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Integration of High-Torque DC Gear Motor Shaft in Wet-based Solar Panel Cleaning System

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Abstract: This paper proposes an integration of a high-torque DC gear motor shaft in a wet-based solar panel cleaning system. Maintaining the performance of the solar panel by cleaning itregularly is vital as to gain the maximum power output from the sun. Bird droppings,dry dust and dirt are inevitably built up on the solar panel. These factors will cause a sharp reduction in the performance and power efficiency of solar panels. The system's performance was evaluated through testing and the data are recorded. A DC gear motor is used to rotate the cleaning brush at high torque. The analysis of the DC gear motor is conducted to get the parameters suitable for the cleaning brush. The high torque DC gear motor successfully rotates the brush at the speed of 285.5 rpm with a torque of 10Nm. The electrical parameters of speed and current are analysed with the varies of torque and voltage values. The results indicate the current increase in the increase of torque. On the other hand, the increase in voltage will increase the speed of the DC gear motor. Other than that, this project aims to prove the efficiency of the cleaning system by comparing the output value from the solar panel after and before it has been cleaned. Overall, it stated that the performance of the solar panel increases by about 2.93% to 2.73% with regular cleaning.

Keywords: Solar Panel, DC Gear Motor, Torque, Efficiency

1. Introduction

Nowadays, Solar panel is an alternative way to produce electricity. This kind of getting energy source is known as non-polluting and the sun is available all the time without the cost of anything to extract the source [1]. The output from the solar panel depends on a variety of factors, including the amount of light, the temperature of the cell, the orientation of the panel, and the size of the panel. However, the issues that are usually overlooked are bird droppings, dust deposition, and water stains. The accumulation of dust prevents the sun's rays from reaching the solar panel's surface. This causes the degradation of the output power of the solar panel [2].

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Therefore, cleaning work needs to be done as to ensure the efficiency of the solar panel output. In the manual way of cleaning, contractors hire workers to clean the solar panels regularly. Normally, solar panels are put at heights such as terraces, and rooftops, which are difficult to access and could provide a serious risk of injury to workers if they fall. Thus, this project is created to overcome this problem. The designed cleaning system automatically functions without requiring labour [3].

Other than that, the motor needs to have high torque to rotate the brush. Otherwise, the brush will remain unmoved. The weight of the brush might cause problems with the motor. The brush weight affects the motor's speed as well as its torques. Thus, the selected motor needs to be analysed as to observe its parameter when connected to the load for the record.

The objectives of this paper are to develop a wet-based solar panel cleaning system. Secondly, to analyse the high-torque DC gear motor used to rotate the brush. Lastly, to analyse the effectiveness of the wet-based cleaning system before and after it has been cleaned by the reading of solar panel output.

2. Materials and Methods

This section will describe the materials and methods that are proposed for developing a wet-based solar panel cleaning system

2.1 Materials

Each component is tasked with a specific feature, but the combination of the component is tasked with one job which is to execute the cleaning process using a rotary brush and water mechanism. Table 1 contains a list of all the components used in the project. To create a complete system of wet-based cleaning system, the required components are needed and must be in a complete circuit.

Table 1: Component functionality

	Component	Function
Input	Limit switch	Send a signal once the cleaning brush reaches the edge of the solar panel to change the direction of a power window motor.
	PIR sensor	Send a signal to the Arduino Uno once it detects the motion from the brush to allow the water pump to flow the water on the solar panel surface.
Process	Arduino Mega	Control the commands for the cleaning system to execute according to the signal it received.
	Arduino Uno	Control the water pump to ensure it turns on when the cleaning system starts to function.
	MDD10A motor driver	Control the direction and speed of the power window motor. It can withstand the current generated by the motor continuously at 10A and 30A peaks.
	L298N motor driver	Control the direction and speed of the DC gear motor. It can withstand the current generated by the motor continuously up to 2A.

Output	DC gear motor	Rotate the cleaning brush of the solar panel cleaning system
	Power window motor	Drive the cleaning brush to the left and right along the solar panel.
	Water pump	Provide the system with the necessary quantity of water.
	Relay	Control the operation of the water pump through the input signal

2.3 Methods

Three motors which stand of two power window motors and one DC gear motor completed the solar panel cleaning system. The power window motor is used to drive the brush along the solar panel while carrying the cleaning brush. The cleaning brush is rotated by the high torque of the DC gear motor. The L298N motor driver is used to control the direction of the DC gear motor. MDD10A regulate the power window motor and changes its direction once it reaches the end of the solar panel. The Arduino Mega is used to control the cleaning system by sending signals to the RTC, which then activates the motors to begin it cleaning process. The Arduino Uno is used to control the water mechanism to synchronise it with the cleaning process.

The dimension of the solar panel is 1005x665x30 (mm). The cleaning system is designed to cover the entire surface of the solar panel. The cleaning brush is made up of 18 slots of a small part brush. Each brush slot weighed around 150g, and 18 brush slots fitted in a rod weighed roughly 2.925kg. The solar panel is installed at a height of 166cm. The water needs to be supplied to the solar panel efficiently. The selection of the water pump is considered using Eq 1.

2.3 Block Diagrams

The diagram in Figure 1 and Figure 2 are a visual of the different components and elements that make up a project, and how they related to each other. The principal parts or functions are represented by components connected by lines that show the relationships of the blocks. There are three separate parts which are the input, the controller, and the output.

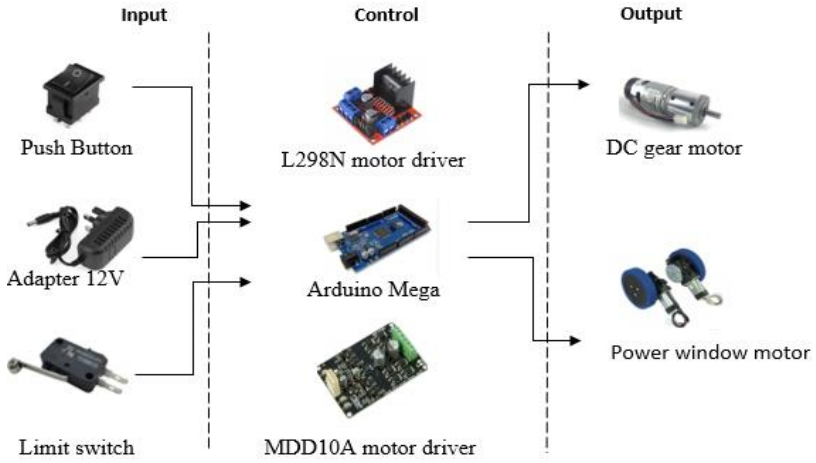

Figure 1: Diagram of the cleaning system

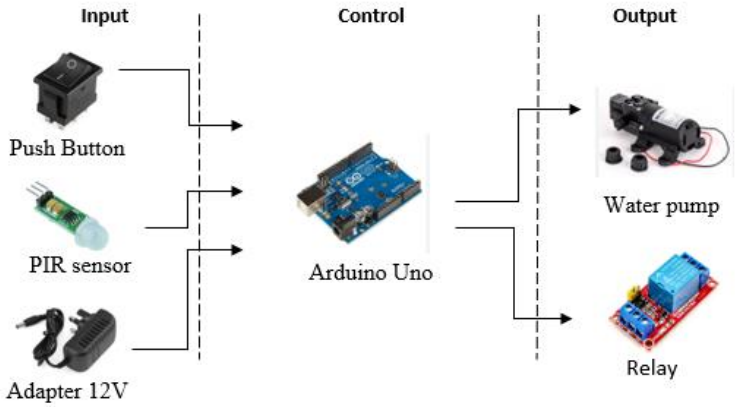

Figure 2: Diagram of the water mechanism

2.4 Equations

The chosen water pump can be determined by identifying the required pumping power [4]. In theory, pumping power refers to the amount of energy or work required to move a fluid from one location to another through a pump. The equation is as follows:

$$Pumping\ power = Water\ flow\ rate\ x\ Water\ Pressure \quad Eq.1$$

The formula in Eq 1 is used during the selection of a water pump to ensure a sufficient amount of water is supplied. Also, the execution of a wet-based cleaning system will record the output parameters from the solar panel for comparison purposes. The output voltage and current are taken directly from the multimeter. The output power is calculated manually using Eq 2 [5]. The equation is as follows:

$$P(W) = I(A)\ x\ V(V) \quad Eq.2$$

3. Results and Discussion

This chapter discusses the result of this project according to the flow of the objectives which focus on the development of the solar panel cleaning system and motor parameters analysis. The test was conducted on 5th January 2023 at the solar site near the UTHM college. Every result and analysis obtained proves that the motor is applicable to drive the brush along the solar panel. Moreover, the effectiveness of the brush to wipe off the foreign particles on the solar panel is determined by the output of the solar panel.

3.1 Analysis of DC gear motor parameters

Table 2 tabulated the parameter of the DC gear motor.

Table 2: The parameters of the DC gear motor

Parameters	DC gear motor
Voltage rating	12 Vdc
Current rating	At free run: 2A With load: 5A
Rated speed	No load: 350 rpm With load: 285.8 rpm
Rated torque	10Nm

In this project, the required torque of the DC gear motor is important to rotate the cleaning brush that weighs 2.93kg. The voltage rating of the DC gear motor is 12Vdc and it is connected to the L298N motor driver. The power supply of 12Vdc from the motor driver is a channel to the DC gear motor. The rated speed of the DC gear motor was recorded using a tachometer in rpm. At no load, the reading reaches a maximum speed of 350 rpm. When the brush is attached to the DC gear motor shaft, the speed decreases to 285.8 rpm. The reduction of speed is due to the brush's existence. The rated torque for the DC gear motor is 10Nm which shows no problem in rotating the brush.

3.1.1 Electrical analysis of DC gear motor

Figure 3 shows the graph of torque versus current. The torque is the manipulated variable which means the torque value is being changed and varied. The current is the responding variable which is measured. The DC gear motor is capable to change its torque by adjusting its gearbox. The torque is increased from 2 Nm to 10 Nm. As the DC gear motor has high torque, 10 Nm produces 2 Amps. In theory, an increase in load will require more torque. Thus, it drew a higher current.

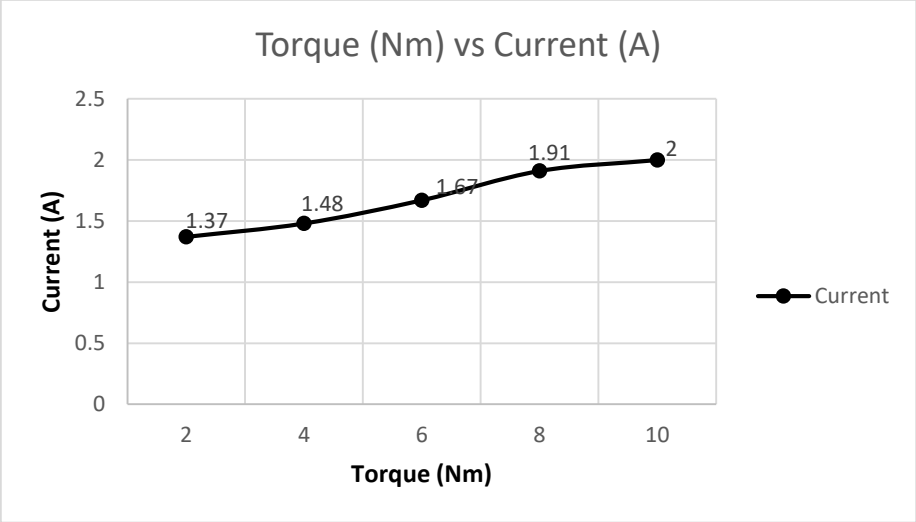

Figure 3: Diagram of the cleaning system

Figure 4 shows the graph of speed versus voltage. The voltage is the manipulated variable which means the voltage value is being changed and varied. On the other hand, speed is the responding variable in which the value is measured. The correlation of voltage and speed are proportional to each other. The increase in voltage will cause the speed to increase. The voltage is increased from 3V to 12V. The reading is taken with load usage. The 285.8 rpm is the value of speed when the voltage supplied is 12V. At a minimum supply of 3V, the DC gear motor rotates but at a lower speed of 148.2V. The motor will only not rotate if no voltage is supplied to the DC gear motor.

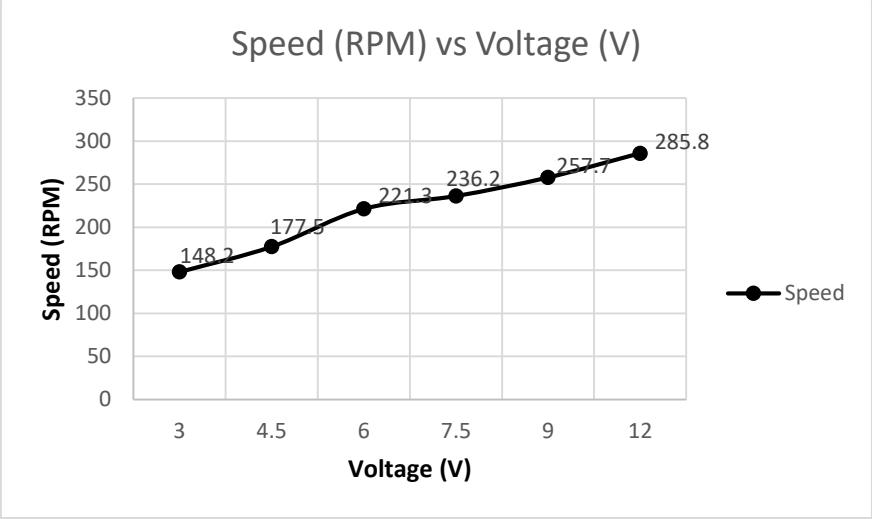

Figure 4: Diagram of the cleaning system

3.2 Data analysis of the solar panel performance

The analysis to get the reading output of the solar panel required a multimeter. The parameter analysed is the voltage produced by the solar panel. The collected data is to show the voltage and current readings of the solar panel output before and after it is cleaned by the wet-based cleaning system. The total day spent doing the analysis is 3 days as tabulated in Table 3, 4 and 5. The time taken was at 10.00 am and 5.00 pm. The power output is calculated using a specific formula. The efficiency increase is also taken into account as to see the increment of the output power at different conditions.

Table 3: Analysis of voltage on solar panel performance

Day	Time	Voltage before cleaning (V)	Voltage after Cleaning (V)
1	10.00am	20.5	21.1
	5.00pm	18.5	19.0
2	10.00am	20.6	21.5
	5.00pm	18.9	19.2
3	10.00am	20.3	20.9
	5.00pm	17.7	18.2

Table 4: Analysis of current on solar panel performance

Day	Time	Current before cleaning (A)	Current after Cleaning (A)
1	10.00am	2.62	3.47
	5.00pm	1.69	1.73
2	10.00am	2.76	3.89
	5.00pm	1.71	1.85
3	10.00am	2.65	3.16
	5.00pm	1.41	1.48

Table 5: Calculated power on solar panel performance

Day	Time	Power before Cleaning (W)	Power after Cleaning (W)
1	10.00am	53.72	73.22
	5.00pm	31.27	32.87
2	10.00am	56.86	83.64
	5.00pm	32.32	35.52
3	10.00am	53.80	66.91
	5.00pm	24.96	26.94

The tables are the observation of solar panels' performance in different conditions. From the data, it can be seen that there are differences in the output power of the solar panel. At 10.00 am, the reading is quite higher as the time is around noon and the sun's position is almost at its highest point. At 5.00 pm, the reading started to drop since the sun fell off from its highest point. This result indicates the effectiveness of the cleaning system to clean up the solar panel from dust.

3.2.1 Graph analysis for the output of a solar panel

Figure 5 shows the graph of the voltage reading for three days at 10.00 am and 5.00 pm. On day 1 at 10.00 am, the reading of output voltage when it stays uncleaned is 20.5V. The reading then changes to 21.1V after cleaning. On the same day at 5.00 pm, the initial output voltage is 18.5V. The cleaning system then increases the voltage to 19V. From that, it is noticed that the output voltage of the solar panel increases a little higher after the cleaning. The increment occurred in every reading for days 1, 2 and 3 which can be seen in the figure.

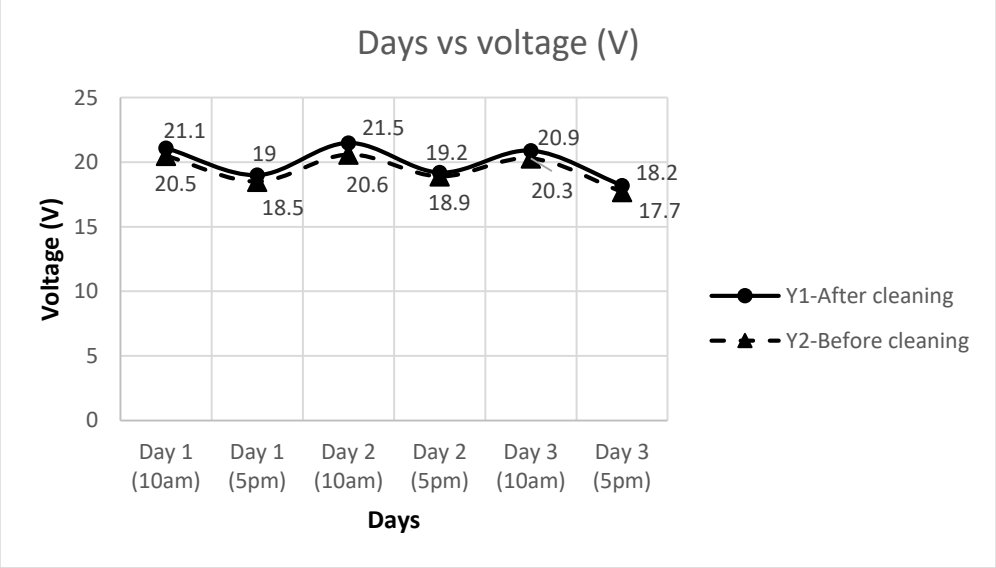

Figure 5: The graph of output voltage versus days

Figure 6 shows the graph of the current reading for three days at 10.00 am and 5.00 pm. On day 1, the reading was taken at 10.00 am. In its initial condition, the solar panel is still unclean. The output current was 2.62A. After the cleaning, the current value increased to 3.47A. In the evening at 5.00 pm,

the reading of the output current before and after the cleaning was recorded and it was 1.69A and 1.73A. The recorded value indicates that the cleaning system helps in improving solar panel performance.

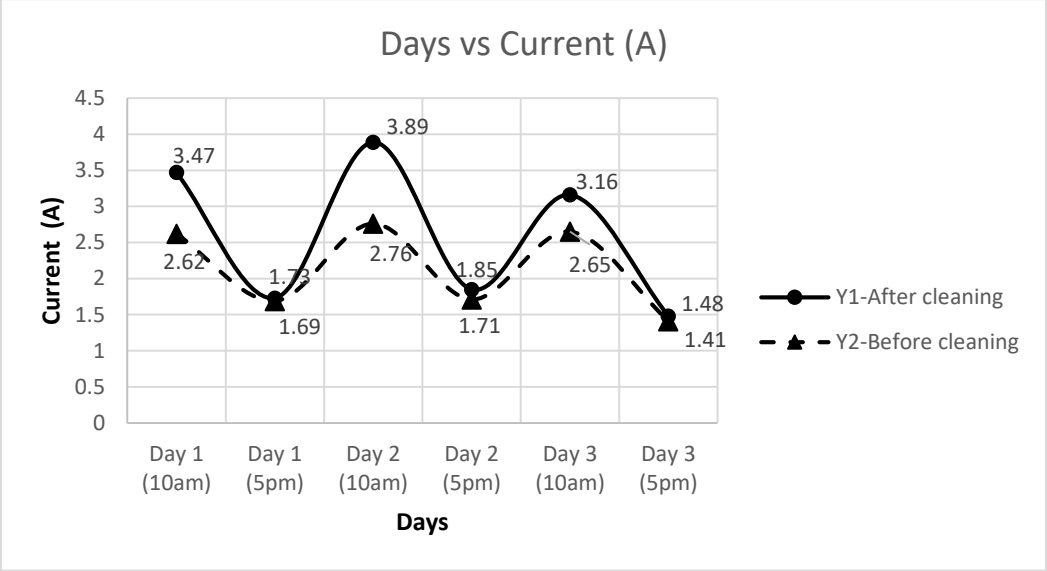

Figure 6: The graph of days vs output current

Figure 7 shows the graph of the power reading for three days at 10.00 am and 5.00 pm. The recorded output power at 10.00 am on day 1 is 53.71W. Basically, the value is calculated using a formula of P = I x V. The cleaning system was executed and the reading was taken again. The output power increased to 73.22W. In the evening at 5.00 pm, the output power value was 31.27W when it was unclean Then, the cleaning process rise the reading to 32.87W. The reading of the output power seems to be higher in every graph as to indicate the effectiveness of the cleaning system.

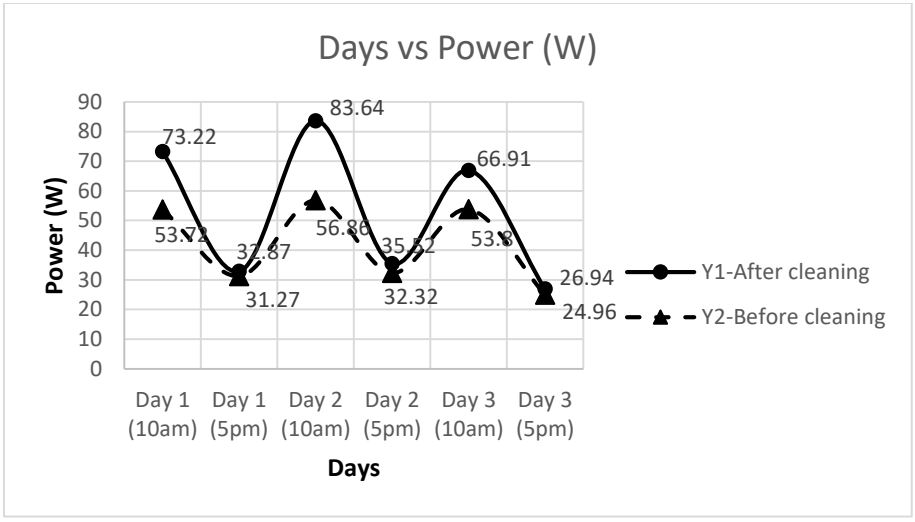

Figure 7: The graph of days vs output power

4. Conclusion

In conclusion, this project successfully achieved all the objectives. The wet-based cleaning system is developed based on the hardware design. The cleaning system is created by referring to the size of the solar panel as to imply it is in a real environment. The water mechanism successfully supplies an amount of water on the solar panel surface during the cleaning process.

The DC gear motor parameters can be analysed using suitable measurement tools. The DC gear motor rotates the brush at 285.5 rpm with maximum torque of 10Nm. At no load, the DC gear motor rotates at speed of 350 rpm. The voltage needed to power up the DC gear motor is 12Vdc. The current will increase when torque is increased. It shows the correlation between torque and current. Other than that, the increase in voltage affects the speed to increase. This is observed from the result analysis. Furthermore, the analysis of the output of the solar panel is been discussed in chapter 4. The efficiency increases for every execution of the cleaning process. Three days were spent observing the output voltage, current and power of the solar panel after and before it had been cleaned.

In a nutshell, the output of solar panels seems to be higher with the use of a cleaning system. The efficiency increase in each day gives good feedback from the project. Regular cleaning of the solar panel is important as to ensure the solar panel operate at maximum efficiency.

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