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

Solar Panels Cleaning System

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Abstract
The goal of the project is to design and create a cleaning system for solar panels. This design prototype's primary goal is to clean solar panels with an electrical mechanism without sacrificing their quality or efficiency. In actuality, the Gulf region Solar panels require regular cleaning because of the numerous dust storms they experience, particularly in Saudi Arabia. Handling the process by hand will be very expensive and time-consuming. The designed mechanism must have water sprinklers and a specific wiping material to guarantee high-quality cleaning.

Keywords- Dust accumulation; Solar PV modules performance; Power output; Dust characterization; Temperature; Solar tracker.

I. INTRODUCTION

1.1 Project Overview

Globally, there is more than enough solar radiation to meet the demand for solar power systems. The amount of solar radiation that reaches the surface of the globe is sufficient to meet the tenfold increase in world energy use. Every square meter of land receives enough sunlight annually to generate 1,700 kWh of electricity. Our planet is greatly impacted by solar panels. Solar power plants require cleaning at least once every three days, however they can improve our environment without the use of other harmful power plants. Generally, it varies on the nation. For instance, in the Middle East, it must be cleaned daily to ensure.

1.2 Project Goals

1. Create a mechanism for cleaning solar panels that will boost their effectiveness.
2. Make more use of solar energy systems.
3. Automate and simplify the solar panel cleaning process.
4. Cut back on human involvement.
5. A cleaning mechanism that preserves the original solar panel's quality.
6. A cleaning system with minimal environmental impact.

1.3 Project Details

1. The solar panel cleaning system is remote-controlled and runs automatically.
2. Make at least a 10% increase in efficiency.
3. Use the cleaning water again.
4. An independent mechanism brush for maintaining the 100 W solar panel clean.

1.4 Product Architecture and Components

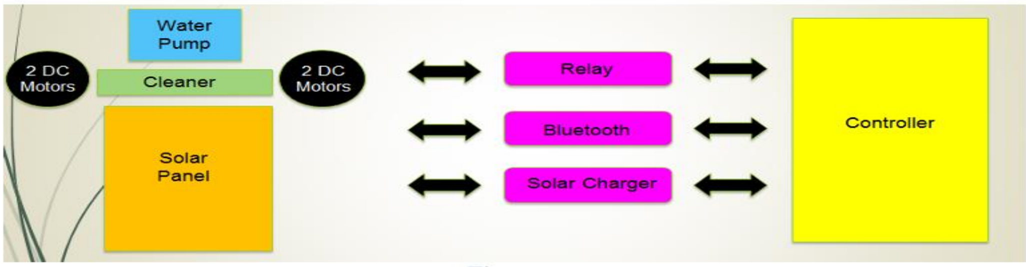

Figure.1 Architecture and Components

1.5 Applications

• In Solar Power Plants.
• In residential houses that use solar power.

II. System Design

2.1 Limitations on Design

There are requirements that must be met for a project to succeed, including design restrictions. We made every effort to tie this project as closely as possible to the Engineering Standards, and that was through reading and looking up earlier research articles written by knowledgeable individuals, all of whom had a general understanding of our topic. Starting with the system's body structure, we can observe that the materials we chose are appropriate for each component. Because iron corrosion reactions will impair both the cleaning process and the cleaner's mobility, we developed the cleaner with a stainless steel body to prevent them. Moreover, we employed stainless tail

2.2 Design Methodology

In order to meet all the requirements of the project, it is divided into several stages and phases. The overall aim of the project is to design a smart solar panel that cleans itself automatically and remotely. Phase 1 (Term 1, Design M.):

- The first stage of the project was to do a primary research in order to check if the project is possible to be made technically.
- The second step that we took is to look into the various sensors, controllers and motors.
- In the next step, we divided the project into categories based on its function. It can be seen that there are two main subsystems on the project and along with this; the project requires some amount of manufacturing and design of mechanical parts to hold the solar panel and the cleaner of the solar panel.
- We started by an AutoCAD sketch of our mechanical structure, so we can build it easily in real life as shown in Figure 2.

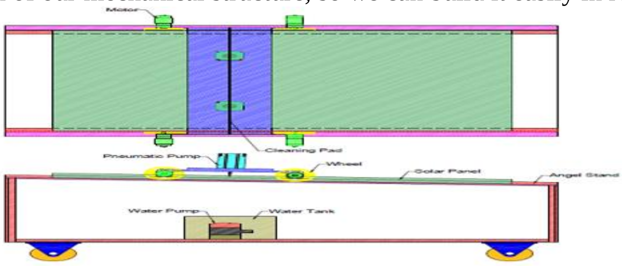

Figure 2: AutoCAD Sketch.

Phase 2 (Term 2, ASSE III): • We calculated the needed power for our automation system to determine the size of the needed battery for our off-grid system, as shown in Table 1 below:

APPILANCE	DC Motor	Water Pump	Raspberry Pi	Charge Controller	
QUANTITY	4	1	1	1	Total Watt Hours per Day
OPERATION (Hours/Day)	0.017	0.017	24	24	
VOTAGE (V)	12	12	5	12	
CURRENT (A)	0.5	1.6	1.8	0.02	
Watts (V*A)	24	19.2	9	0.24	
Watt-Hrs (V*A*Hours/Day)	0.4	0.32	216	5.76	222.48

After calculating the wattage hours per day for the system, we found that it consumes 222.5 W-Hrs per day. Thus, its wattage consumption equals to 9.27 W as shown in Equation 1.

54.48 W-Hrs / 24 Hrs = 9.27 W Equation 1

However, according to the performance characteristics shown in Figure 3, the battery (Solar Gel Acid Battery 12 V 65 AH / 10 HR, 1.8 V / Cell) supplies 10.8 V. So, as it can be seen in Equation 2, the automation system consumes 0.86 A. Therefore, the battery will supply the system with maximum daily consumption for 75.73 Hrs long as shown in Equation 3.

9.27 W / 10.8 V = 0.86 A Equation 2

65 AH / 0.86 A = 75.73 Hrs Equation 3

So, as it can be noticed in Equation 4, the total power consumed by the automation system of the total battery capacity per day equals to 48%.

[(24+24+0.017+0.017) Hrs / 75.73 Hrs] ∗ 100 = 48% Equation 4

Performance Characteristics

Nominal Voltage	12V
Number of cell	6
Design Life	5 years
Nominal Capacity 77ºF(25ºC)	
20 hour rate (3.4A, 10.8V)	68Ah
10 hour rate (6.5A, 10.8V)	65Ah
5 hour rate (11A, 10.5V)	55Ah
1 hour rate (45.1A, 9.6V)	45.1Ah

Figure 3: The Performance Characteristics of the Solar Gel Acid Battery

The control system for our project was divided into three subsystems: DC motors control, water pump control and charge tracker control in which each subsystem will be controlled and interfere with each other by Raspberry Pi. • To control the speed and the direction of the +12V DC motors, Raspberry Pi 3 B+ was coded and then connected to a motor driver. However, we found that the required speed and direction control could be achieved by replacing the motor driver with two relays and connecting the motors in parallel. In fact, this replacement helped us to reduce our project's cost. • The water pump control was designed by using only one relay. However, the amount of water needed to clean the panel was reached by trial-and-error method. In our control code, we have tried different times until we found that 5 seconds is applicable. • We have designed a control circuit for both the DC motor and the Water pump by using SRD-05VDC-SL-C 4-channel relay. As shown in Figure 4, two relays were controlled for the four DC motors (forward and backward) and one for the water pump (on or off).

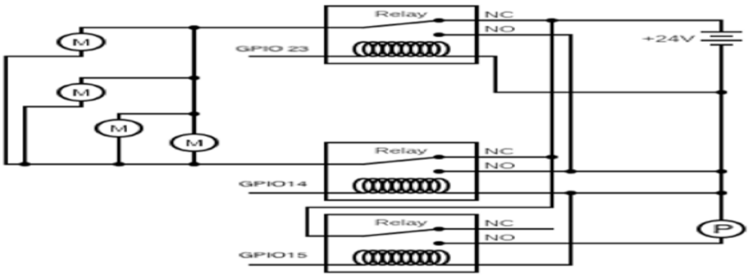

Figure 4: Schematic Diagram of the Dc Motors and Water Pump Control.

We chose Victron MPPT charge controller for making the cleaning decisions. By mining wattage data from the charge controller to the Raspberry Pi, we will write a python code that will detect the dirt on the panel based on three factors: the determined efficient wattage, time and weather as shown in the following algorithm diagram in Figure 5.

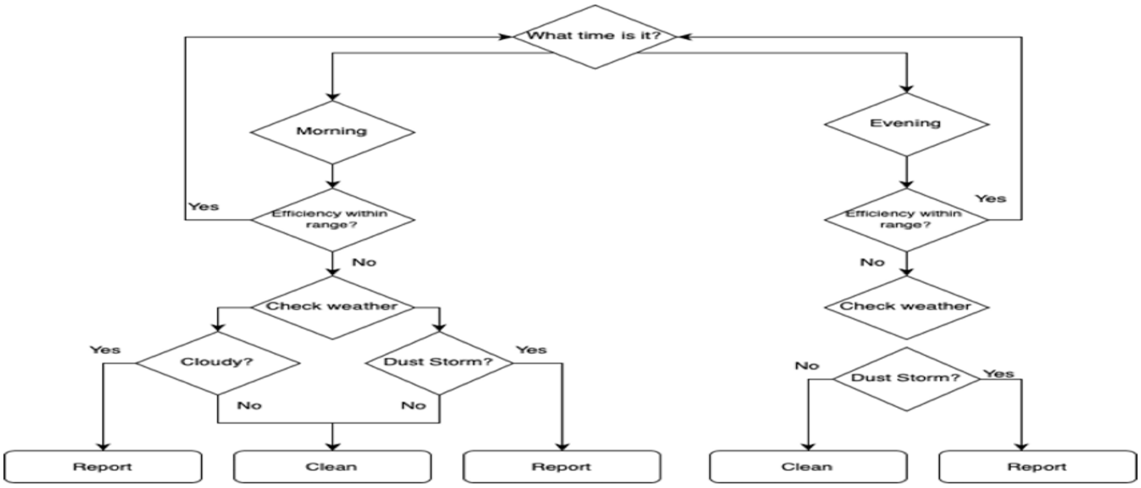

Figure 5: The Cleaning System Algorithm Diagram

The efficient wattage was founded by calculating an approximate loss then comparing it to our solar specifications. Therefore, for an off-grid solar system, there is 25% loss caused by global incident below threshold, irradiance loss, IAM factor on global, soiling loss factor, temperature, quality and mismatch loss, and ohmic wiring. Thus, by knowing that our solar panel provides 100 W peak power, a clean solar panel will grant 75 W during the useful hours.

- The charge tracker will be connected and tested.
- All the system will be integrated and tested if they function well.
- Add data acquisition system to take measurements.
- Check the system efficiency.
- The final report will be written.

2.3 Product Subsystems and Components

2.3.1 Communication Subsystem:

Bluetooth and WIFI to initiate the cleaner manually. We have chosen Bluetooth over the WIFI to initiate the cleaner manually. Thus, for the connection between the charge controller and the raspberry pi, Bluetooth analog will be used so data can be read from the MPPT controller.

2.3.2 Automatic Control Subsystem:

LDR, Dust Sensor and data analysis, to initiate the cleaner automatically. We chose to use data analysis of the efficiency reading. We will use the raspberry pi to collect the data from the charge controller then make the cleaning decision. 3.3.3 Power Subsystem: 100 W Solar Panel. The 100W solar panel embedded with the Solar Gel Acid Battery (12V 65AH/10HR, 1.8V/Cell) is sufficient for our project. In fact, the automation system will consume approximately %50 of the battery if continually operated.

III. Implementation

We have implemented the AutoCAD sketch that was shown in Figure 6. So at the end of the first semester, we could say that we have finished the Mechanical structure, and we have fitted the Panel on it and we have tested the initial mechanism of the cleaner as shown in Figures 6-8.

Figure 6: Installing the Cleaner that has Four DC Motors and Four Wheels on the Structure Figure 7: Fitting the Solar Panel on Board. Figure 8: Final Sketch.

At the beginning of the second semester, the solar panel position was adjusted on the frame structure to avoid any sunlight blocking that was faced in the initial fabrications. Also, a steel gear track was added for the DC motors to smoothen the dynamics of the wheels as shown in Figures 9 and 10.

Figure 9: Adjusted Frame.

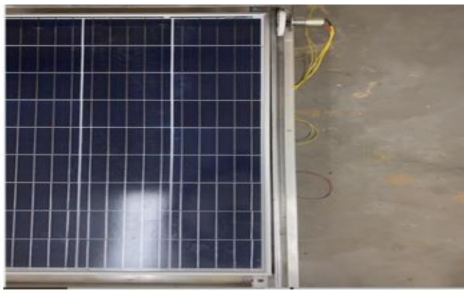

Figure 10: Motor Steel Track.

As it can be seen below in Figure 11, we implemented the control circuit we have designed for the motors and the pump. Figure 12 shows the Raspberry Pi wiring connection of our system.

Figure 11: 4-Channel Relay Wiring Termination.

Figure 12: Raspberry Pi Wiring Connection.

Finally, after completing the hardware connections, we wrote the control code in Python by the Raspberry Pi. In fact, the general-purpose input/output (GPIO) number 15 was set up to control the water pump where GPIO 23 and GPIO 14 were chosen for the DC motors. However, we tested that adding 5 Python sleeping time is appropriate for the water pump. Furthermore, 1 Python sleeping time for the motors to move forward and 1.4 to move backward. Thus, the following script was implemented:

III. System Testing and Analysis

3.1 Subsystem 1: Mechanical Subsystem The mechanical system was tested and we found that it's applicable to our project and strong enough to hold the solar panel along with the battery and the water pump. Also, the structure is equipped with wheels, and that gives it more flexibility since anyone can move it from one place to another.

3.2 Subsystem 2: DC Motors Control The DC motors control system was tested and verified, this subsystem is very important since the cleaner will be driven by the motors along the solar panel to clean it. Along with the testings, we found that the four DC motors are enough to drive the cleaner forward to the bottom end of the solar panel then backwards to the top end of the solar panel.

3.3 Subsystem 3: Water Pump Control The water pump control system was accomplished and verified. The water pump can pump the water on the solar panel through some holes installed in the cleaner, and it can deliver a perfect amount of water to the panel in such a short time. Also, after the cleaning process, the water that we used to clean the panel will fall into a path that was adjusted on the structure to collect the water. From there, recycling techniques will take a place.

Conclusion

The Solar Panel Cleaning System project aimed to bring a better solution for maintaining solar efficiency. The main scope was to develop a machine that can clean a solar panel by a proper control system. This project is a developed prototype to expand on a new and increasing market. The project team hit many obstacles along the way. Designing the control system required learning Raspberry Pi configurations, python coding and its interference with the electrical components. Using soldering boards to implement the designed circuit, hardware wiring, relays and machinery were new experiences. This being said, the project fulfilled the desired design with the planned control and mechanism. The DC motors were controlled by both relays and drivers to accomplish speed and directions control. Also, control code for the DC motors and the water pump were written then implemented in the system. Finally, the MPPT charge controller was connected to the off grid system. However, the prototype was not completed because of the challenges and the limitations that were mentioned earlier.

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