

# Cleaning Various Length of Solar Panels using Modular Robot

**Rahul V Bhakare<sup>1</sup>, Vikramsingh B Vakte<sup>2</sup>, Nitin S Aher<sup>3</sup>**

Department of Mechanical Engineering, Sanjivani K.B.P. Polytechnic Kopergaon

**Abstract.** This paper discusses about the design and feasibility study for building a modular robot for cleaning solar panels. The objective was to design a universal module for transmission and manipulation that can be used with different length of solar panels and different arrangements in solar panel. The concept of a modular solar panel cleaning robot is an automatic system that is easy to set-up, low cost, and applicable with various size of solar panels. After the design and prototype processes, the robots are aimed to reduce dust on solar panel and consequently increase the performance in producing electricity. Since there are various configurations for arranging the solar panel, this robot can be modified using an advantage of modular robots. The principle of working is to clean a solar panel with water, spiral brush, and rubber sweeper. The modular concepts were validated for the solar panel with a range of 1 to 4 meters in both testing and field environments. The solar panels cleaning robot can clean dirt and dust on the panel and increase the power generation of the solar panels. The target applications for this design can be extended for a solarfarm, solar rooftop, and floating solar panels.

## 1. Introduction

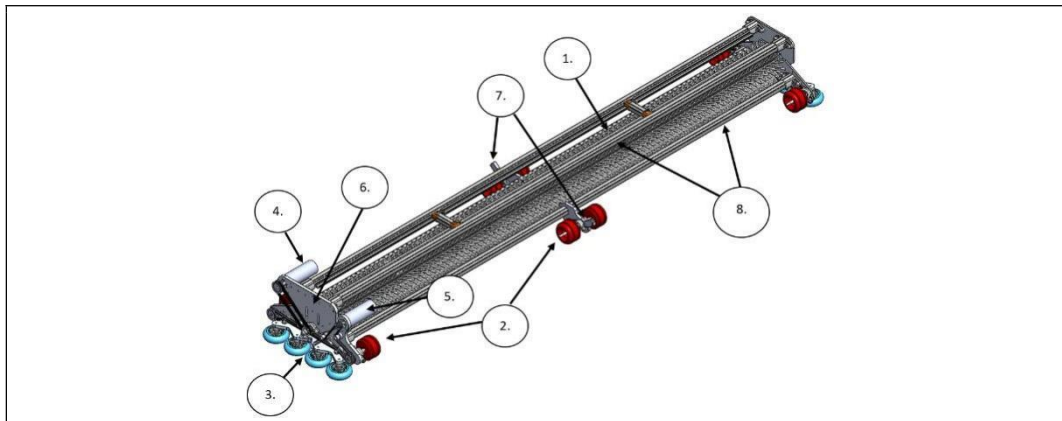
The cleaning process is crucially important to maintain the production of solar panels. Cleaning methods with water is suitable for Thailand due to bird droppings and agricultural dust [3]. Mostly, a solar power plant in Thailand still use a manual cleaning that is high cost (approximately 300 USD for 1 MW power plant) and need a lot of labours to clean up. The most common method for cleaning solar panels is a telescopic pole and bathroom mop.

## 2. System overview

Robots are designed with a modular concept to serve the panels with a length of 1-4 meters. The main method of cleaning arrays of solar panels is a rotation of cleaning brush on the top surface of panels with a spray of water. The design consists of a universal module for transmission that can be used with various length of the brush and different design in solar panels. This robot can be modified using the advantage of a modular robot that can be combined and disassembled within a short period of time. Each module is 2 meters in length with a total weight of 25 kg. The design considerations for this modular robot are a simple design, easy to operate and set-up, adjustable, lightweight, and low cost.

### 2.1. Components

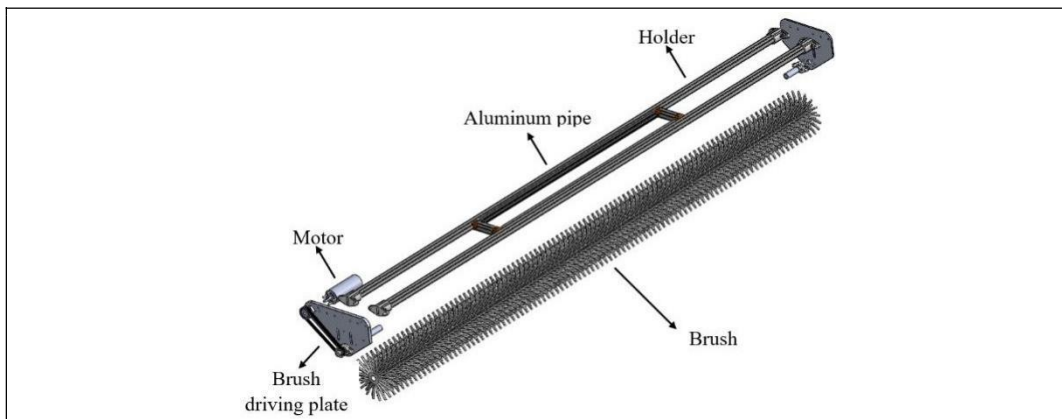
The prototype for the modular robot for cleaning solar panels is designed for typical length of solar panel. The model of the prototype is with 1 modular (2 meters) as shown in Fig. 1.



## 2.2. Design and specification

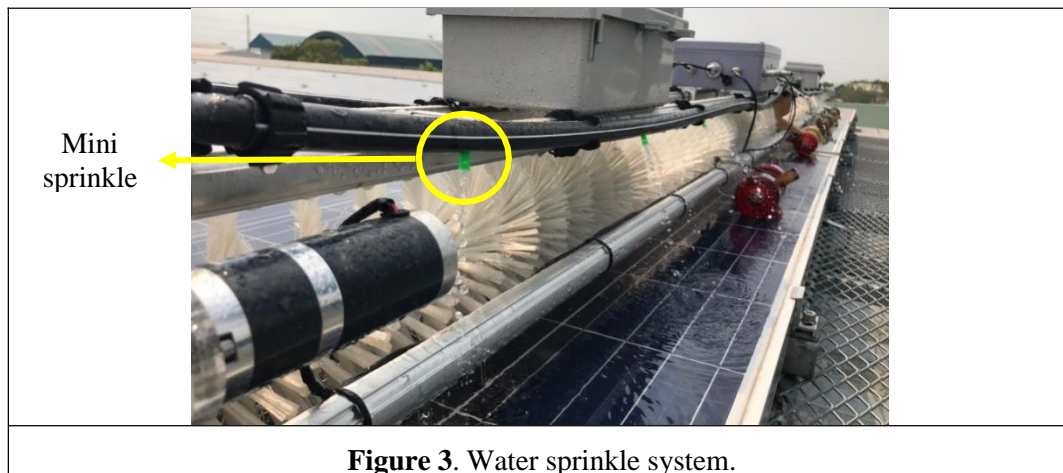
This robot can be separate into 3 main systems which are (1) brush driving system (2) wheel driving system (3) adjustment system for the brush's compression distance. The detailed explanation is included in this section.

(1) Brush driving system: The brush driving system will be mounted a topmost part on the side-plate so that it is easy to adjust and disassembly. It consists of one DC motor for a nylon roller brush (spiral-shape) with a length of 194 centimeters, and a diameter of 15 centimeters as shown in Fig. 2.



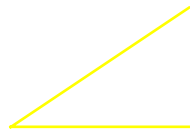
**Figure 2.** A module for brush system

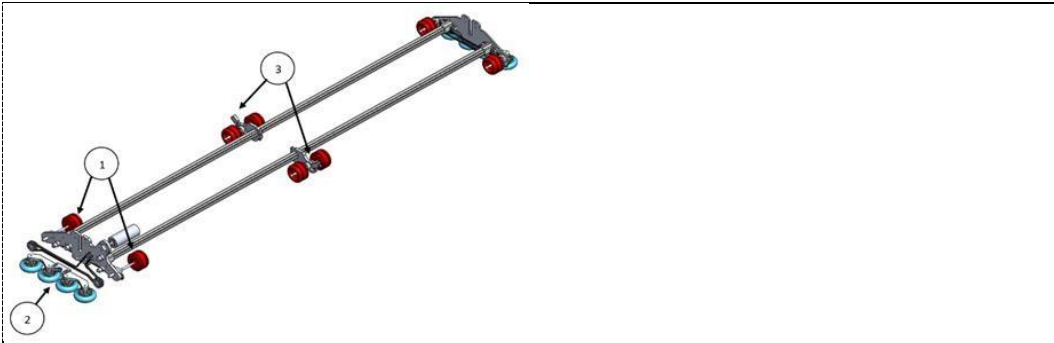
This robot also has mini water sprinkler for wetting the solar panels while cleaning as shown in Fig. 3. The pipe is 2 centimeters in diameter and it is mounted on the top of aluminium pipes in brush driving system.



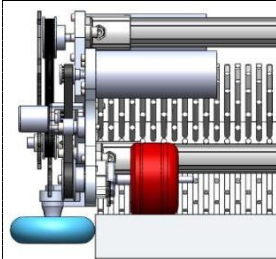
**Figure 3.** Water sprinkle system.

- (2) **Wheel driving system:** The transmission system for wheel driving system can be separated into 3 main components which are (1) wheel driving that is connected to one motor with three-level of adjusted speed (0.6, 0.8 and 1.0 km/hr). These wheels are on the top surface of solar panels and are controlled by using encoders and PID, (2) supporting wheels on the side view that will move on the frame of solar panel, and (3) photoelectric sensors. The overview of the wheel driving system is shown in Fig. 4. The supporting wheel is shown in Fig. 5. A robot for solar panels cleaning in autonomous mode also has edge-falling protection. Hence, two photoelectric sensors are installed in a front and rear position near the middle supporting wheel with the orientation of  $45^\circ$  angle as shown in Fig. 6.
- (3) **Brush compression system:** This system is designed to adjust the distance between the brush and the solar panels to ensure a complete surface contact as shown in Fig. 7. The brush compression system is in the triangle form with a brush driving system on the top of the wheel driving system. The adjustment system will attached both modules together by using 4 bolts. This can be adjusted for a range of 1 centimeter in a compression distance.

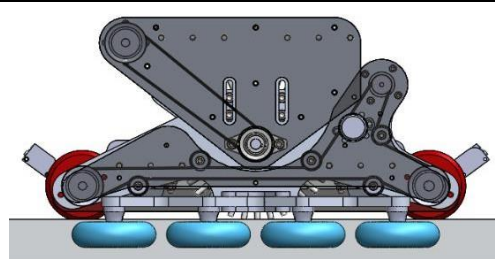




**Figure 4.** Wheel driving system and its components.



Side view



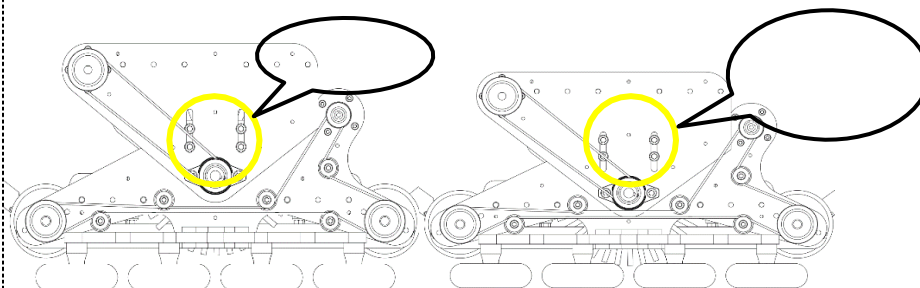
Front view

**Figure 5.** Supporting wheels.



**Figure 6.** Positions for sensor installation.

Highest Lowest  
4 bolts Adjustable up to 1 cm. downward.

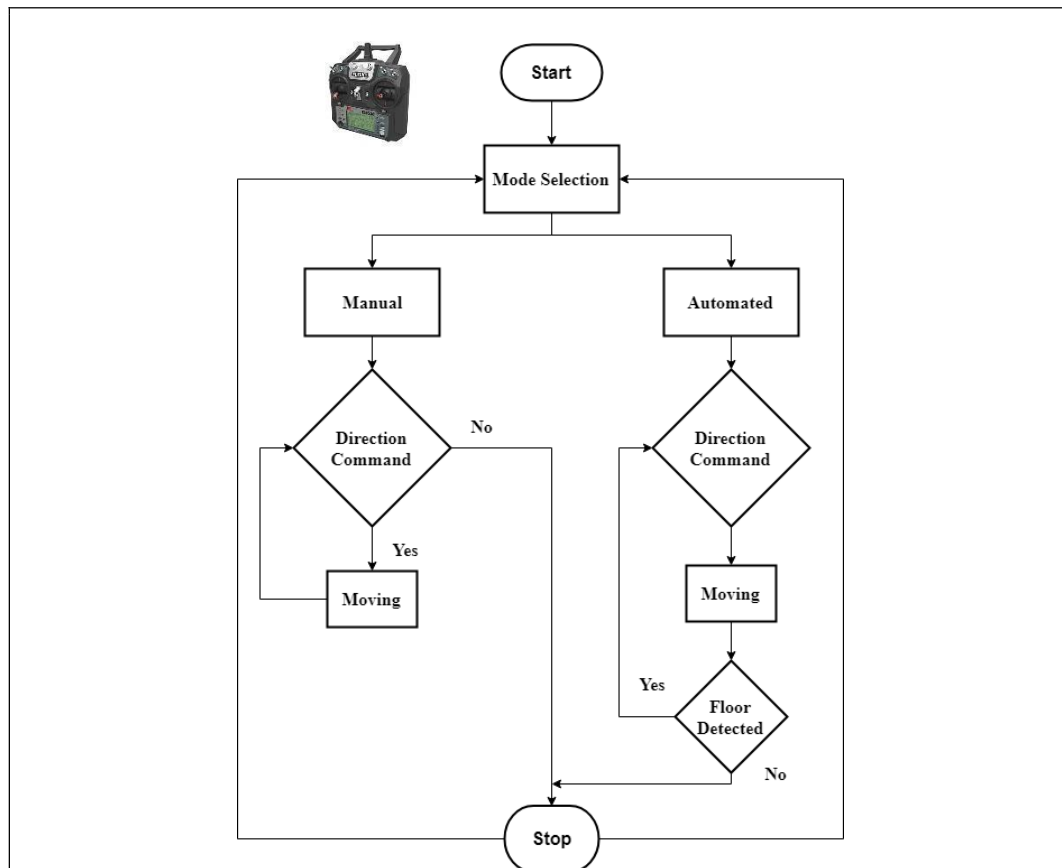


**Figure 7.** Brush adjustment and the assembly (side view).

**Table 1.** Summary of robot specification

Robot Specifications		
1.	Length	200 cm
2.	Width	40 cm
3.	Weight	25 kg
4.	Battery working hours (20 Ah)	4-5 hr
5.	Maximum capacity for cleaning (1 2000 m <sup>2</sup> /hr module, Length: 2 meters)	

Robot for cleaning solar panels is controlled by a microcontroller and protection sensor edge solar panels, when working in an automated system. The control diagram is shown in Fig. 8. This robot can be operated in both manual and automatic modes by selecting an option from a radio-frequency channel.



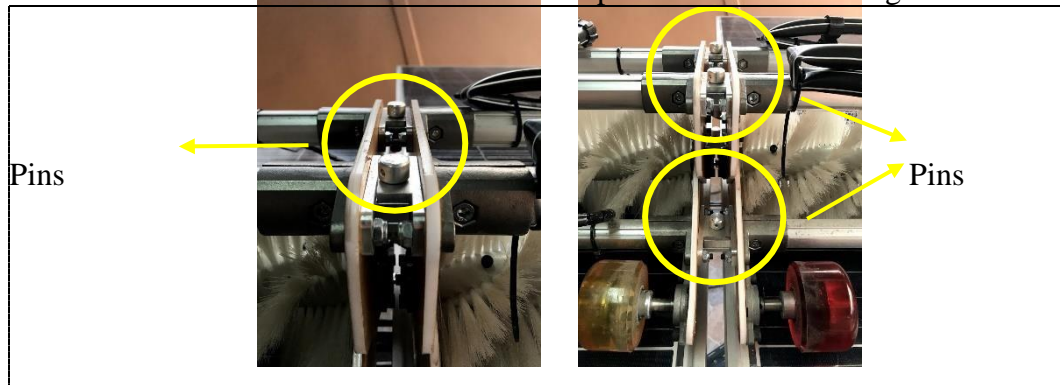
In such cases, the robot can go to the desired locations that need a re-cleaning. In an autonomous mode, the robot can be operated with the one-start button. The performance for the cleaning will continue until it reaches the other end of the strings, then it will return back to the original position on the other end.

In a manual mode, the robot can be controlled by using a joystick on a RF controller. The operator can easily control the direction of the cleaning and the beginning and ending time for the brush rolling.



### 2.3. Assembly of robot modules

Since there are various configurations for arranging the solar panel, this robot can be modified using an advantage of modular robots. Connection between each modular robot is 4 pins with a supporting plate between them as shown in Fig. 9. In this design of cleaning robot, they can be adjusted and connect to other module to obtain a desired length as shown in Fig. 10. Recently, the available range of total length is between 1 to 4 meters and it can be adjusted to match with customer's requirements in any length. The fabricated robot for 2-meters and 4-meters solar panels are shown in Fig. 11 and 12.



**Figure 9.** A connection method and supporting plate between each module.



**(a)** Robot length 2 meters.



**(b)** Robot length 4 meters.

**Figure 10.** Robot for cleaning solar panels in laboratory environment with a length of (a) 2meters and (b) 4 meters.

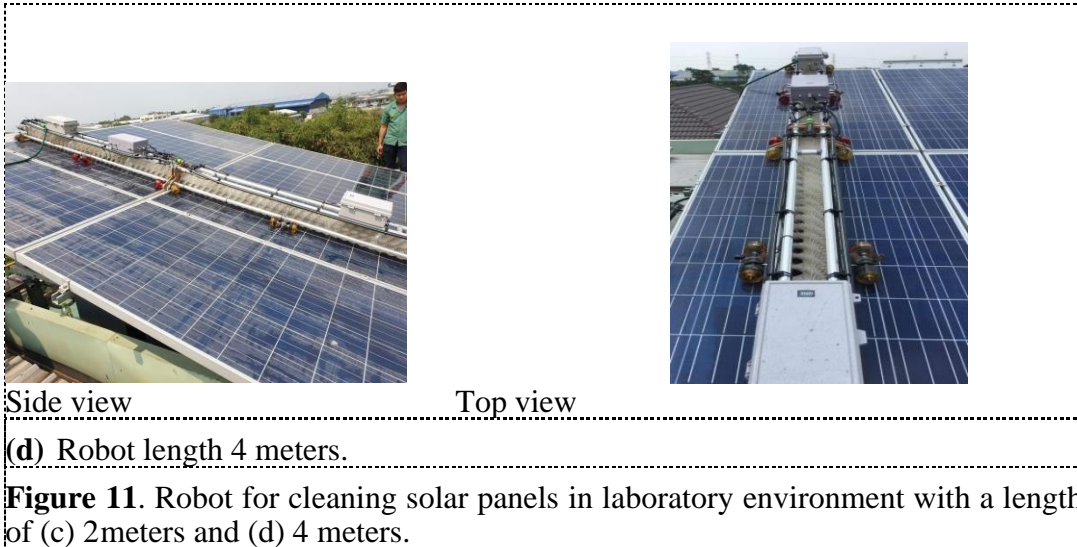


Side view



Top view

**(c)** Robot length 2 meters.



### 3. Results

There are three experiments on the performance for solar panel cleaning robot as follows.

#### 3.1. Speed control

In this test, the speed of movement is designed to meet the 3 levels; slow, medium, and fast. The duty cycle of the PWM (pulse width modulation) is used to control the brush motor and drive motor. The values of PWM percentages and measured speed are shown in Table 2.

#### 3.2. Solar panel gaps

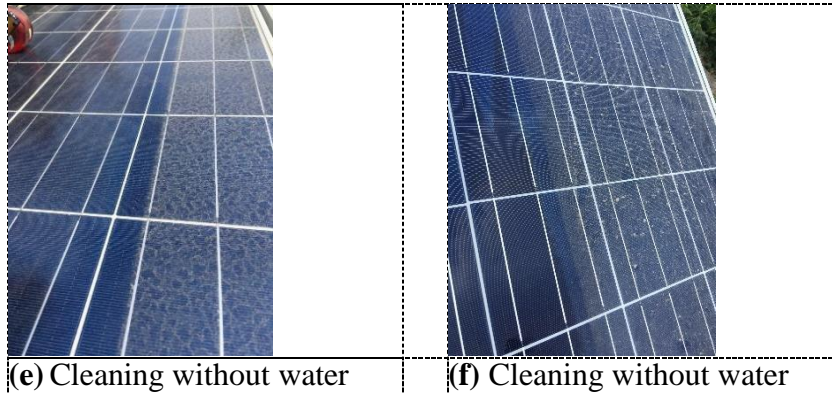
In this experiment, The performance is recorded and evaluated for the successful and failed cases. In this design, the maximum gap that the robot can pass is 3 centimeters. In case that the gap is less than 3 centimeters, all trials are successful the robot is evaluated to find the maximum values of the gap distance between the solar panel in each row. . However, if this value for gap distance increase, the front wheel can be modified for larger diameter as well.

#### 3.3. Edge-falling protection sensors

From the results, edge-falling protection systems can work properly at slow and medium speeds, the distance between the robot and the solar panel edge is 2.54 and 2.34 centimeters respectively and the robot does not fall off the solar panel. However, the robot is tested with a high-speed level, the stopping distance is decreased to 2.04 centimeters, but the sensor can be adjusted to increase this stopping distance.

### 4. Results and discussion

Robot for cleaning solar panel is tested in power plants environments. In this test, the robot can clean better with water as shown in Fig. 13.

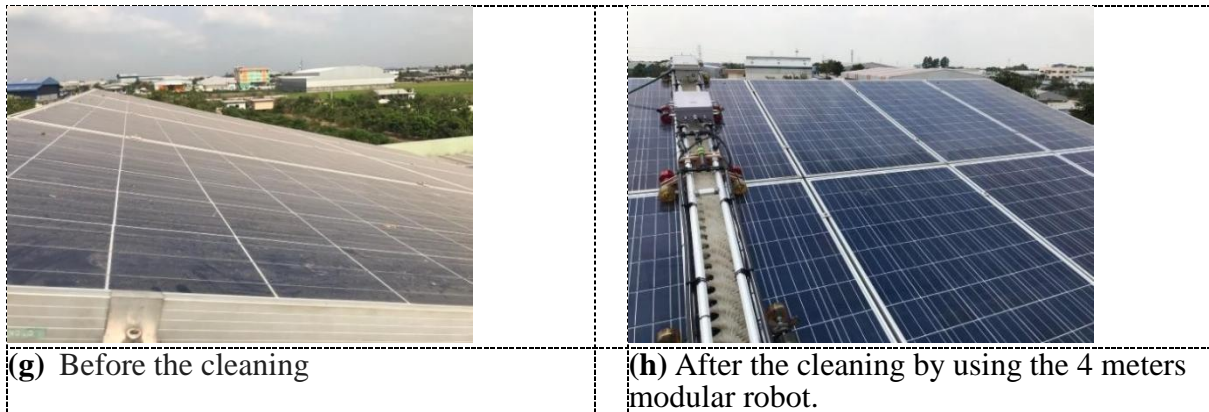


(e) Cleaning without water

(f) Cleaning without water

**Figure 12.** The experiment results from using robots to clean solarpanels (e) without water (f) with water.

For the comparison of dust characteristics, Fig. 14 demonstrates the difference between the solar panel before and after the complete cleaning.



(g) Before the cleaning

(h) After the cleaning by using the 4 meters modular robot.

**Figure 13.** Dust characteristics on the solar panels (g) before the cleaning (h) after the cleaning byusing the 4 meters modular robot.

The overall electricity production of solar cells is compared for the day before and after the cleaning. As a result, shown in Fig.15, the solar panels after cleaning with robot can increase the electricity production approximately 3.40%. However, the efficiency of electricity production may increase if the dirt on the solar panel is very dirty.

For testing the efficiency of solar panels cleaning robot, the power plant is analyzed and compared between the two adjacent area with a number of 40 panels per set. The two group of data is collected for each set of panels; 1) Panel that is not cleaned (controlled set) 2) Panel that is cleaned by the robot.

## 5. Conclusion

The characteristics of speed, gap distance, and stopping distance are examined for this design. The solar panels after cleaning with robot. A robot can clean reduce dirt and dust on the panel are generating electricity have increased.

The modular robot for cleaning solar panels with various length of the brush is successfully demonstrated for a range of 1-4 meters of solar panels. The module consists of the driving wheels and supporting wheels on the top and along the frame of solar panel respectively. The robot also has a fall-detection technique using photoelectric sensors. The robot will clean with water sprinkles and Nylon brush that will not deconstruct the surface of solar panels.



**6. References**

- [1] Solar power generation status report of Thailand 2014-2015, 2017, pp 13-17.
- [2] N. Sakarapunthip, D. Chenvidhya, S. Chuangchote, K. Kirtikara, T. Chenvidhya and W. Onreabroy, “Effects of dust accumulation and module cleaning on performance ratio of solar rooftop system and solar power plants”, Japanese J. Phys, 56, 2017.
- [3] B. Liamphrachan, Ph. Thamkaew, K. Buayai and K. Kerdchuen, “The Study for Performance Ratio Increasing of Soiling Solar PV Systems”, EENET J., vol. 1, 2017.