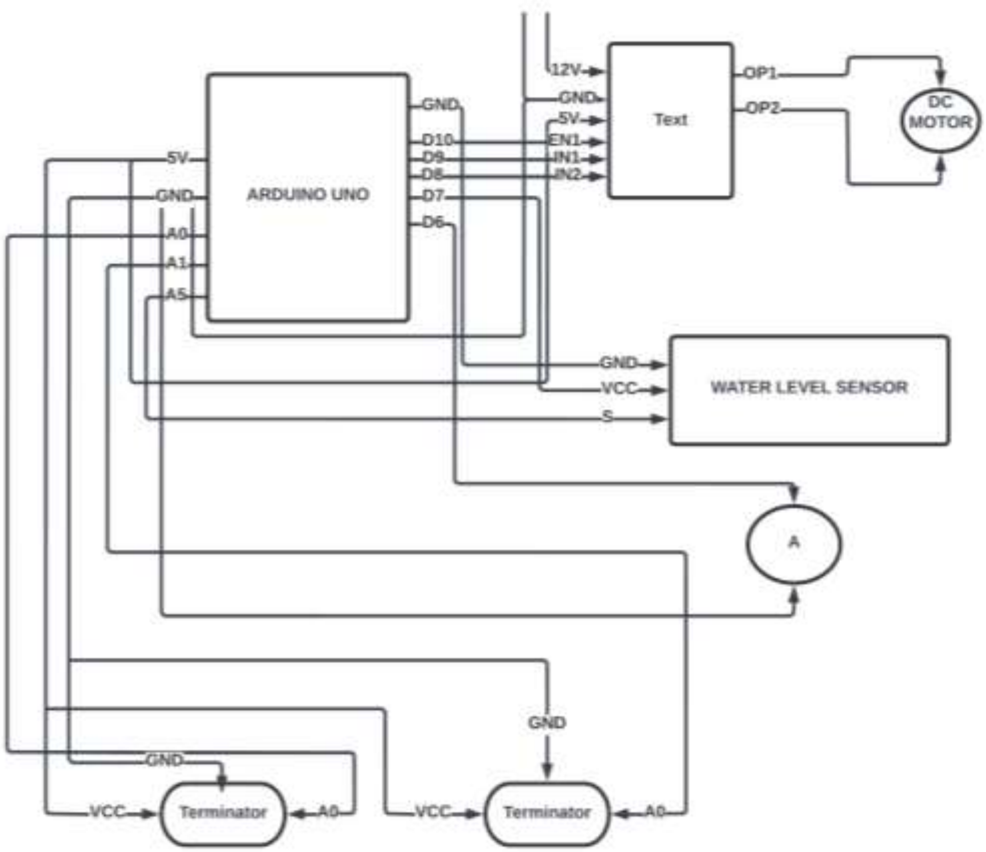
A complementary resistor with a value of 1kΩ is used to get the desired output voltage signals.

The output voltages are calculated by using the following equation;

For maximum, let R1= RLDR(max) = 10KΩ ,
Assume, R2= 1kΩ, using voltage divider,
Vout= [R2 /(RLDR+R2)]×Vcc and
the output voltage is 0.4 V.
For midpoint, let R1 = RLDR(mid) = 1kΩ,
Assume R2 = 1kΩ , the output voltage is 2.5 V

Water level indicator:

When the system is turned on, the water level sensor receives a high signal via the Arduino's digital pin, and the sensor is immersed in water. It contains a series of exposed parallel wires that operate as a variable resistor (similar to a potentiometer) whose resistance varies with the level of water. The resistance change corresponds to the distance between the sensor's tip and the water's surface. The resistance is inversely proportional to the height of the water. The further water the detector is immersed in will affect in better the conductivity and lower resistance. The lower water the detector is immersed in will result in poor conductivity and high resistance. The detector produces an affair voltage according to the resistance, by measuring it, the water position can determine. An analog read pin sends the output voltage to Arduino. The Arduino analyzes the voltage output from the water sensor. If the water sensor's voltage is less than the threshold voltage, Arduino sends a high value to the buzzer via a digital pin. This supplies power to the buzzer. When a voltage is applied across a piezoelectric material, a pressure differential is created. A piezo type is made up of piezo crystals sandwiched between two conductors. When there is a potential difference between these crystals, they shove one conductor and pull the extra conductor through their intrinsic property. As a result of this



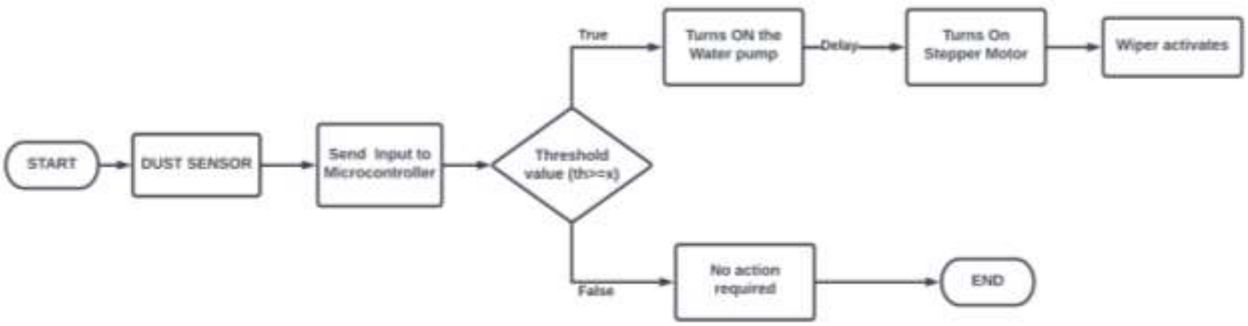
continual activity, a sharp sound signal will be produced.

Circuit Diagram of Tracking System

Working Model :

Cleaning system:

The initiation of the cleaning system begins with a dust sensor, controlled by the microcontroller, sensing the debris intensity on the PV panel. If the reading observed by the dust sensor is equal to or higher than the given threshold value, the programmed microcontroller will instruct the water pump to turn ON, allowing the water to spread on the surface of the PV panel. Subsequently, the microcontroller will also signal the stepper motor to move the wiper back and forth to clean the PV panel surface. The microcontroller will keep following the same loop until the reading of the dust sensor reaches below the defined threshold value. Once the debris intensity falls below the defined threshold value, the microcontroller will give the command to turn OFF the water pump and the stepper motor. Alternatively, if the dust sensor detects a lower debris intensity reading than the defined threshold value at the start of the operation then no action will be required by the microcontroller.

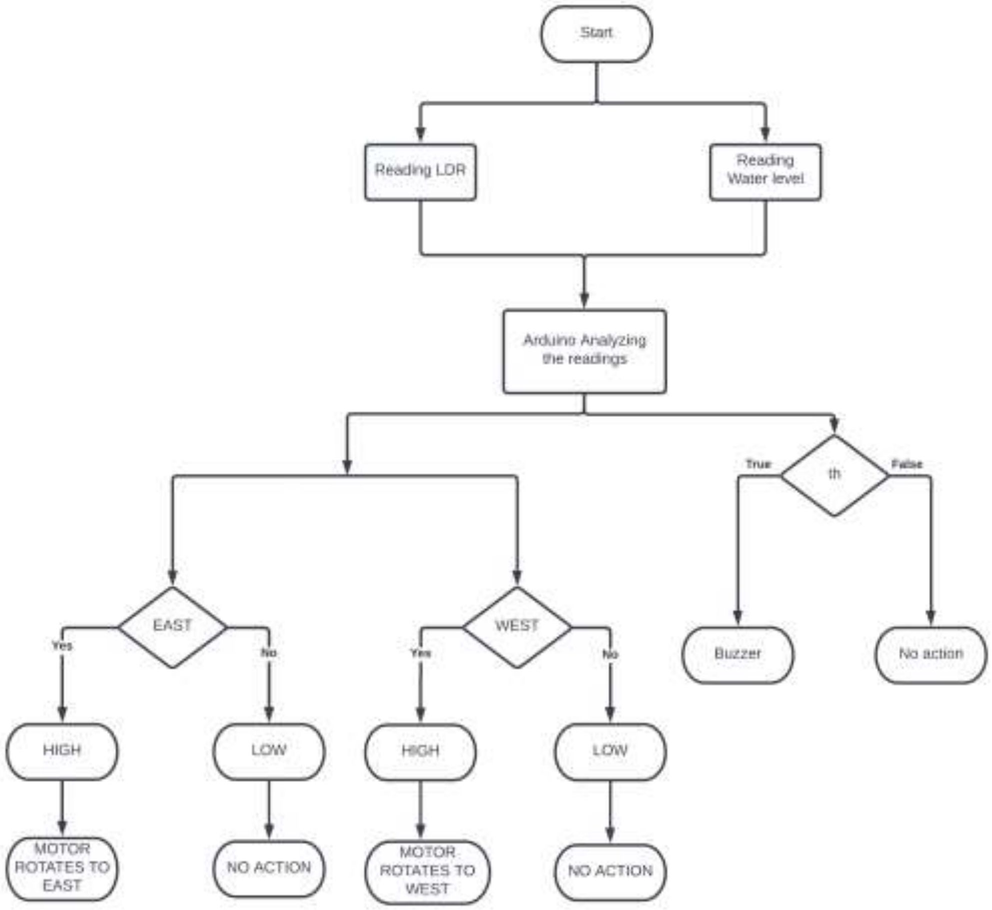


FLOWCHART OF CLEANING SYSTEM

Tracking system:

The tracking system begins with initializing the Light Detecting System and Water Level Indicator, controlled by the microcontroller, by reading the voltage of the Light Dependent Resistor (LDR) and observing the water level by the water sensor which will be analyzed by the programmed microcontroller and the system will act accordingly. In a light detecting system, The microcontroller will check the voltage of both LDR which are placed on the opposite side of each. Whichever voltage will be high, the microcontroller will instruct the motor driver to rotate towards it through the DC motor to receive maximum radiation. In a water level indicator, the microcontroller will observe the resistance value through the water sensor. If the value is below the threshold value, the microcontroller will instruct the buzzer to produce a sound to fill the tank. Alternatively, If the value is equal to or greater than the threshold value then no action is required by the microcontroller.

FLOWCHART OF TRACKING SYSTEM



Simulation and Result :

The real-time navigation of the automatic system on the solar panel is verified by creating some cases where the system acted accordingly. The installation of the system was completed swiftly and with the highest precision. We executed the code and drew an inference from the findings. After a few passes, the code ran flawlessly and without issue. The code was recognized by the system, and the dust sensor employed offered a quick reaction time. We assumed that the system would respond to the code, and after a series of successful experimental trials, we can state that our findings validated our theory.

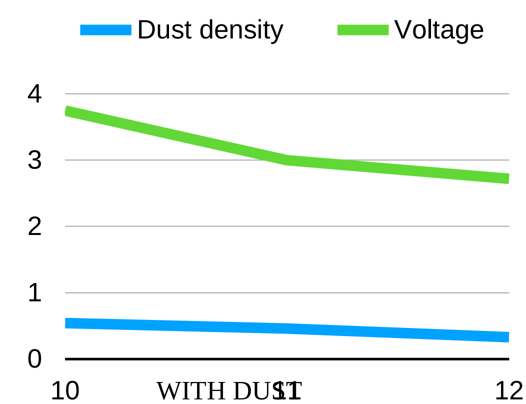
FIG.1

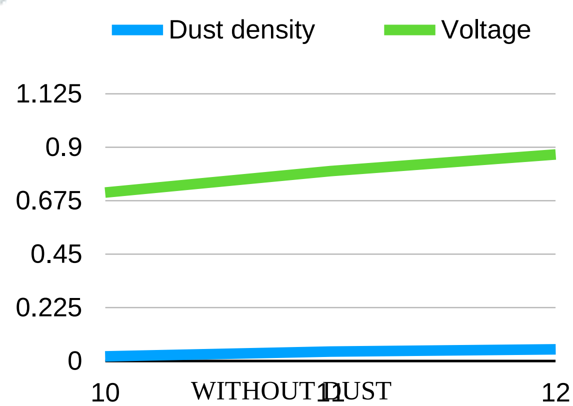
FIG.2

FIG.4

FIG.3

Conclusion :





An automatic-based model named automatic cleaning and the sun-tracking system is presented, mainly focussing on its implementation for residential use and also it is cost-effective. A control strategy for the automatic cleaning and sun-tracking system has been designed and tested. The two subsystem mechanism is very effective in improving the efficiency of solar panels. Cleaning the panel until the value reaches below the threshold value shows an improved performance in terms of the effectiveness of cleaning. The quantity of dust deposited on the solar panel can significantly affect the output voltage measured. Cleaning a PV module using a stepper motor is both quiet and inexpensive with water improves the panel's performance and efficiency by removing the majority of the debris that has accumulated on the panel and by using a DC motor which was sufficient to drive the panel to receive maximum radiation. Attaching the frame to the solar panel helped to lift all the weight of the devices which is used in this project. Finally, the results indicate that the output voltage measurement can be increased by up to. The system mechanism will assess the system parameters, allowing the user to make decisions accordingly, proving the system to be efficient, productive, and profitable.

Reference :

[1] Shaikh, Mohd Rizwan Sirajuddin. "A review paper on electricity generation from solar energy." (2017).

[2] https://economictimes.indiatimes.com/small-biz/productline/power-generation/polycrystalline-vs-monocrystalline-solar-panels-which-type-of-solar-panel-would-be-suitable-for-you/articleshow/74668227.cms?from=mdr

[3] Jiang, Yu, and Lin Lu. "A study of dust accumulating process on solar photovoltaic modules with different surface temperatures." *Energy Procedia* 75 (2015): 337-342.

[4] Sulaiman, Shaharin Anwar, Atul Kumar Singh, Mior Maarof Mior Mokhtar, and Mohammed A. Bou-Rabee. "Influence of dirt accumulation on the performance of PV panels." *Energy Procedia* 50 (2014): 50-56.

[5] Dorobantu, L., M. O. Popescu, and C. L. Popescu. "Yield loss of photovoltaic panels caused by depositions." In *2011 7TH INTERNATIONAL SYMPOSIUM ON ADVANCED TOPICS IN ELECTRICAL ENGINEERING (ATEE)*, pp. 1-4. IEEE, 2011.

[6] Habib, Md Rawshan, Md Shahnewaz Tanvir, Ahmed Yousuf Suhan, Abhishek Vadher, Sanim Alam, Tahsina Tashrif Shawmee, Koushik Ahmed, and Abdelrhman Alrashed. "Automatic solar panel cleaning system based on Arduino for dust removal." In *2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS)*, pp. 1555-1558. IEEE, 2021.

[7] Sugiartha, N., I. G. N. Ardana, I. M. Sugina, I. B. G. Widiantara, I. N. Suparta, and I. K. Adi. "Preliminary design and test of a water spray solar panel cleaning system." In *Journal of Physics: Conference Series*, vol. 1450, no. 1, p. 012108. IOP Publishing, 2020.

[8] Amber, Khuram Pervez, Imdad Hussain, Anila Kousar, Muhammad Anser Bashir, Mohammad Waqar Aslam, and Bilal Akbar. "A self-cleaning device for pole mounted solar photovoltaic installations." *Thermal Science* 23, no. 2 Part A (2019): 739-749.

[9] Manju, B., Abdul Bari, and C. M. Pavan. "Automatic solar panel cleaning system." *International Journal of Advances in Scientific Research and Engineering* 4, no. 7 (2018): 26-31.

[10] Vaghani, Milan, Jayesh Magtarpara, Keyur Vahani, Jenish Maniya, and Rajiv Kumar Gurjwar. "Automated Solar Panel Cleaning System using IoT." *International Research Journal of Engineering and Technology (IRJET)* 6, no. 04 (2019): 1392-1395.

[11] Noh, Faridah Hanim Mohd, Muhamad Faizal Yaakub, Ili Najaa Aimi Mohd Nordin, Norain Sahari, Nor Aira Zambri, Sim Sy Yi, and Muhammad Syukri Mohd Saibon. "Development of solar panel cleaning robot using Arduino." *Indonesian J. Electr. Eng. Comput. Sci* 19 (2020): 1245.

[12] Rao, Archana, and S. Santosh Kumar. "Smart IoT based Solar Panel Cleaning System." In 2018 3rd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), pp. 2357-2361. IEEE, 2018.

[13] Savani, Nirav, Zalak Korat, Harsh Kikani, and Chintan Khunt[4]. "Design and analysis of integrated solar panel cleaning system." *International Research Journal of Engineering and Technology* 6, no. 4 (2019).

[14] Thomas, Shajan K., Shelvin Joseph, T. S. Sarrop, Sahad Bin Haris, and R. Roopak. "Solar Panel Automated Cleaning (SPAC) System." In *2018 International Conference on Emerging Trends and Innovations In Engineering And Technological Research (ICETIETR)*, pp. 1-3. IEEE, 2018.

[15] Patil, Satish, and H. M. Mallaradhya. "Design and implementation of microcontroller based automatic dust cleaning system for solar panel." *Int. J. Eng. Res. Adv. Technol.(IJERAT)* 2, no. 01 (2016): 187-190.

[16] Tranca, Dumitru-Cristian, Daniel Rosner, and Alexandru-Viorel Palacean. "Autonomous flexible low power industrial IoT controller for solar panels cleaning systems." In *2017 21st International Conference on Control Systems and Computer Science (CSCS)*, pp. 106-112. IEEE, 2017.

[17] Priyadharsini, K., Dinesh Kumar JR, A. Srikanth, V. Sounddar, and M. Senthamilselvan. "Elegant method to improve the efficiency of remotely located solar panels using IoT." *Materials Today: Proceedings* 45 (2021): 8094-8104.

[18] Wable, Swanand S., and Somashekhar Ganiger. "Design & manufacturing of solar panels cleaning system." *Int J Res Appl Sci Eng Technol (IJRASET)* 5, no. 07 (2017): 191-197.