Clearance of Dust Accumulation and Aggregation on PV panel using Automatic Solar Panel Cleaning System

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***Abstract*- Photovoltaic panels are one of the most emerging components of renewable energy integration. However, where the PV systems bring power conversion efficiency with its bulk installation setup and eco-friendly feasibility, it also brings the factors that could amber the performance and efficiency of the system. The accumulation of dust on the surface of the solar modules decreases the amount of sunlight that hits the solar cells beneath, lowering the solar panel's efficiency.The large numbers of solar panels are used now days to generate the large amount of electrical energy. As the solar energy is available in large amount and free of cost the solar panels are used to generate the electrical energy from the solar energy. The big problem is that the efficiency of the solar panel is low as compared to the other method like hydro power plant, thermal power plant. The efficiency of solar panel is further decrease due to the effect of dust and dirt takes place on the panel. Cleaning becomes difficult and expensive in this area due to water scarcity. Several methods of solar panel cleaning such as Self-cleaning panel, Robot cleaning systems, Drying agents, Ultraviolet light, Water harvesting, automatic cleaning systems. We are using automatic cleaning system with dry cleaning process to improving the efficiency of solar panel.**
Keywords: solar panel, battery, PIC microcontroller, rainfall sensor, LDR, brushes.

I.INTRODUCTION

It aims to increase the efficiency and cost-effectiveness of solar energy systems while reducing their environmental impact. Dust on solar panels can reduce their efficiency and overall performance by blocking sunlight from reaching the photovoltaic cells.The electricity production companies like reliance power, adani power now days focus on the renewable energy sources to produce the electrical energy. Cleaning solar panels is important because accumulated dust, dirt, and other debris can significantly reduce the panels' efficiency by blocking sunlight. Regular cleaning helps maintain the performance of the panels and ensuresThey are producing the maximum amount of energy possible.Diverse solutions exist in the present scenario, but their applicability depends on the quantity of panels involved. For instance, extensive solar parks, such as large-scale solar power plants, employ automated solar panel cleaning mechanisms[3]. While effective, these mechanisms tend to be operationally expensive, making them feasible primarily for sizable solar parks. Conversely, smaller systems rely on manual labour for cleaning, a risky endeavor in extreme conditions that poses potential harm to personnel and system integrity due to the methods employed[3] (such as brushing that may damage panel surfaces). The settling of airborne particulates on solar panels can profoundly affect the functionality of the embedded photovoltaic cells. Given that these light- sensitive cells facilitate the transformation of solar to electrical energy, proper alignment according to that installation site's geographical conditions is vital[4]. Dust particles obstruct the necessary sunlight, leading to insufficient energy production, and the hindrance they create can result in severe damage to the silicon wafers within the panels.

Problem Statement

The presence of airborne particulates settling on solar panels can significantly impact the functioning of the embedded photovoltaic cells. These light- sensitive cells are responsible for converting solar energy into electricity, making it crucial to ensure an ample sunlight source through proper alignment according to the geographic characteristics of the installation site. These particles obstruct the required amount of sunlight, leading to insufficient energy production.[2] Additionally, the hindrance caused by these particles can result in severe damage to the silicon wafers inside. For instance, if dust accumulates and blocks a small area of a cell, it can cause the essential element within the cell to burn, resulting in the appearance of black spots on the panel's surface.[3] The severity of this problem varies from one location to another, depending on the environmental surroundings of the installation sites. Industrial areas may emit various types of particles such as fly ash and brick powder, while areas with low buildings and residential neighbourhoods might face issues with bird droppings.[4] In dry regions like deserts, sand accumulation from frequent sandstorms can cover the panels. This problem can lead to a substantial reduction of 40-50% in energy production within a specific timeframe, depending on the location. Consequently, the overall efficiency of the solar system diminishes, making it challenging to operate and rendering it less effective.

Drawing inspiration from PDEA's College of Engineering Manjari, which serves as an exemplary solar installation, the necessary design measure- ments were obtained, and the prototype was simulated on that system. The college features commercial-sized solar arrays, as depicted in Figure 1.

Fig. 1: Commercial sized solar arrays installed.

Furthermore, the significance of aligning the system's lifespan with that of a solar panel, which typically spans around 30 years, was recognized. Consequently, the primary emphasis during the design phase was placed on enhancing durability and ensuring long-term sustainability.[7] Given the environmental challenges in Pune, including drought and atmospheric conditions, dedication was directed toward the creation of a cleaning system that minimizes water usage in the cleaning process, thereby promoting eco-friendliness and sustainability.[8]

Literature Review

The insights into the impact of soiling on solar panels have been gleaned from research supported by universities and associations dedicated to solar energy. These studies delved into various facets of soiling, exploring its effects on solar panel performance.[3]The research conducted by Boston University's Department of Electrical and Computer Engineering uncovered a significant 24% decrease in efficiency attributed to soiling in Lovington, New Mexico, over a one-month period. Notably, the study emphasized that while rain serves as a primary cleaning agent for solar panels, it is not entirely sufficient for optimal performance. The Boston University study also undertook a comprehensive analysis of costs and benefits associated with three prevailing solar panel cleaning methods. These approaches encompass regular cleaning via raining, manual cleaning, or cleaning facilitated by an electrodynamics system (EDS). The findings indicated that for rain to maximize its cleaning effect, panels should be equipped with a glass shield and positioned in a near-vertical orientation. Manual cleaning, involving water and detergent, was identified as effective but incurred notable labour costs (constituting 45.7% of the total cost) and fuel costs (constituting 20.5% of the total cost). The research thus provided valuable insights into the multifaceted considerations involved in maintaining optimal solar panel performance in the face of soiling challenges.

The IEEE study led by P. Burton and B. King delved into the impact of diverse types of dirt on solar panel efficiency, with a specific focus on the compositions commonly encountered in the south-western United States. Notably, the study discovered that yellow-colored dirt had a less detrimental influence on solar panel efficiency as compared to other types of dirt, particularly those in various shades of red. The findings underscored the importance of considering the specific characteristics of regional dirt compositions when assessing the potential impact on solar panel performance, providing valuable insights for optimizing solar energy systems in the south-west.

The figure 2 illustrates the I-V characteristics of PV panels before and after cleaning, showing an increase in power output after the cleaning of the PV panels.[5]

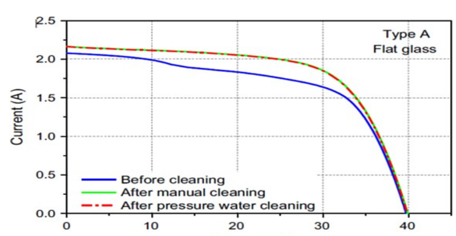

Fig. 2: I-V characteristics of the PV panel

According to research conducted by Rashmi Chawla at YMCA University of Science and Technology,[5] dust gathering on panels significantly impacts their concert parameters. Therefore, adopting appropriate techniques to mitigate losses caused by dust is essential. Regularly cleaning solar panels to remove dust and other debris from their surfaces remains a key solution to minimize energy losses and sustain panel efficiency.

Methodology Methodological Approach

The foundational pillars of the methodology included Data Accumulation and Analysis, Design, Simulation and Analysis, Optimization, and Experimental Testing. Design considerations were applied after analyzing the data from primary and secondary sources, encompassing both quantitative and qualitative aspects. A CAD model was created, taking into account all the necessary parameters resulting from the data analysis. Subsequently, Simulation, Analysis, and Optimization were performed for the entire design structure and individually for the major components. A series of experiments was accompanied to appraise the performance of that system. In future, Simulation, Analysis, and Optimization will be carried out for the overall design structure and major components. A set of experiments will be conducted to assess the functionality of the cleaning system.[9] Depending on the experimental feedback, if the results are to be positive and as expected, a scale- down model will be manufactured at the same college in the Mechanical engineering department. If the outcomes deviate from expectations, a review of the design, analysis, and optimization is to be conducted to address the noted aspects for redesign.

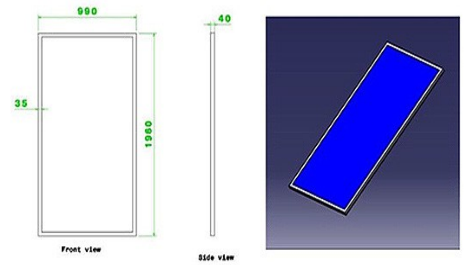

Fig. 3: WAAREE Solar Panel CAD design

The solar panel at Shreenivasa College of Engineering, b.pallipati is manufactured by WAAREE and belongs to the WS-330 module.Its electrical characteristics under Standard Test Conditions (STC) are as follows.[11]These specifications are evaluated under STC conditions, which include 1000 W/m^2 of irradiance, AM 1.5 spectrum, and the cell temperature is 25°C. For the Simulation, the Solar panels situated on the terrace of same college mentioned above were first designed. Exact measurements were taken on-site, and based on those measurements, rough 2D figures were created. Using CATIA V5 software, these 2D figures were subsequently transformed into a 3D design. Given that the Solar panel arrangement comprises 60 panels, only a few were designed on the CAD model for the sake of convenience in simulating the cleaning machine on it. The design is as shown in Figure 4.

Locomotion Unit

The Locomotion Unit plays a vital part in facilitating the machine movement across the panel. Initially, the machine's design features a progressing brush that smoothly traverses along a series of solar panels. To achieve this, the machine securely attaches to the panel arrangement with rollers that hold the panel's edge of frame, effectively utilizing them as rails for seamless movement. The primary cleaning mechanism involves a spinning brush that effectively clears any accumulated dust or debris on the panel surface.

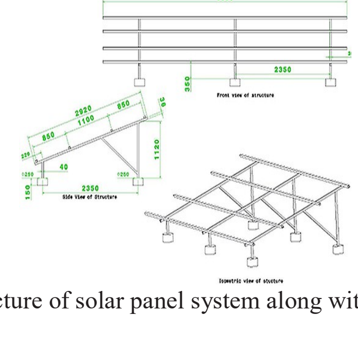

Fig. 4: Structure of solar panel system along with dimensions

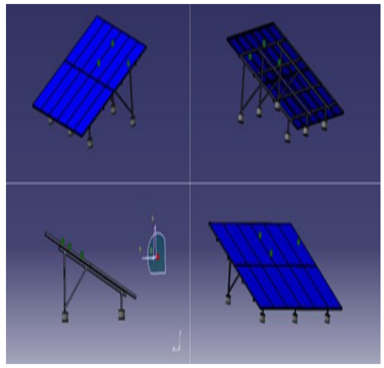

Fig. 5: CAD deign of solar panel structure

The system is designed for application on large-scale commercial solar arrays commonly found on school campuses and within industrial settings. Users can easily install the machine onto a panel array and leave it to operate autonomously. The machine is designed to function without the need for human control or regular maintenance, providing a user-friendly and efficient solution for solar panel cleaning. The two L-shaped channels are positioned at the top of the mainframe. These L-shaped channels are installed for safety reasons and to prevent damage to the solar panels. In the event of a wheel failure that may cause the machine to tip over, given the angle of the solar panels, these L-shaped channels will serve to prevent the machine from falling and will secure the machine in a suspended position on the solar panel frame itself. Plastic wheels are provided to grip on the Solar panel structure frame and get the proper traction for the movement of the machine.

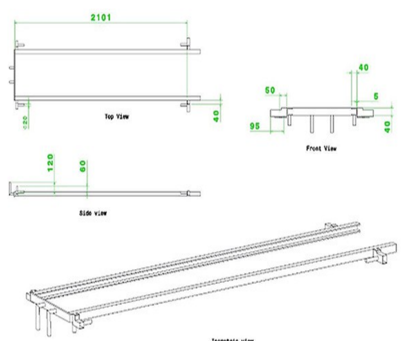

Fig. 6: Dimensions of Main frame

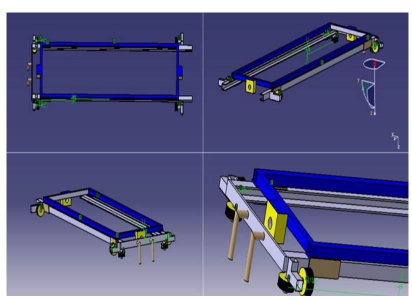

Fig. 7: Main frame CAD design

Roller Frame

The Roller Frame is maintained as a separate component from the Mainframe. Given the diverse orientations and sizes of solar panels available in the market, the decision has been made to keep the Roller frame distinct. This Roller frame will accommodate the shaft and motor for the cleaning brushes and can be adjusted in size to align with different solar systems and customer requirements while retaining the same main frame. The

Roller frame is designed with C sections, allowing it to be attached to the mainframe using nuts and bolts. Through this configuration, the same Mainframe can be employed for various arrangements of solar panel systems.

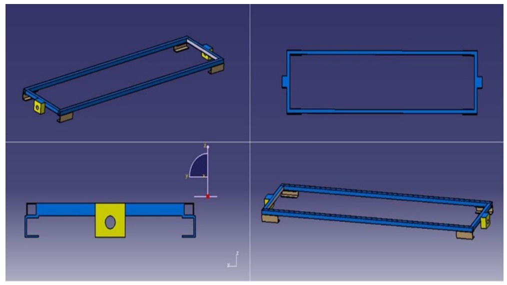

Fig. 8: Roller frame

Roller/ Cleaning Brush

In automated solar panel cleaning machines, the material employed for the cleaning brushes plays a crucial role. The machine utilizes rotating brushes made of thread-like bristles crafted from scratch-resistant material to clean photovoltaic and solar panels. This material ensures effective dirt removal without causing damage to the solar panel. Additionally, a water supply system or other detergent solution is positioned in front to proactively address the dirt to be removed.

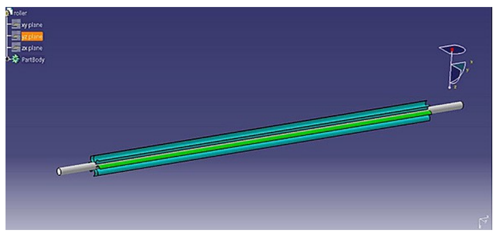

Fig. 9: Cleaning brush CAD design

In an automated solar panel cleaning machine, soft nylon brushes are utilized to clean the panel. These brushes, which are rotating brushes mounted on the shaft, facilitate the self-cleaning process after dust removal. A sprinkler is also employed for this purpose.

Fig. 10: Cleaning brush

Assembly and Simulation

The cleaning unit is set into operation by moving back and forth along the solar panel. Equipped with a clockwise-rotating cylindrical brush, it travels along the axis of the solar panel, effectively guiding dust along its path of motion and ultimately blustering it away at the edge of panel. Upon reaching the end of the row of solar panels, the direction is reversed, and the cleaning unit returns to its starting point. Once it reaches the initial position, the cleaning unit is brought to a halt. Subsequently, the cleaning unit is activated again, and this process is repeated multiple times to ensure thorough cleaning of the solar panels. Once one array of solar panels is cleaned, the machine can be utilized for cleaning another array. Simulation is carried out with the assistance of Catia V5. After the assembly of various components of the solar system, such as the Locomotion unit and cleaning roller, various constraints are applied to the parts. A fixed constraint is applied to the Solar Panel System to enable the simulation of the cleaning machine's operation on the panels.

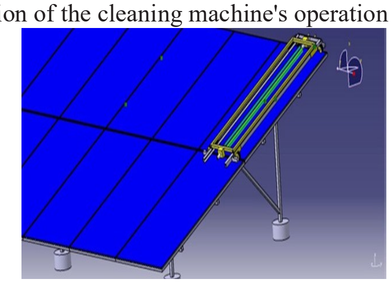

Fig. 11: Assembly

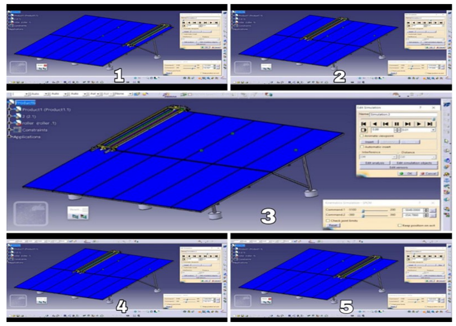

Fig. 12: Simulation Screenshots

KMU Kinematics interface in Catia V5 is used to simulate the machine. By giving appropriate constraints to parts proper and required Degree of Freedom is established to the Locomotion Unit and Cleaning Roller. Prismatic joints are made Length Driven and values are assigned according to the solar panel system. Revolute Joint is made Angle driven and joint limits are assigned accordingly. Here are some screenshots from the simulation. The Above figure shows five different screenshots of simulation taken while simulating the machine in KMU Kinematics in Catia V5.

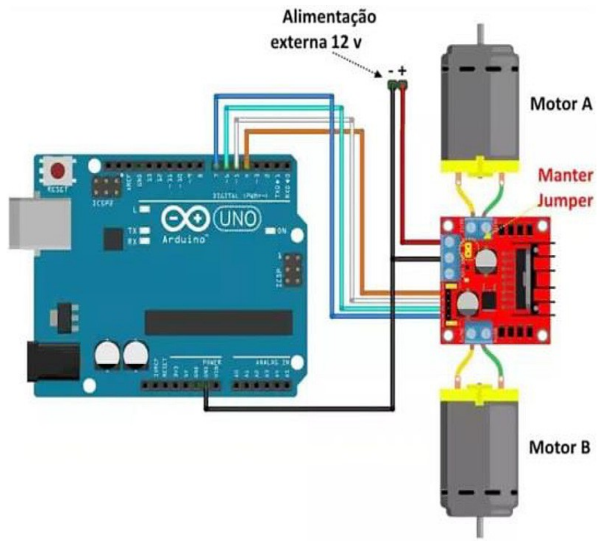

Fig. 14: Motor interfacing with Arduino

Automation and Working Principle

The Arduino UNO Original R3 is a microcontroller board developed by Arduino officials, featuring the ATmega328P. This Arduino UNO is furnished with 14 digital pins for input/output, six number of analog inputs, a quartz crystal of 16 MHz, with USB connection, a power jack, an ICSP header, and a reset button. Now, the machine is equipped with two IR sensors at both ends, which are connected to the Arduino. Additionally, there are two DC servo motors responsible for propelling the machine, and one DC motor is utilized for rotating the shaft on which the cleaning fiber is mounted. Through programming, instructions are conveyed to the Arduino, which subsequently issues commands to the sensors and motors.

Upon powering on the machine, electricity is directed to the Arduino and other integral components. The initiation of the motors prompts the machine to begin its movement and initiate the brushing operation on the panel. Once the machine reaches at the end of the panel, the IR sensor, strategically mounted on the machine, detects the edge of the panel. This detection is facilitated by a special triggering object positioned at the solar panel's end. Subsequently, the sensor registers the object and transmits a signal to the Arduino, prompting it to halt the motor. This marks the completion of the cleaning cycle for one row of panels.

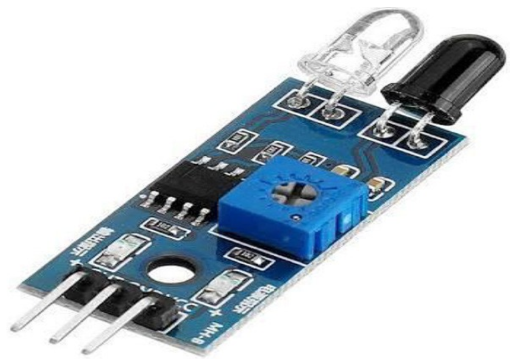

Fig. 14: IR Sensor

III. CONCLUSION

The systematic automated solar panel cleaning mechanism has been developed to counteract the detrimental effects of soiling on photovoltaic cells. Several issues encountered in manual panel cleaning, including damage caused by brushes, increased risk to personnel, and ineffective cleaning, are addressed by this innovation. While there are some atomized water cleaning machines in the industry, they tend to consume excessive amounts of water, making them unsuitable for arid regions. Both residential and commercial consumers are served by the mechanism, which offers automated cleaning capabilities, including obstacle detection through various sensors. The cleaning system utilizes high-quality microfiber cloth to effectively remove dust from panel surfaces without the need for water, making it suitable for arid areas. Additionally, provisions have been included for a water sprinkler to address stubborn stains like bird droppings that cannot be removed solely with the cloth. The overall impact of this mechanism will result in an increased rated power output from the panels, which had previously been compromised due to the mentioned issues. This not only reduces maintenance and repair costs but also extends the lifespan of the solar panels, encouraging consumers to choose solar energy as a viable renewable source. After the frame material is selected, the cleaning cloth will be designed to fit the panel's length and be attached to the machine's shaft. Manufacturing will involve sourcing high- quality local materials and employing precise machining processes to ensure a precise fit and finish for the end product. The machine will then be equipped with sensors for seamless motion control and paired with multiple motors: one for the shaft's movement housing the microfiber cloth and a couple of others for moving the entire frame over the solar panel.

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