An Automated Solar Panel Surface Cleaning Control System Model for Optimizing Electricity Generation

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ABSTRACT
One of the factors that can impact the process of generating electricity from solar panels is the cleanliness of the solar panel surface. The level of dirt on the solar panel surface can result from the accumulation of dust during the dry season, and the dust on the surface of the solar panel tends to adhere when the surface is wet.

This research aims to develop a system model capable of automatically cleaning the surface of solar panels by activating a cleaning mechanism placed on the solar panel to perform the cleaning process. To detect the level of dirt on the surface of the solar panel, current and voltage sensors are applied to detect a decrease in the power output produced by the solar panel. If there is a decrease in power output from the solar panel, the system will then detect the intensity of sunlight using an LDR (Light Dependent Resistor) sensor. If the light intensity value is within the normal range, which is above 100 lux, the system will automatically activate the surface cleaning mechanism in response to the decrease in power output.

From the results of testing conducted on the system model, it has been found that this system model can detect dirt on the surface of solar panels. When the light sensor detects that sunlight intensity is above 100 lux but the power output from the solar panel decreases, the system will make the decision that the solar panel surface is dirty. Consequently, the system will automatically activate the cleaning mechanism installed on the surface of the solar panel to initiate the cleaning process. If it is detected that the power output from the solar panel has returned to normal, the system will automatically deactivate the solar panel cleaning system.

Keywords
Model, Simulation, Solar Panel Cleaner, Automatic.

1. INTRODUCTION
Solar panels are devices consisting of solar cells that convert light into electricity using the sun's energy (solar energy) as a source [1][2][3]. Solar energy is an energy source that will never run out, and it can be utilized as an alternative energy source that can be converted into electricity using solar cells [4]. Solar cells, also known as photovoltaic cells, generate energy without producing pollution, making them a clean source of electricity production without the need for combustion like fossil fuels such as oil and coal. Solar cells operate by harnessing light as particles or waves known as photons. Photons can be viewed as energy particles or as waves with specific wavelengths and frequencies.
Cleaning the surface of solar panels is crucial to ensure the optimal absorption of energy from the sun. Over time, the surface of solar panels is bound to accumulate dirt and dust due to changing weather conditions, the presence of animal debris, and strong winds carrying airborne dust that settles on the panel surface. All these factors can hinder the efficient absorption of solar energy by the solar panel [5][6][7].
Currently, the cleaning of solar panel surfaces is still carried out manually. To address this issue, there is a need to introduce a device for the optimization of solar panels. This device would work by detecting the presence of dirt or dust on the surface of the solar panels, triggering the release of water through pipes and the automatic activation of wipers/brushes. This innovation aims to simplify the cleaning process for solar panels and reduce the workload on workers while optimizing the power output.
The research related to this research includes:

1. The study titled "Design of a Prototype Solar Panel Cleaner with an Automated Motion System" by Faridah Hanim Binti Mohd Noh and his colleagues, published in the 2020 edition of the Indonesian Of Electrical Engineering and Computer Science, in this paper a robot design for automatic cleaning of PV panel surfaces is presented. This design utilizes an Arduino controller system to control the movement of the robot during the cleaning process. Apart from that, it is equipped with two rough sponges and a water pump system which can be used to clean dust or dirt on the surface of the PV panels. The efficiency of PV panels before and after the cleaning process is also considered. The results show that the developed solar panel cleaning robot is able to clean the panels effectively and increase the output current and maximum power of the panels by 50%, after the dust on the PV panels is cleaned. [8].

2. The research titled "Design and Construction of a Solar Panel Cleaner Device Using Outseal PLC and IR Proximity Sensor Connected to Android via WiFi Module DT-06 and Bluetooth Module HC-05" by Bambang Ardi, published in the "Electrical Engineering Journal," focuses on the development of a solar panel cleaner in the form of a tank-like robot that can be remotely controlled via an Android application using the HMI Modbus interface. The robot is controlled through the WiFi module DT-06 and Bluetooth module HC-05, with Outseal PLC Nano V.5.0 serving as the microcontroller. The system comprises DC motors for the tank's movement and the cleaner roller, and an IR Proximity sensor acts as a safety feature to stop the robot when it reaches the boundary of the solar panels. The design also incorporates relays to connect the DC motors and batteries as the power source for the system. From the control testing results, it was found that the robot tank can operate as per commands issued through the HMI Modbus Android application when connected via WiFi within a range of less than 14 meters without obstacles and less than 10.5 meters when obstacles are present. When connected via Bluetooth HC-05, the robot can establish a stable connection within a range of less than 18 meters

without obstacles and less than 12 meters when obstacles are present. The total power consumption of this system is approximately 3.7 watt [9].

2. METHODOLOGI

The method used in this research is design and manufacturing methods, which include system design and manufacture, in the form of an integrated control circuit and software to run the entire system. The system testing process is done by simulating it through Program simulation.

2.1 System Design

System design is made to facilitate the system development process by modeling it in the form of a Block Diagram, as shown in Figure 1.

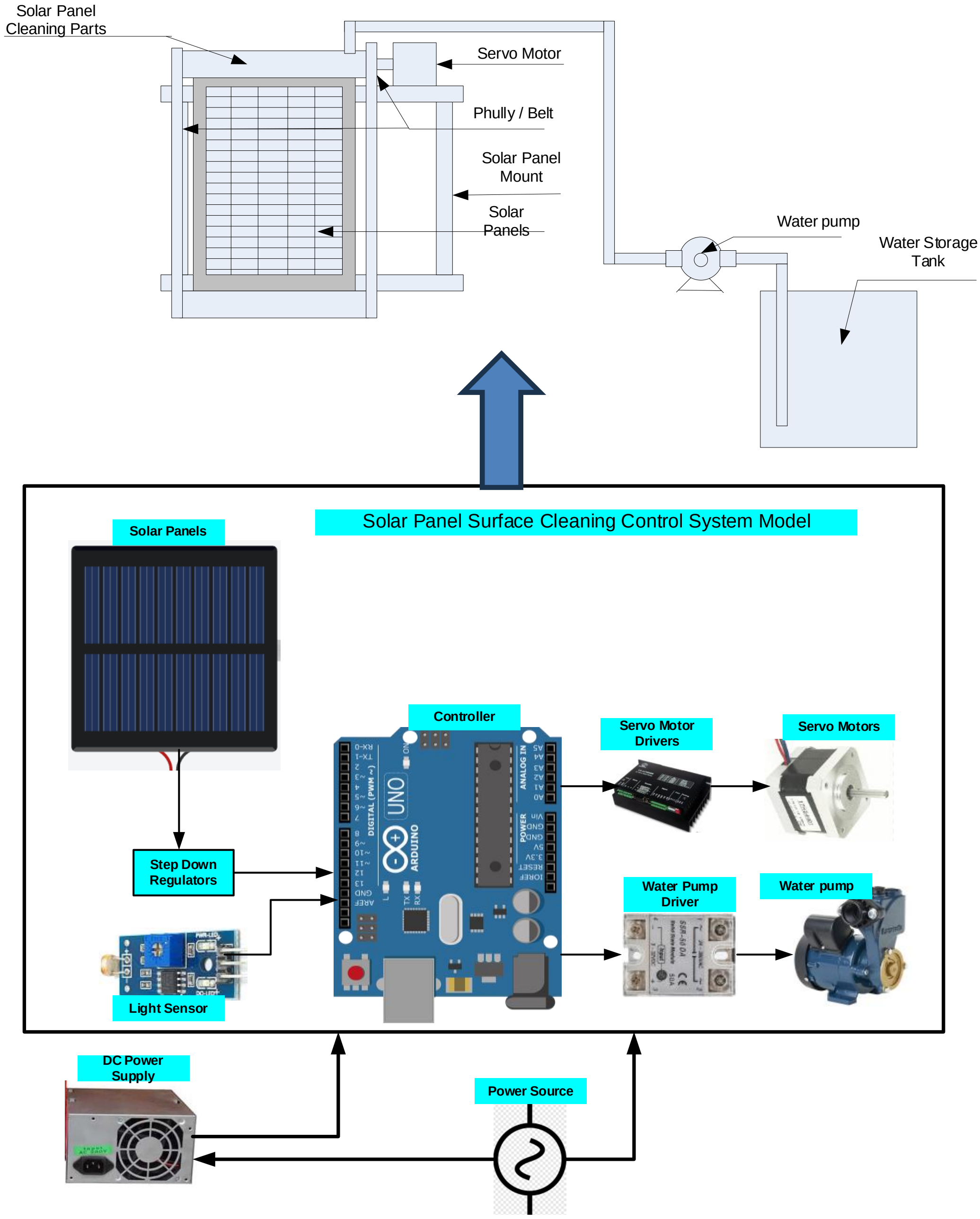

Fig. 1 Block diagram system

Image Caption 1:

1. Controller: Functions as the central data processing unit for the solar panel surface cleaning system, where the controller activates the operation of the solar panel surface cleaning components based on inputs from the voltage sensor and inputs from the light sensor. When a decrease in power generation from the solar panel is detected through a decrease in its output voltage, and the controller detects that the sunlight intensity level is above 100 lux, the controller will automatically activate the solar panel surface cleaning components until it detects that the output power has returned to normal, in accordance with the sunlight intensity conditions received by the light sensor.
2. Step-down Regulator: Serves as the voltage sensor to detect any voltage changes generated by the output of the solar panel.
3. Light Sensor: Functions as a medium for detecting the

level of sunlight intensity.

4. Solar Panel: Serves as a medium for generating electrical energy based on the level of sunlight.
5. Servo Motor Drive: Functions as the connection medium between the controller and the Servo Motor, serving as a switch (On/Off).
6. Servo Motor: Functions as the driving medium for the solar panel surface cleaning components.
7. Water Pump Driver: Serves as the connection medium between the controller and the Water Pump, functioning as a switch (On/Off).
8. Water Pump: Acts as the medium to transport water from the reservoir to the solar panel surface cleaning components for the purpose of cleaning the solar panel surface.
9. DC Power Supply: Functions as the medium to provide DC electrical support for the control system.
10. Power Source: Serves to deliver 220 Volt AC electricity to the DC Power Supply unit and provides electrical supply for the operation of the Water Pump.

2.2 Soft Ware Design (Flow Chart)

Flowchart system (algorithm), is a representation of the workflow or process to run the system, where the resulting algorithm is translated in the form of software, which will be embedded into the controller to run system work. This system flowchart is shown in Figure 2.

The operational principles of the system based on the Algorithm in Figure 2 are as follows:

- When the system is activated, it initiates a process that includes: Initializing the LCD Display, Initializing the Servo Motor, and initializing the variables used in the program.
- After the initialization process is completed, the next procedure is to read input data generated by the voltage sensor, based on the voltage output from the solar panel. If the received data falls within the range of 4 volts to 6 volts, the procedure involves deactivating the Servo Motor, deactivating the Water Pump, and displaying information on the LCD Display regarding the detected voltage magnitude, the detected light intensity, and the information that the solar panel surface is clean. Following this, the system will repeat the procedure to continuously monitor the voltage output condition of the solar panel.
- If the voltage output from the solar panel is detected to be below 4 volts, the system will initiate a procedure to detect the sunlight intensity level by reading data from the light sensor. If the light sensor data received is below 100 lux, the system will run a program to deactivate the Servo Motor, deactivate the Water Pump, and display information on the LCD Display regarding the amount of voltage detected, the intensity of the light detected, and the required information. the solar panel surface is clean. The system will then repeat the procedure to continuously monitor the voltage output condition of the solar panel.
- - If the light sensor data received is above 100 lux, the system will run a program to activate the solar panel surface cleaning component. This includes activating the Servo Motor which will operate in a movement range of 0o to 180o, as well as activating the Water Pump to channel water from the reservoir to the solar panel surface cleaning components. Apart from that, information will appear on the LCD screen indicating that the surface of the solar panel is dirty.
- While the process of cleaning the solar panel surface is ongoing, the system will continuously detect changes in the voltage output from the solar panel. If it detects that the voltage output from the solar panel, as sensed by the voltage sensor, has risen above 4 volts, the system will automatically deactivate the solar panel surface cleaning components.
- This cycle will continue continuously until the system is deactivated.

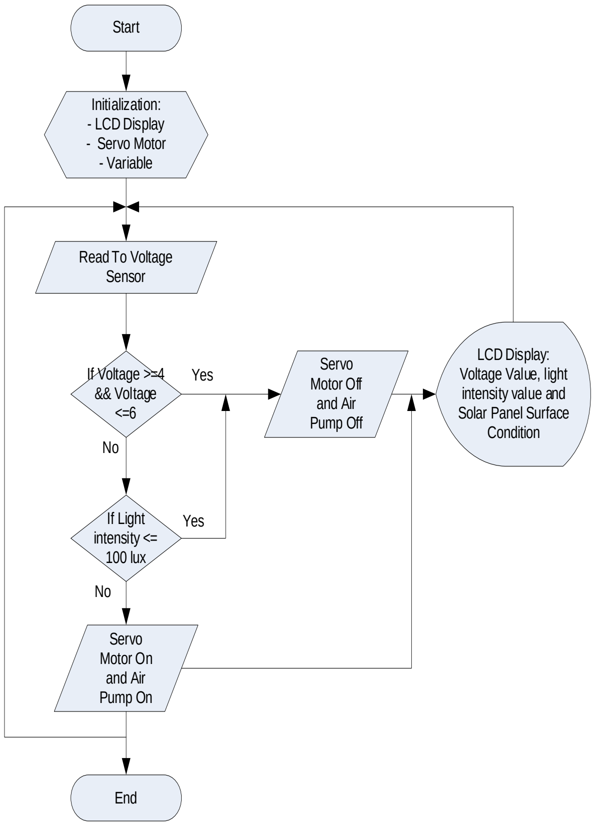

Fig.2 Flowchart system

2.3 System Design

The system design refers to the block diagram that has been created, where the Voltage sensor module, light sensor module, solar panels module, LCD display, Servo motor module and LED as an indicator for the water pump. These modules are integrated with the controller module, where the controller module used is Arduino Uno. Arduino Uno controller which functions as the overall work controller of the system. Figure 3 shows the system design created.

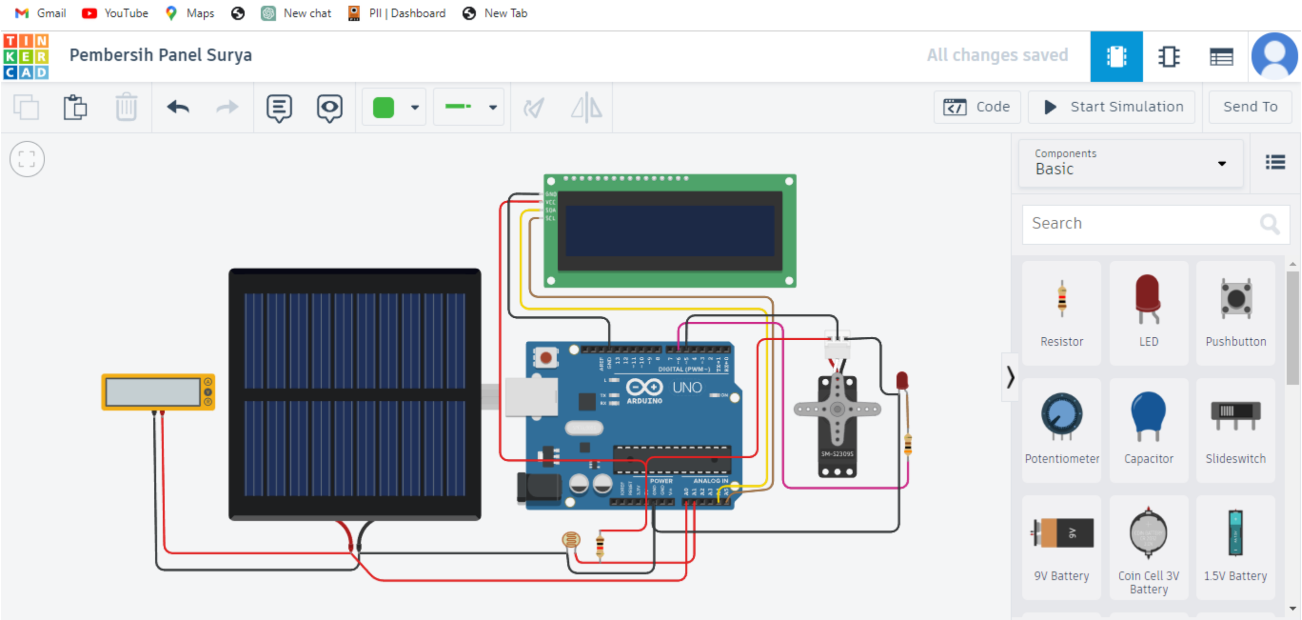

Fig. 3 System Design

2.4 Software Making

The software is made based on the system algorithm that has been generated. The process of making software, made through the TinkerCad program simulation. Program creation is shown in Figure 4.

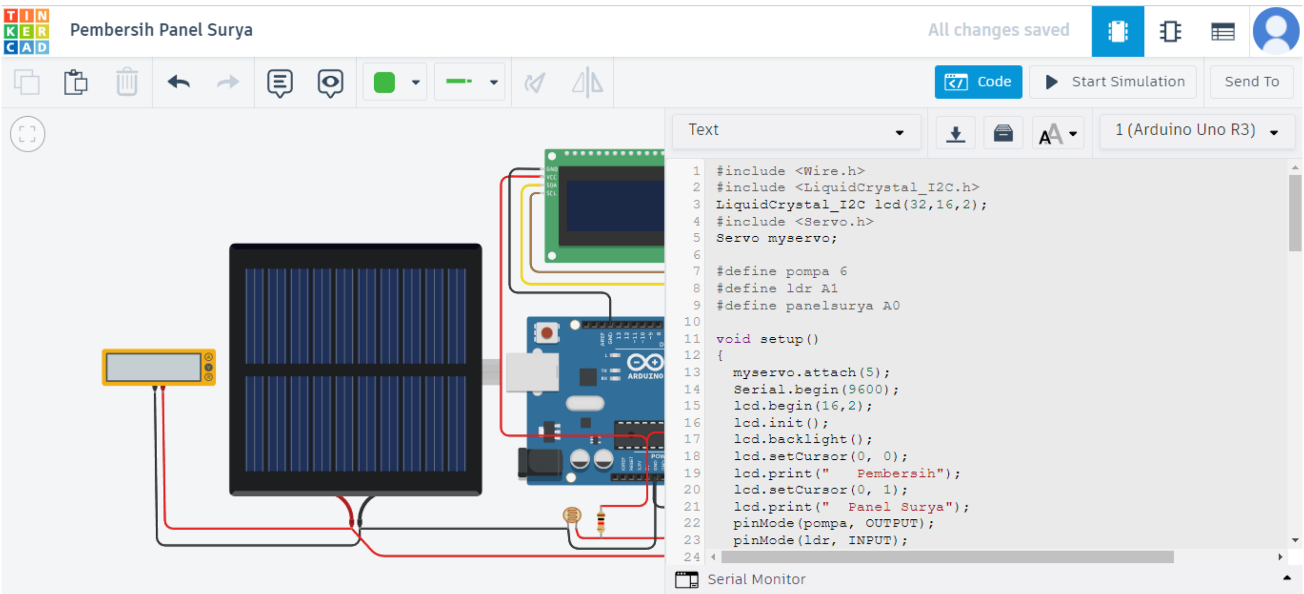

Fig. 4 Program creation

3. RESULT AND DISCUSSION

The system testing process is carried out through the TinkerCad program simulation, by embedding the program created based on the algorithm program via TinkerCad program simulation in section coding. Stages of system testing as follows:

3.1 System Testing When First Activation

When the system is first activated, the first part that is executed is the setup section, where in this section the system will configure the LCD display that is used as the information media. The system will then display information via the LCD display about the function of the system created.

The system setup program section is as follows:

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(32,16,2);
#include <Servo.h>
Servo myservo;
#define pompa 6
#define ldr A1
#define panelsurya A0

void setup()
{
 myservo.attach(5);
 Serial.begin(9600);
 lcd.begin(16,2);
 lcd.init();
```

```
lcd.backlight();
lcd.setCursor(0, 0);
lcd.print("   Cleaner");
lcd.setCursor(0, 1);
lcd.print("  Solar Panels");

pinMode(pompa, OUTPUT);
pinMode(ldr, INPUT);
pinMode(panelsurya, INPUT);
  myservo.write(0);
  delay(1000);
}
```

The initial display when the system is first activated is shown in Figure 5.

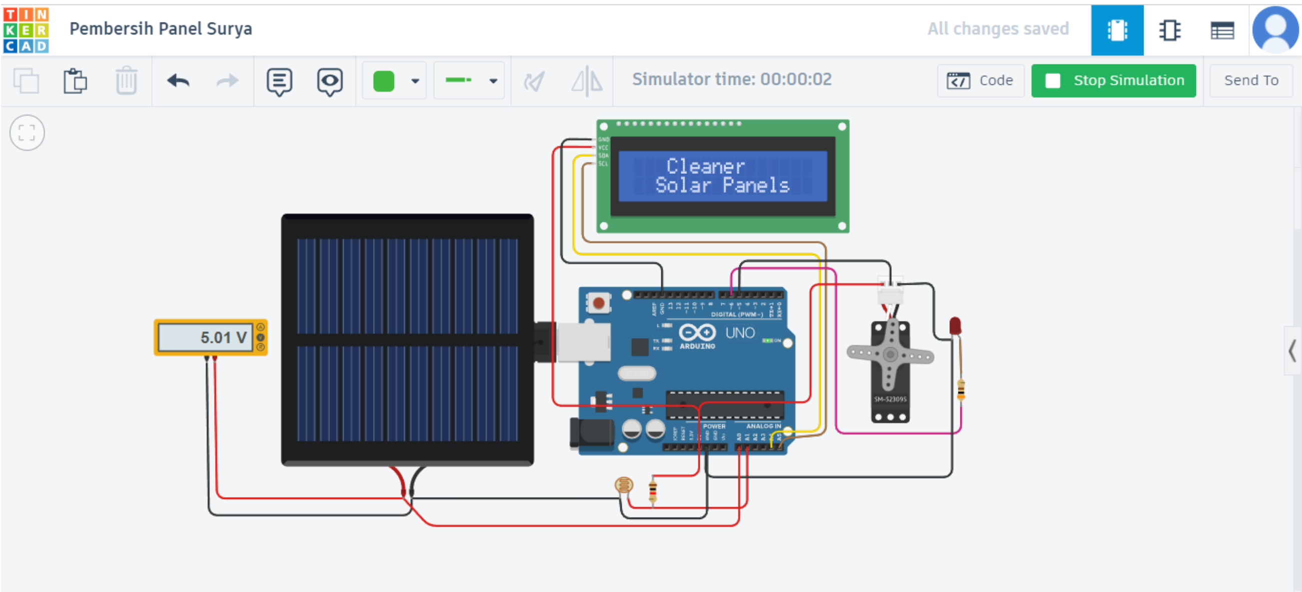

Fig. 5 Testing when the system was first activated

3.2 Testing When Detected Solar Panel Surface Is Clean

After the setup process is complete, the system will enter the voltage sensor reading section, where the voltage sensor will detect the output voltage from the solar panel. In the voltage sensor reading section, if the data received is in the range between 4 volts to 6 volts, then the procedure carried out is to deactivate the servo motor and deactivate the water pump. and informs via the LCD screen regarding: the amount of output voltage from the solar panel detected via the voltage sensor, the amount of light intensity detected via the light sensor and displays information that the surface of the solar panel is clean. The test results are shown in Figure 6.

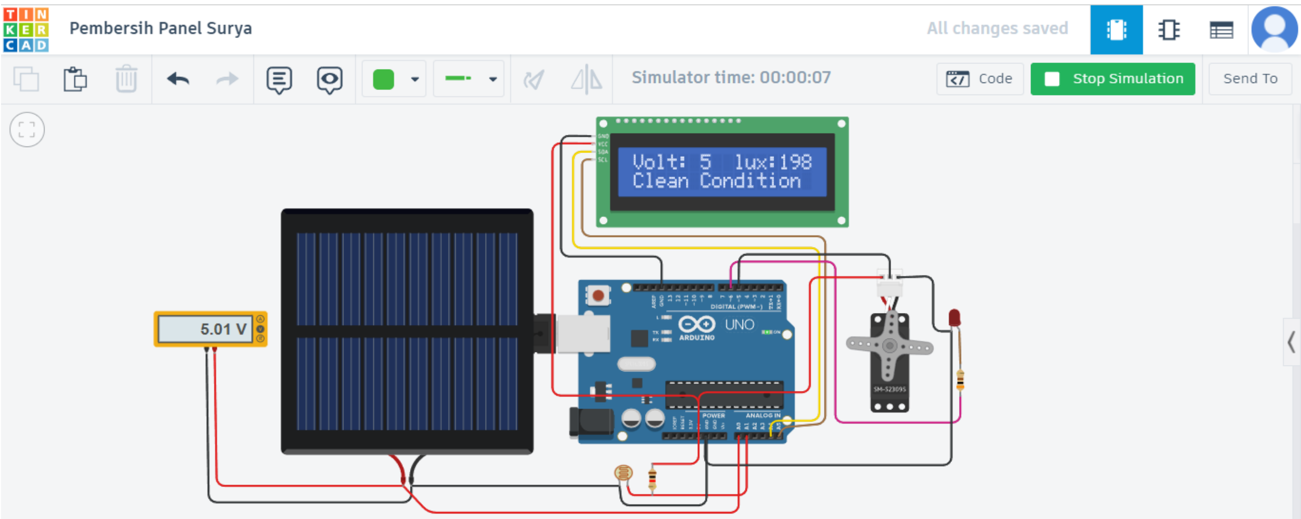

Fig. 6 Testing of conditions for Panel Surface Is Clean

From the results of the testing conducted, as shown in Figure 6, it is demonstrated that when the voltage sensor detects a voltage value generated by the solar panel of 5 volts, which falls within the range of values from 4 volts to 6 volts, the control system will deactivate the Servo Motor, deactivate the Water Pump, and display information on the LCD Display regarding the detected voltage magnitude, the detected light intensity, and the information that the solar panel surface is clean.

The part of the program that is executed is as follows:

```
if (output_value >= 4 && output_value <= 6){
  lcd.setCursor(0, 1);
  lcd.print("Clean Condition");
  Serial.println ("Condition Of The Solar Panel Surface Is Clean");
  digitalWrite(pompa, LOW);
  myservo.write(0);
```

If the detected voltage value falls below 4 volts (3.82 volts), the system will proceed to detect the level of sunlight intensity by reading the light sensor. If the light sensor data received is below 100 lux (77 lux), the system will execute the program to deactivate the Servo Motor, deactivate the Water Pump, and display information on the LCD Display regarding the detected voltage magnitude, the detected light intensity, and the information that the solar panel surface is clean. Figure 7 shows the system test results when it is detected that the solar panel output voltage is below 4 volts.

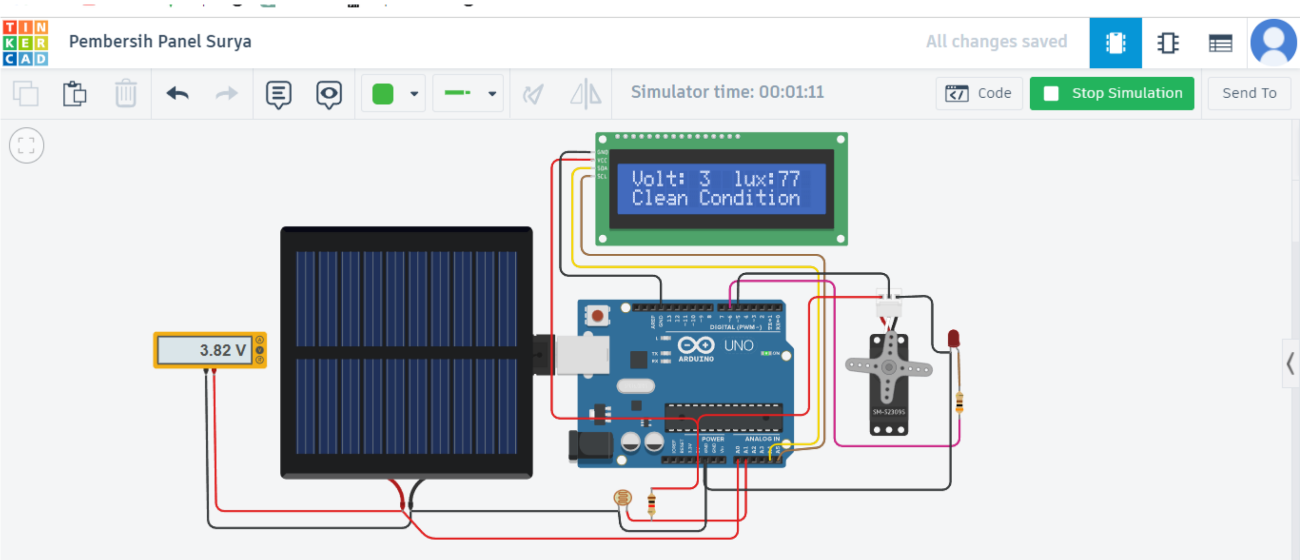

Fig. 7 The system test results detected that the solar panel output voltage was below 4 volts and the light intensity was below 100 lux

From the test results, it is evident that when the detected voltage output from the solar panel falls below 4 volts (detected at 3 volts), and the sunlight intensity value detected by the light sensor is below 100 lux (measured at 77 lux), the system will execute the program to deactivate the Servo Motor, deactivate the Water Pump, and display information on the LCD Display regarding the detected voltage magnitude, the detected light intensity, and the information that the solar panel surface is clean.
The part of the program that is executed is as follows:

```
else {
   if (output_value1 <= 100){
   lcd.setCursor(0, 1);
   lcd.print("Clean Condition");
   Serial.println ("Condition Of The Solar Panel Surface Is Clean");
   digitalWrite(pompa, LOW);
   myservo.write(0);
  }
```

3.3 Testing When Detected Solar Panel Surface Is Dirty

Testing was carried out to assess the performance of the system in detecting the output voltage of solar panels via a voltage sensor and the value of sunlight intensity via a light sensor. If the solar panel output voltage is detected below 4 volts, the system will start a procedure to detect the intensity level of sunlight by reading data from the light sensor. If the light sensor data received is above 100 lux, the system will run a program to activate the solar panel surface cleaning component. This includes activating the Servo Motor which will operate in a movement range of 0º to 180º, as well as activating the Water Pump to channel water from the reservoir to the solar panel surface cleaning components. Apart from that, information will appear on the LCD screen indicating that the surface of the solar panel is dirty. Figure 8 shows the system test when it is detected that the surface of the solar panel is dirty.

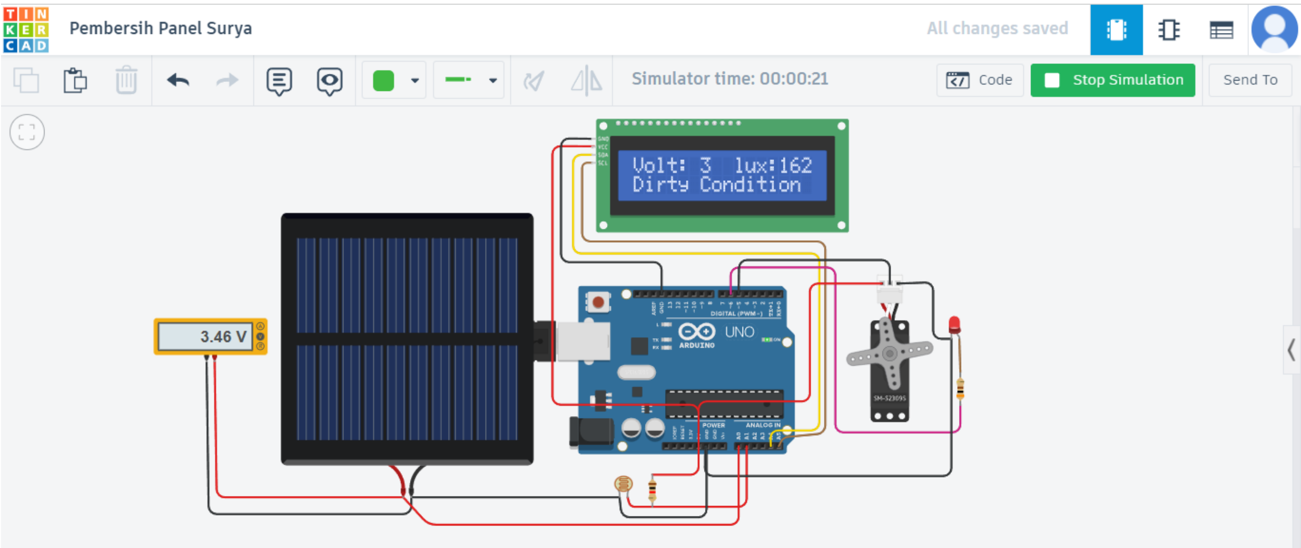

Fig. 7 System test when it is detected that the surface of the solar panel is dirty

From the test results as in Figure 8, it can be seen that when the control system detects that the solar panel output voltage falls below 4 volts (measured at 3 volts) and the intensity of sunlight through light sensor data is detected to be above. 100 lux (measured 162 lux), the system will run a program to activate the solar panel surface cleaning component. This includes activating the Servo Motor which will operate in a movement range of 0º to 180º, as well as activating the Water Pump to channel water from the reservoir to the solar panel surface cleaning components. Apart from that, information will appear on the LCD screen indicating that the surface of the solar panel is dirty.

This condition will continue continuously until the control system detects that the solar panel output voltage increases above 4 volts, and will automatically deactivate the work of the solar panel surface cleaning section.

The parts of the program implemented are as follows:

```
else{
        lcd.setCursor(0, 1);
        lcd.print("Dirty Condition");
        Serial.println ("Condition Of The Solar Panel
Surface Is Clean Dirty");
        digitalWrite(pompa, HIGH);
        myservo.write(20);
        delay(1000);
        myservo.write(40);
        delay(1000);
        myservo.write(60);
        delay(1000);
        myservo.write(80);
        delay(1000);
        myservo.write(100);
        delay(1000);
        myservo.write(120);
        delay(1000);
        myservo.write(140);
        delay(1000);
        myservo.write(160);
        delay(1000);
        myservo.write(180);
        delay(2000);
        myservo.write(160);
        delay(1000);
        myservo.write(140);
        delay(1000);
        myservo.write(120);
        delay(1000);
        myservo.write(100);
        delay(1000);
        myservo.write(80);
        delay(1000);
        myservo.write(60);
        delay(1000);
        myservo.write(40);
        delay(1000);
        myservo.write(20);
        delay(1000);
        myservo.write(0);
        delay(1000);
    }
```

4. CONCLUSIONS

Based on the testing results, it can be concluded that the model of the solar panel surface cleaning control system can carry out the process of cleaning the solar panel surface by detecting the voltage output from the solar panel and changes in sunlight intensity. Specifically, when the voltage output from the solar panel is detected to be below 4 volts, the system initiates a procedure to detect the level of sunlight intensity by reading data from the light sensor. If the light sensor data received is above 100 lux, the system executes the program to activate the solar panel surface cleaning components. This includes activating the Servo Motor, which operates within a range of movement from 0º to 180º, and activating the Water Pump to flow water from the reservoir to the solar panel surface cleaning components. Additionally, it displays information on the LCD display indicating that the solar panel surface is dirty.

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