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Programmed solar panel purgation system: Solar purgator

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Abstract: Solar energy is the most appealing green energy conversion technology. Interestingly, solar panels usage has increased enormously, and it is a subject of fascination since they are widely available. Dust characteristics are one of the major factors affecting Photovoltaic (PV) panel performance as well as the cost of maintaining and producing electricity from a PV system. The PV panel performance depends on a series of parameters: Internal and external factors. Internal factors are one from which solar cell material is made, depending upon different materials and manufacturing technologies. Efficiency of the solar PV panel varies, whereas the parameters affecting externally are climatic conditions, humidness, solar irradiance, panel orientation. It was observed that dust builds up on the modules front surface which blocks the sun incident light had a significant impact on the power producing ratio of PV modules, so it significantly decreased their ability to produce power output capacity by up to 50% and their efficiency by 58%. Hence, an Arduino based automated cleaning system based on piezoelectric actuator system is proposed to ensure that a solar panel operates at the best state of generation while using the solar panel in a dusty environment. For cleaning, this method employs two procedures. According to experimental findings, the suggested cleaning technique can function with an efficiency of 87-96%.

Keywords: Solar energy, PV Panel Purgation, Piezoelectric Actuator

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1. Introduction

Solar PV technology is the fast-growing method of solving global demand for energy. The dust particles on the solar panel are analysed and cleaned using a sliding robot with cloud interface (Ali, 2023). Scheduled cleaning of solar panel brought about to maintain efficiency of solar panel. A system that uses a colour recognition tool to detect dust and removing the same. Arduino and TCS3200 are utilized for this operation (Olorunfemi et al., 2023). A drive inclined panels with minimum folding are preferred for cleaning dust accumulated over the PV panel. It uses a specialized drive unit design for faster movement of robot is designed and implemented here (Jang et al., 2023).

A soiling model for large PV Panel connected is made and analysed for a specified duration to reduce soiling in PV panels. By this the output power and efficiency of panel can be increased (Redondo et al., 2023). For PV systems used in snowy areas, the accumulations of dust in the form of snow are a big problem. Zheng et al. (2023) inferred that the design developed uses the power from PV panel to eliminate the snow present in the panel.

An overview and review of various strategies to mitigate dust deposition on solar panels is analysed. The comparison with advantages and disadvantages of one method over other is discussed by Humble et al. (2023). We are having many methods of cleaning dust covered on the panel. One such method is implemented with machine learning algorithm and image processing scheme for clearing dust deposition by Kaiss and Hassan (2023).

Numerical data on dust deposition in surface mounted panel is discussed. It shows the exact time at which maximum deposition of dust occurrence takes place. From this design, purging methodology for PV system process become much easier (Chavan & Patil, 2022).

The dust granules over the solar panel are analysed with dust scaling characteristics, effect of dust pollution. The results analysed by Liu et al. (2021) have shown various particles for causing dust. A semi-automatic wiper system with DC motor for powering is used. Scheduled spraying of water with wiper moving from side to side is done.

An experimental study is done thereby output voltage, output current, panel efficiency before and after cleaning are analysed by Zouaghi and Zouzou (2021). Cleaning of PV boards in dusty areas can increase efficiency to 15-20 percent. Robotic systems are utilized in cleaning panels, to minimize water usage.

The robots are programmed to use a certain amount of water, thereby water usage is drastically reduced. It's been mentioned that around only a half a cup of water is needed to clean a panel. Robots are designed, programmed for different solar panel structures and operated accordingly. (Ölmez et al., 2021). Maximum solar power extraction is done by employing fuzzy logic controller (FLC) with maximum power point tracker (MPPT). Fuzzy supervisory control system provides results from PV. MPPT is used to produce paramount power from panel. The results are analysed by Abbas et al. (2021) using MATLAB/Simulink package for different conditions. From the simulation it is identified that the fuzzy control algorithm works better compared to other systems.

There were four main tasks, designed in solar panel front surface cleaning. It comprises a measuring, logical, executive part with device's power system. Purgatory working involves stages. First, the sensors sense the measuring; convert the continuous measurands into discrete values. The digital signals are given to Arduino; it compares the values with the original program values. If the triggering condition is met, then controls are activated. By receiving controls driver operates (Kanimozhi & Rabi, 2016).

Optical air standard detectors are used to sense the dust particles, which comprise an infrared diode, phototransistors. It senses the density of dust particles by receiving the reflected light from the dust. In accordance with the monitored values from the dust sensor the control is given to Arduino which operates wiper to clear out the dust (Zhang et al., 2021).

The robotic cleaning method with usage of a special brush made of silicon is used by Mithhu et al. (2021) remove dust from solar panel. It is a silicon made foam brush which can remove dust more effectively than other brushes. Robots with crawling wheels are made to run on solar panels for cleaning. Cleaning brush, cleaning sponges are attached with the setup for cleaning process

We are witnessing a gradual increase in the share of renewable energy sources in developed countries. Not only for commercial companies, but for all private sectors even facing a problem with cleaning panels. A linear actuated principle-controlled Arduino setup is utilized to resolve this issue by Kanimozhi and Shunmugalatha (2016). A frame is made to which motors are connected; mechanism is made to shift from one panel to other. The cleaning involves 300 sec, once a panel is cleaned it moves to next.

In this article a programmed solar panel purgation method is proposed. In Section 2 the problem identification and objective of research are discussed. In Section 3 and 4 proposed methodology, design and results are discussed respectively. In Section 5 conclusion and future work are discussed.

2. Materials and Methods

2.1. Problem Identification

In accordance with the literature survey carried out, the ensuing breach have been identified.

- Almost focus on automatic solar panel cleaning by wet/ dry cleaning method has been adopted by researchers. There is no such system that uses both dry and wet cleaning method together for solar panel purgation.
- Traditional methods comprise of either wiper or water sprayer blown by a motor to remove dust.
- Research work has been done for making further small advancements like change in operating mechanism, usage of materials etc.
- Most preferable method of cleaning panels is by using robots.
- But by using robots there occurred the damage of panels as these robots run above panels.
- Instead of increasing the output power and lifetime of panel this process made the condition even worse.
- Later a setup around the edges of panel is planned so that the panel is not damaged.

2.2. Objective of the Investigation

The following is a list of the uniqueness and significant contributions of this proposed study.

I. Designing a novel programmed solar panel purgation which uses both dry and wet cleaning mechanisms for clearing up dust on one end of the panel.

II. Developing a hardware setup with aluminium frame fixed with motors, limit switches to clear up the dust and to decide among the priority of resources by using a processor unit.

III. Developing an optimal setup for every source by prioritizing the supply and selecting the optimum conditions.

IV. Framing the algorithm, flowchart, truth table to allocate the switches as per the operation.

V. Evaluating the operation based on certain conditions like scheduled cleaning of panel with wiper and weekly clearance using water.

3. Methodology and Design

Solar energy has become the most accepted green design solution, including zero-emission buildings powered entirely by rooftop solar (PV) energy. As result of the variation in output power and intermittency by dust formation, PV frequently needs some upgraded mechanism to clear out various dusts. The architecture of programmed solar panel purgation (PSPP) setup built by considering panel size, cleaning requirements and their operation is shown in Figure 1. The PSPP consists of a DC gear motor, Li-ion battery, converter, Arduino, solenoid, 4 channel relay, limit switches, driver, RTC module, thread rod, shaft coupler, roller and an aluminium frame.

Supply can be fed from Li-ion battery, and it can be recharged from the power produced by the panel. A converter module (buck boost) is preferred when we need a constant supply. Arduino board is charged either by USB ports, or by a 5 V supply. Thread rod and shaft couplers are used for the smooth movement of wiper in both forward and backward direction. This rod and coupler are fixed in boundary of solar panel designed with a L-type aluminium frame.

A truth table and a flowchart are made based on required operation under different conditions. It is transformed to a code using Arduino 2.0.3 software. A time is set and is programmed to RTC, thereby every day at a particular time the solar panel is automatically cleaned. Also, weekly cleaning using solenoid is programmed in addition.

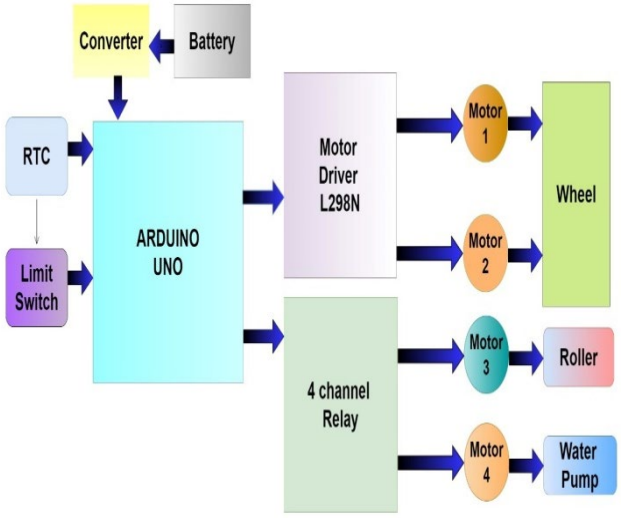

Figure 1. Block diagram of Proposed Programmed Solar Panel Purgation System.

Figure 2 shows the model of PSPP system comprising a solar panel fitted with a motor for controlling wiper and water sprayer operations. A 12V battery supply is needed for the setup. A L298N motor driver and a 4-channel relay is used in guiding the motor operations. The power is taken from battery, given to motor driver 12V which is responsible for forward and backward movement, the input of 5V taken from driver to power Arduino. Both dry and wet cleaning methods are used here. Wiper is used for dry cleaning, water sprayer used for wet cleaning. Out of the 4 motors used, 2 is for wiper movement, 1 is for wiper rotation, 1 is for water spraying. To add further, for the setup aluminium frame, foam sheet is needed along with RTC, limit switches.

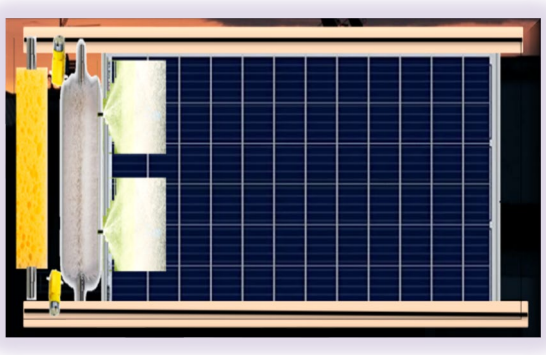

Figure 2. Structure of Proposed PSPP.

3.1. Algorithm of proposed solar panel purgation system

The flowchart shown in Figure 3 gives us a clear concept of working procedure. The steps are furnished below.

Step 1: The purgatory begins with Arduino control network and a timer, which validates the initial stage of forwarding relay process to the programmed device. On sensing the forward relay condition as no change motor revolves and initialization of the purgatory is achieved.

Step 2: In follow, up with the preprogrammed schedule the controller validated the next stage and tries to reverse the relay. On sensing no change mode, the motor revolves next stage is completed.

Step 3: Now the Arduino control network validates the time taken to initiate the next move of the relay. On decrementing the timer, the process reiterates from the initial stage.

4. Results and Discussions

The proposed solar panel cleaning system is automatic and handmade. Simple architectural design is seen in this system including solar panel, cleaning shaft. A 3W solar panel module is used here which provides an output voltage of 10.9V (open circuit voltage). The output of the solar panel depends on the sunlight. A buck boost converter is used here to keep the output voltage constant. The output voltage of the converter is set at 12V DC. Therefore, the variation of the sunlight does not have any effect on the output voltage. Two reference lines are set for the movement of cleaning. Each line consists of one motor. When the time set by the user, our mechanism starts to clean the panel and the whole system is designed in such a way that the system will start its operation at the end of the day typically between 5-6 pm. Therefore, the proposed system is effective for any types of dust (soil, leaves, bird secretions).

Regular cleaning of PV panels is a certain limitation. Recommended cleaning for roof-top panels is 2 – 3 weeks and for near or on the ground panels are once every 10 days due to proximity to vehicular traffic. The cleaning system comprises of three parts, mechanical system, motor control and sensors. The replacement duration is once in two years if there are any malfunctions or depreciation in efficiency. The purpose of this solar panel purgatory system is to enhance efficiency and hence it does not affect the cost of photovoltaic systems. PV has no recurring fuel costs, and it is promoted as a simple energy technology that is durable and relatively maintenance-free because it has no moving parts.

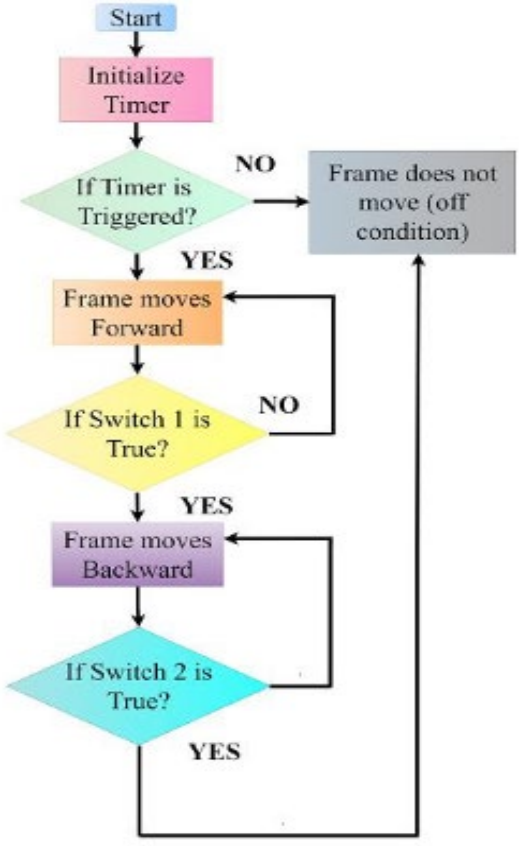

Figure 3. Flowchart of PSPP Operation.

PV panel's output voltage at different conditions is measured which is shown in figures and tables. Experimental results validate that the proposed solar panel cleaning system works efficiently at desired level. System efficiency and number of swept vary depending on the type of dusts. The efficiency of the proposed system is around 87- 96% respectively. The number of swept for completing the operation depends on the type of dust respectively. This proposed system works with and without water. The proposed system is affordable and constructed with useful components. Figure 4 shows the prototype of the proposed PSPP.

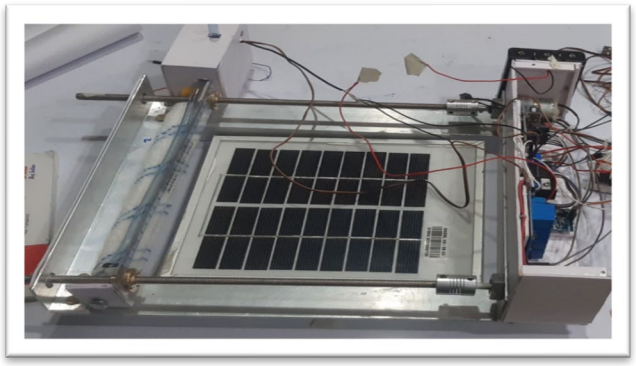

Figure 4. Prototype of Piezoelectric based Purgation.

The voltage is observed with appropriate measuring devices and is shown in Table 1.

Scenario1: Direct sunlight (flat position)
Scenario2: Sunlight with shadow
Scenario3: Complete dark
Scenario4: Dark with shadow

Table 1. Measurement of Voltage.

Condition	Voltage
Sunlight + partial shadow	8.92V
Sunlight + shadow(leaves)	9.27 – 9.63V
Sunlight + dust(soil)	9.95V
Sunlight + shadow(paper)	9.19V
Shadowing effect using notebook	4.24V

Shadowing effects with different materials like cloth, paper, leaves, and dust are observed, and listed in Table 1. Firstly, reading of complete darkness with the notebook placed on the panel is taken. A voltage of 0.95V is taken as output. Secondly, notebook is replaced with a cloth material and a voltage of about 0.06V is got as output. Next, cloth is replaced with paper. The voltage ranging between 6.69-7.51V is taken as output. Subsequently, paper is replaced with leaves and soil. A voltage changes of 7.72-8.32V to 8.45V is observed.

5. Conclusions

An independent PV panel purgation methodology is proposed and implemented with microcontroller. The solar purgation based on piezoelectric actuator is affordable. This solar purgation technique is contingent on a two-stage mechanism, with dry cleaning doing the first step. The second step is to clean with water. This feature protects the panel's safety by virtue of absence of any type of creak. It is not visible during real time testing, and it is employed for boosting output efficiency and reduce human labour. The purgation method described is found to be effective.

An optimal PV installation with the right orientation and placement has a payback period of 4- 5 years. The vertical tilt, or angle, at which the solar panels are installed in a PV system will have an impact on the amount of electricity they can generate. A higher tilt angle can limit the amount of snow and ice that accumulates on the surface of the panels by rainfall to slide off. The tilt can also limit soiling from dust, sand and dirt in dry, polluted or desert areas that can block sunlight and reduce energy conversion. But tilting rows of solar panels creates shading of the adjacent parallel rows, which partially obstructs their exposure to direct sunlight. Panel backtracking results in more efficient electricity generation than PV systems with fixed structures. But it is important to note that as it requires motors to adjust the tilt of the panels, it is more expensive to install and has more equipment parts to maintain than fixed structures.

We would consider this point in future research works.

Conflict of interest

The authors have no conflict of interest to declare.

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References

Abbas, A. K., Abed, K. W., Abd, O. I., Al Mashhadany, Y., & Jasim, A. H. (2021). High performance of solar panel based on new cooling and cleaning technique. *Indonesian Journal of Electrical Engineering and Computer Science*, *24*(2), 803-814. https://doi.org/10.11591/ijeecs.v24.i2.pp803-814

Ali, A. (2023). To Investigate the dust particles and improve the performance of photovoltaic panels by using sliding cleaning technique. *Research square* ,20(9), 451-462. https://doi.org/10.21203/rs.3.rs-2450311/v1

Chavan, S., S. & Patil, A., J. (2022). Critical Review on Automatic Solar Panel Cleaning System. International Journal of Advanced Research in Science, Communication and Technology, 2(5).

Hwang, H. P. C., Ku, C. C. Y., & Huang, M. C. Y. (2023). Intelligent cleanup scheme for soiled photovoltaic modules. *Energy*, *265*, 126293.
https://doi.org/10.1016/j.energy.2022.126293

Jang, W. J., Kim, J. G., Lee, S. H., & Kim, D. H. (2023). Mechanism design for walking typed solar panel-cleaning robot using triple driving lines. *IAES International Journal of Robotics and Automation*, *12*(1), 1.
https://doi.org//10.11591/ijra.v12i1.pp1-19

Kaiss, E. C. A., & Hassan, N. M. (2023). Numerical modeling of dust deposition rate on ground-mounted solar photovoltaic panels. *Journal of Solar Energy Engineering*, *145*(4), 041003.
https://doi.org/10.1115/1.4056217

Kanimozhi, K., & Rabi, B. R. M. (2016). Development of hybrid MPPT algorithm for maximum power harvesting under partial shading conditions. *Circuits and Systems*, *7*(8), 1611-1622.
https://doi.org//10.4236/cs.2016.78140

Kanimozhi, K., & Shunmugalatha, A. (2016). Photovoltaic systems with passive lossless cuk converter using hybrid sliding mode control. *Journal of Circuits, Systems and Computers*, *25*(05), 1650036.
https://doi.org/10.1142/S0218126616500365

Liu, X., Yue, S., Lu, L., & Li, J. (2021). Investigation of the dust scaling behaviour on solar photovoltaic panels. *Journal of Cleaner Production*, *295*, 126391.
https://doi.org/10.1016/j.jclepro.2021.126391

Mithhu, M. M. H., Rima, T. A., & Khan, M. R. (2021). Global analysis of optimal cleaning cycle and profit of soiling affected solar panels. *Applied Energy*, *285*, 116436.
https://doi.org/10.1016/j.apenergy.2021.116436

Olorunfemi, B. O., Nwulu, N. I., & Ogbolumani, O. A. (2023). Solar panel surface dirt detection and removal based on arduino color recognition. *MethodsX*, *10*, 101967.
https://doi.org/10.1016/j.mex.2022.101967

Ölmez, B. B., Ergezer, Ö., & Güğül, G. N. (2021). Autonomous solar panel cleaning robot with rubber wheeled and air-absorbing motor. *International Journal of Energy Applications and Technologies*, *8*(4), 182-187.
https://doi.org/10.31593/ijeat.938629

Redondo, M., Platero, C. A., Moset, A., Rodríguez, F., & Donate, V. (2023). Soiling Modelling in Large Grid-Connected PV Plants for Cleaning Optimization. *Energies*, *16*(2), 904.
https://doi.org/10.3390/en16020904

Zhang, J., Wang, S., Xin, Y., Hang, M., & Gao, D. (2021). The cleaning force of solar panel based on flexible beam. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 1-22.
https://doi.org/10.1080/15567036.2021.1928335

Zheng, J., Liu, W., Cui, T., Wang, H., Chen, F., Gao, Y., ... & Liu, W. (2023). A novel domino-like snow removal system for roof PV arrays: Feasibility, performance, and economic benefits. *Applied Energy*, *333*, 120554.
https://doi.org/10.1016/j.apenergy.2022.120554

Zouaghi, A., & Zouzou, N. (2021). Numerical modeling of particle motion in traveling wave solar panels cleaning device. *Journal of Electrostatics*, *110*, 103552.
https://doi.org/10.1016/j.elstat.2021.103552