Design and Prototyping of an Automatic Solar Panel Cleaner Based on Arduino

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Abstract

This research paper presents the design and construction of an automatic solar panel cleaner on Arduino. Since dust is an important factor affecting the efficiency of the cell panel, regular washing of the cell panel is necessary for the photovoltaic system to increase its efficiency of the system. This research was tested using an 80 W monocrystalline panel and an Arduino washing control. It is easy to use and cheap to allow the control of the panel to achieve the desired results. In collecting the experimental results, the relationship between the electric power before and after cleaning the panel was collected. In the first case, the solar panel was cleaned every 1 hour. The results showed that the output power of the washed and unwashed panels is approximately the same. Due to too frequent a wash control timer, the dust accumulation is not enough to see the change in power output. Case 2, the solar panel washing time is controlled every 3 months. The results showed that after 3 months of solar panel cleaning intervals, the amount of dust accumulated was about 2.5 grams per square meter. The power was greatly reduced. When cleaning the panel, results in higher power output. Then calculate the efficiency of the panel system increased by automatic panel washing. It was concluded that the calculated efficiency of the panel system was increased to 12.11%.

***Keywords*:** Effect of dust on a solar panel, Efficiency, Automatic

I. INTRODUCTION

Solar energy is the largest natural energy source, it is clean and ubiquitous. Especially Thailand is a country located on the equator of the world. Therefore, it is an area that receives sunlight all day long. Therefore, it is suitable for the use of solar energy [1]–[3]. However, the efficiency of the solar panels will have many variables, including the type of solar cell. Mounting and mounting of panels, temperature, light intensity, dust, etc [4]. Many researchers have studied the effects of dust on the efficiency of solar panels. They found that thick dust on solar panels reduced light transmittance from 88.9% to 69.1% [5], causing a maximum 6.9% reduction in efficiency [6].

The research of the College of Renewable Energy, Naresuan University, Phitsanulok Province, has studied the effects of dust accumulation on solar panels. The study found that, The number of dust results in reduced light transmittance resulting in reduced peak power. In the period of 60 days and 30 days, the electric power was reduced to 2.83% and 6.03%, respectively [7]. Thailand tends to increase the amount of dust accumulated every year[8]. The trend of PM2.5 volume in 2011–2018 Thailand is shown in Figure 1.

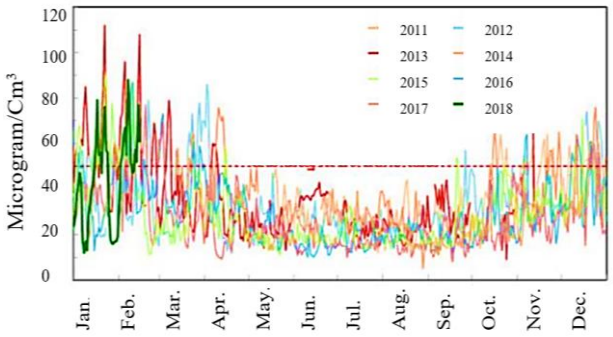

Figure 1: The trend of PM2.5 volume in 2011–2018 [8]

Currently, Automation has played a huge role in human life. It is also a working system that tends to develop and grow more and more. The main function of automation is to facilitate human life. Whether it is a timer in the microwave Using the remote control for turning on and off the car or a room temperature sensor in some air conditioners, etc. If considering the benefits of an automated system. It can be seen that automation can control and reduce the damage caused by human labor. It is convenient and easy to operate [9].

Therefore, this research has designed and built a prototype-based Arduino-controlled automatic solar panel washing machine for cleaning solar panels. This helps reduce dust accumulation on solar panels which increases the efficiency of the photovoltaic system [10], [11]. It also reduces the cost of hiring workers to clean the solar panels for solar power system operators. and reduce the danger of accidents that will occur in the case of washing solar panels on the roof.

II. LITERATURE REVIEW

A. Solar Cell

Basic Solar cell I-V characteristics

The light energy is directly converted to electricity by using solar panels. If the energy stored in the photon is greater than the energy bandgap of the solar panel, Electrons move and release energy in the form of electrical energy to the external circuit [12]–[14]. The process of generating electricity from the Sun is shown in Figure 2.

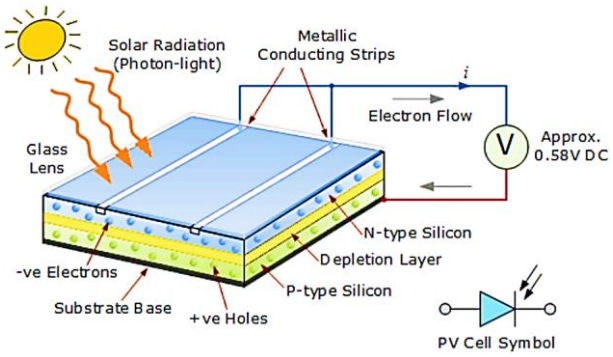

Figure 2: The process of generating electricity from the sun [15]

The basic Equivalent Circuit of Solar cells is shown in Figure 3 [16]. The model consists of a photocurrent source I_{ph}, a diode, parallel resister R_{sh}, and series resister R_s. The mathematical modeling of the I-V characteristic of the solar PV cell can be calculated as in (1) [17].

$$I = I_{ph} - I_0[exp\left(\frac{Vh+IRs}{nV_T}\right) - 1] - \left(\frac{Vph-IRs}{R_{sh}}\right) \quad (1)$$

Where I is the output current, I_{ph} is photocurrent, I_0 is reverse saturation current of diode, V_{ph} is photovoltage, n is diode ideality factor (1 for an ideal diode), V_T is the terminal voltage, series resistance (R_s) Shunt Resistance (R_{sh}), parallel resistance. There are used to calculate power output on a PV system.[18] As shown in Figure 3.

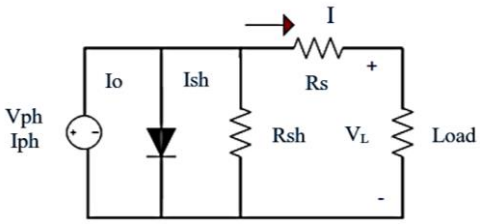

Figure 3: Equivalent circuit of solar cell [16]

The output power is dependent on the solar irradiant and temperature module. As the temperature increases, the open-circuit voltage (Voc) decreases. This in turn decreased the power output. On the other hand, irradiance will also affect power output, with a high of irradiation consequentially an increased power output [19]. The temperature and irradiance affect I-V curves on the solar cell are shown in Figure 4.

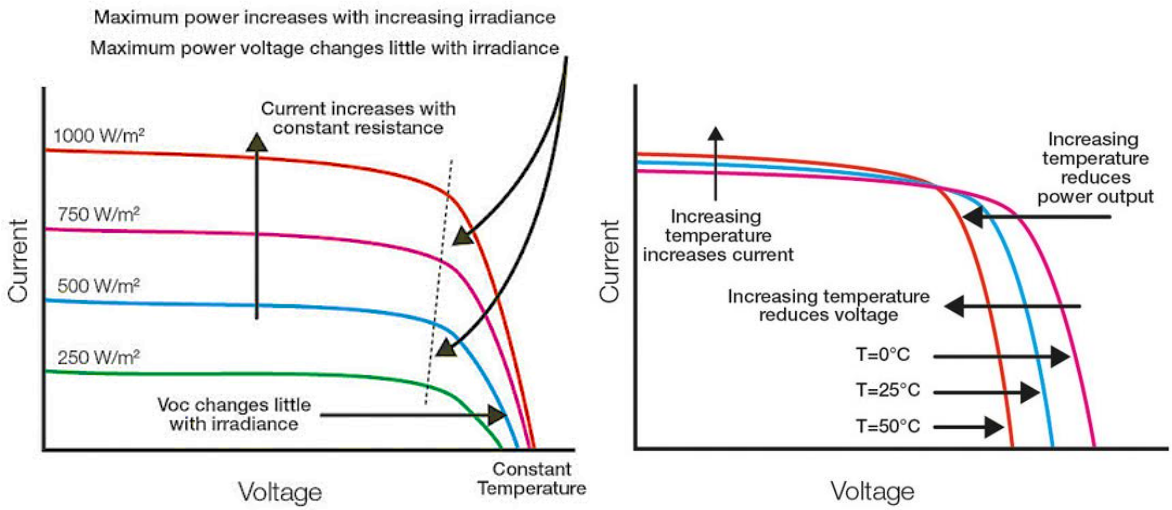

Figure 4: The temperature and irradiance affect I-V curves on solar cells [19]

B. Factors Affecting PV Plants Performance

The meteorological effect is the impact of weather events on the atmosphere of the world.

In PV plants, the input is the value of radiation from the sun, and its output is electrical energy. While generating electrical energy, many meteorological factors are affecting the performance of the PV plants. These factors lead to losses in the production of electrical energy. Investors want to minimize these losses to avoid financial damage. Losses can occur due to meteorological factors as well as the design of solar PV plants. These can be shading, material quality, incompatibilities between parts, and inverter losses [20]. The losses that may occur in a solar power plant are shown in Figure 5.

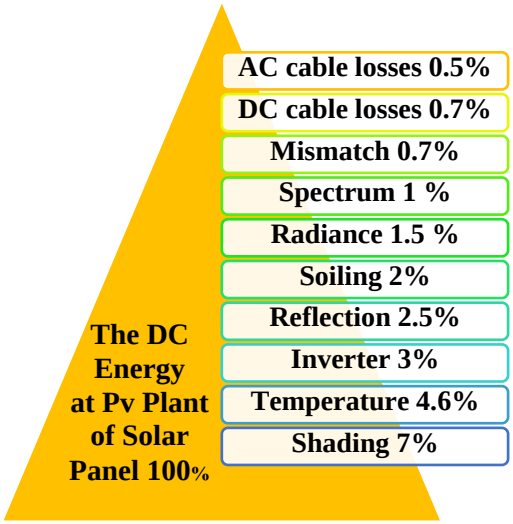

Figure 5: The factors affecting PV plants performance [20]

C. Effect of Dust on Solar Panel

In many research studies on the effects of dust on solar panels. It was discovered that dust accumulating on the glass sheet reduces the transmission of light. Interestingly, it was found that if the accumulation of fine dust particles was very dense, this would result in a reduction in the solar intensity the solar panels would receive because the dust would obscure the path of the light. For this reason, it can be concluded that dust is a factor affecting the efficiency of solar panels. If there is a lot of dust accumulation, the efficiency of the solar panel will also decrease [21]–[23]. The Examples of potential dust on the solar panels shows in Figure 6.

Figure 6: Examples of potential dust on the solar panels [23]

D. Data Processing and Measurements

In this experiment, it was necessary to use basic equations to verify the validity of the data with the following parameters to be calculated:

The maximum power factor can be calculated as shown in equation (2).

$$P_{max} = I_{mp} x V_{mp} \tag{2}$$

where Imp is the current max, Vmp is voltage max. To calculate the parameters of standard IEC 61724, which details how to calculate[24].

Solar energy ($E_{i,\tau}, kWh/m^2$)

$$E_{i,\tau} = \tau_r \times \sum\nolimits_{\tau} P_i \tag{3}$$

Solar energy per unit area ($E_{r,\tau}, kWh$)

$$E_{r,\tau} = E_{i,\tau} \times A_c \tag{4}$$

A_c = solar panel area (m^2)

Electricity from solar panels ($E_{A,\tau}, kWh$)

$$E_{A,\tau} = \tau_r \times \sum\nolimits_{\tau} P_{DC} \tag{5}$$

Solar panel efficiency $(\eta_{A,\tau}, \%)$

$$\eta_{A,\tau} = \frac{E_{A,\tau}}{E_{r,\tau}} \times 100 \tag{6}$$

The performance efficiency loss of the PV module can be calculated through Equation (7) [24].

$$\eta_{loss} = \frac{\eta_{clean} - \eta_{dirty}}{\eta_{clean}} \tag{7}$$

III.RESEARCH METHODOLOGY

In the prototype design, the Arduino-controlled automated solar panel washer aims to increase the efficiency of the photovoltaic system. The method of

operation is as follows:

A. Solar Panel Cleaner Component

1) PV module characteristics

This research uses an 80 W Mono-Crystalline solar panel. which is a high-efficiency panel. The electrical properties are shown in Table 1 and the picture of the cell panels used in this research is shown in Figure 7.

Table 1: PV module characteristics at Standard Test Conditions (STC) (1000 W/m^2, 25 °C, AM1.5)

Solar Module Type: PRPVM-80	
Maximum power	80 W
Voltages at Pmax	18 V
Current at Pmax	4.44 A
Open-Circuit Voltage	21.6 V
Short-Circuit Current	4.88 A
Power Tolerance	+/- 3%

Figure 7: The 80 W monocrystalline solar panel

2) Design a structure solar panel structure

Design a structure to support the solar panel to receive the most light. In Thailand, 15 degrees in the design use the Sketch-up2018 program to determine the height of solar cells installed on land. The height in front of the cell panel is 33.3 cm, the height behind the cell is 50 cm, the width is 67.1 cm and the length is 74.7 cm, which determines the height of the solar cell installed on the water surface, height 19.2 cm, width 143.1 cm, length 25 cm, as shown. In Figure 8.

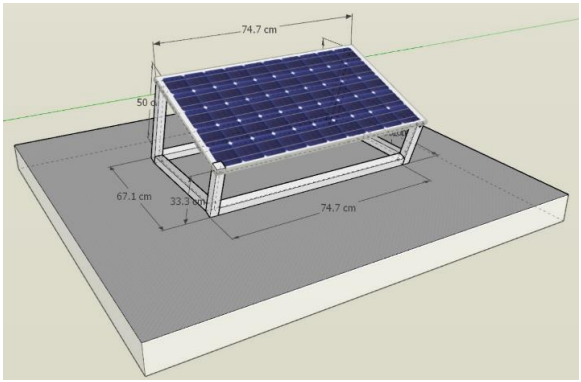

Figure 8: Solar panel structure in this research

3) Solar panel cleaner structure

1. A ConFigure a prototype of an automatic solar panel cleaner controlled by Arduino using an aluminum profile size 8 × 8 mm, assembled into a square, size 70 × 30 cm, using a 110 rpm 12 V DC motor. Figure 9 shows the Solar panel cleaner prototype.

Figure 9: Solar panel cleaner prototype

2. In the part of the control of the solar panel washing machine. The panel washer will run in a top-to-bottom manner. Use a rubber squeegee to clean the solar panel. There is a water spray head to spray water to clean the panel. This study divided the test into 2 cases, Case 1 was cleaning time every 1 hour and Case 2 cleaned every 90 days. The solar panel cleaning system operation flow chart is shown in Figure 10.

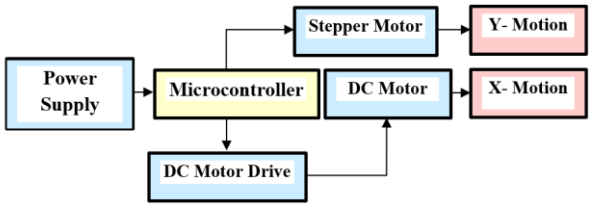

Figure 10: Solar panels cleaning system operation flow chart

In Figure 10, The power supply is the power source for the microcontroller board. The microcontroller is responsible for controlling the operation of the DC Motor Drive and Stepper Motor. The DC motor moves on the x-axis and the stepper motor moves on the Y-axis.

IV. RESULTS AND DISCUSSION

Once the design and construction of an automatic solar panel cleaner have been completed. Then experiment to collect the power values obtained when cleaning the panel. Compared to the power without washing the panel. To determine the relationship between panel cleaning that affects the power and efficiency of the solar panel. The results of the experiment were divided into 3 topics as follows:

Table 2: Summarizes the accuracy of the solar panel cleaning machine efficiency test

Machine working case	The total number of times to test	The number of times the machine works accurately.	Accuracy (%)	Error (%)
Set the machine to start working every 15 minutes.	10	10	100	0
Set the machine to start working every 30 minutes.	10	10	100	0
Set the machine to start working every 60 minutes.	10	10	100	0

A. Automatic Solar Panel Cleaner Control

As for the control of the solar panel cleaner, this research uses Arduino. Test the operation by setting the start-up time of the machine to 3 values: 1) Every 15 minutes, 2) Every 30 minutes and 60 minutes, the test results are shown in Table 2.

From Table 2 it can be seen that the solar panel cleaner can work exactly for the set time of 15, 30, and 60 minutes, representing 100 percent.

B. Cleaning the Cell Panel and the Solar Cell's Output Power

1) Daily panel cleaning

The researchers collected the results of daily light intensity and daily solar panel temperature. In order to know the fundamental behavior of the solar cell which affects the output power of the solar panel as well. The solar radiation from 8:00 a.m. to 5:00 p.m. and temperature modules from 8:00 a.m. to 5:00 p.m. as shown in Figures 11 and 12.

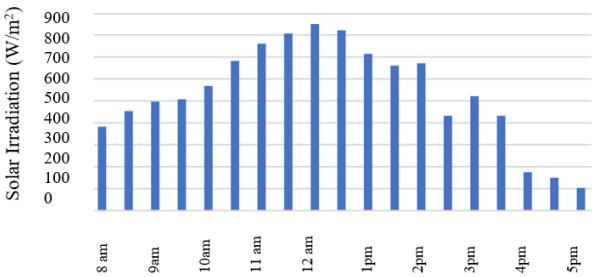

Figure 11: Solar Irradiation from 8:00 a.m. to 5:00 p.m.

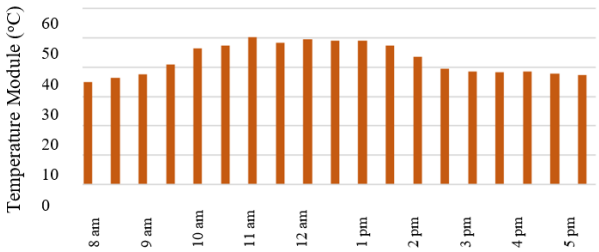

Figure 12: Temperature Module from 8:00 a.m. to 5:00 p.m.

The Power of solar panels on Daily panel cleaning is shown in Table 3.

Table 3: The power of solar panels on daily panel cleaning

Time	Power (W)		
	Before Dust	During Dust	After Cleaning
08.00 am	2	52	54
09.00 am	52	52	54
10.00 am	58	59	60
11.00 am	63	64	67
12.00 am	65	65	68
1.00 pm	69	70	72
2.00 pm	64	64	65
3.00 pm	54	55	58
4.00 pm	38	38	38
5.00 pm	24	24	25

From Table 2, It was found that when we set the panel cleaning to clean every 1 hour. As a result, the total power was only slightly increased, but from the observation on the panel, there may not be enough dust to accumulate to reduce the power. But the increase in power may be caused by washing the solar panels. With that water, the panel is cooled. During high-temperature times, such as between 11:00 AM and 2:00 PM in Thailand, when washing the panel, the panel temperature decreases. The voltage is, therefore, higher, increasing power accordingly.

2) Monthly panel cleaning

In this section, we will design a 3-month collection of experimental results to see the relationship between dust accumulation affects solar panel efficiency. The amount of dust will be collected before the panel is cleaned and the power quantity is compared before and after cleaning the solar panel. The results of the experiments are shown in Table 4.

Table 4: Power of solar panels on 3 monthly panel cleaning

Months	Dust amount (g/m^2)	Power (W)	
		Before Dust	After Cleaning
January 1, 2020	2.67	67	72.6
March 31, 2020	3.53	64	74.3
June 30, 2020	1.35	58	62
September30,2020	2.38	63	69

The results of the experiment can be seen over a period of 3 months. There is a large amount of dust accumulated. As a result, the power that the cell panel produces is less. When the panel is cleaned, the power will increase noticeably. In June 2020, In Thailand is the rainy season. Therefore, the amount of dust accumulation is not much. and resulting in a very small reduction in power.

C. Compare the Efficiency of the Panel Washer

Comparison of the efficiency of solar panel washer with the amount of dust as shown in Figure 13.

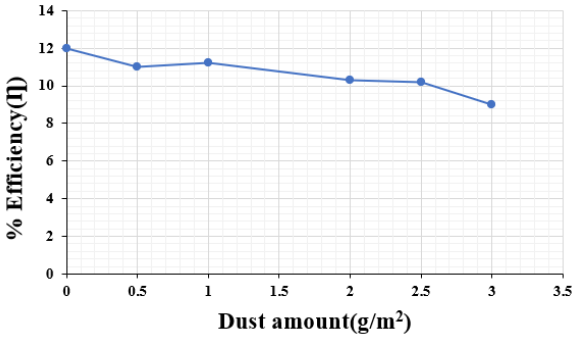

Figure 13: The relationship of the efficiency of the solar panel washer with the amount of dust

V. CONCLUSION

Researching the design and construction of an automatic solar panel cleaner on the Arduino. For this reason, dust is an important factor affecting the efficiency of the panel, so washing the panel regularly. Therefore, the photovoltaic system must increase its efficiency of the system. This research was tested using

an 80 W monocrystalline panel and an Arduino washing control. It is easy to use and cheap to allow the control of the panel to achieve the desired results. In collecting the experimental results, the relationship between the electric power before and after cleaning the panel was collected. In the first case, the cell panel was cleaned every 1 hour. The results showed that the output power was close to that. did not wash the panel due to too frequent washing time causing the dust to not accumulate enough. Then the cell panels were washed every 3 months. The results showed that when leaving the cell panel cleaning intervals for 3 months, the amount of dust accumulation was about 2.5 grams per square meter. The power was significantly reduced. when cleaning the panel will result in higher power costs. The efficiency of the increased panel system was then calculated. From the automatic panel washing, it was concluded that the calculated efficiency of the panel system increased to 12.11%.

At present, in Thailand, more solar rooftop systems are installed. On the roof area, cleaning is difficult and poses a risk of accidents to workers. This research has created an automatic cleaning machine to solve this problem on a low-cost basis.

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