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Performance Analysis of PV Loading Management System based on Weather Conditions

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***Abstract*— The photovoltaic loading management system has been designed according to weather conditions. The performance analysis of the PV loading management system based on weather conditions is presented in this paper. The load management mechanism works as follows: when the charging current drops but the battery capacity is still large, the high load option is maintained. When the charge current decreases and the battery capacity is medium, the loading option will switch to medium load. If the charging current drops lower and the battery terminal voltage is lower than 22.3 Volts, then the low load option will be selected. The PV current fluctuation affects the battery voltage, which causes a reduction in the maximum load that the loading management system can serve. The charging current can be estimated from the difference between PV current and recharging current. The analysis results show that an increase in the supply of renewable energy generation can also be done on the demand side. Therefore, it is necessary to apply PV loading management to improve and maintain the continuity of electricity supply from solar sources in the future.**

***Keywords*— loading management system, photovoltaic, continuity supply, and renewable energy.**

I. INTRODUCTION

Installation and utilization of renewable energy plants to reduce dependence on fossil fuels and the need to reduce carbon emissions will continue to increase near future [1]. Future sources of power generation will increasingly be dominated by renewable energy sources dependent on the weather, which is variable and uncertain by nature [2]. Solar power generation uses photovoltaic (PV) panels made of semiconductor materials to convert the electrical energy of sunlight into electrical energy. The power output of solar panels is characterized by non-linear behavior due to variations in solar irradiance moving from east to west and solar cell temperature [3]. The equatorial region has more solar radiation energy than the sub-tropical and polar regions [4].

Solar photovoltaic is a form of renewable energy that does not run out when used, unlike other conventional resources which run out when fed and its availability is running low. [5]. In addition, solar energy is also called green energy, which does not produce carbon emissions. Excessive gas emissions can cause global warming or the greenhouse effect such as acid rain. As a green energy, solar PV does not pollute the surrounding environment so that it becomes an alternative energy that is widely chosen [6]. This energy plant only requires the existing land for the PV panel placement area, while the remaining space can be used for other purposes such as agriculture. You can also use the roof of the building to place its solar panels, which is called PV rooftop.

The disadvantages of solar energy are difficult to predict [7] and intermittent energy [4]. Power plants with energy sources from nature are generally unpredictable but can be arranged to obtain sustainable and continuous energy [8]. Various methods are applied to smooth out fluctuations in the output power of new and renewable energy generators. Energy management and energy storage devices are commonly used to smooth out intermittent generation output variations due to unpredictable power sources. [9]. However, the use of energy from fossil fuels still has an essential role because of its convenience and high reliability. It is still used as a backup source of renewable power plants. [10], [11]. Therefore, considering electricity supply from new and renewable sources still needs to be mixed with fossil energy.

Research related to renewable energy sources has received significant attention due to their economic and sustainable characteristics [12]. Although availability has been intermittent, it can now be overcome by using smart grid technology, digitizing, and coordinating the available generation. However, research to get the right and accurate techniques and algorithms is still being carried out and will continue to be improved.

II. PV LOADING MANAJEMENT SYSTEM DESIGN

Several sensors will be connected directly to the Arduino Mega 2560 microcontroller. There is no need for other communication support to get the photovoltaic current value and voltage on the battery is reading data. However, a manual multimeter needs to be calibrated by comparing the output bit analog readings with the RMS readings. The solid-state relay can also be directly connected to the Arduino Mega 2560 microcontroller as a component to activate and deactivate the load line. More details can be seen in Fig. 1 Load Management System Series.

In Fig. 1, you can see a series of analog pins and digital pins connected to several sensors used. The DC Voltage Sensor circuit is connected to pin A1. Meanwhile, the DC current sensor is connected to pin A2 on analog IN. Meanwhile, 3 Solid State Relays are connected to digital pins 2, 3, and 4. The supply voltage for each component used is connected in parallel with the supply voltage of Vcc 5V.

Testing all components installed and connected to the Arduino Mega 2560 was carried out on the 2nd floor of the Electrical Engineering Department, Universitas Andalas. The readings from each sensor used as load channel selection parameters can be seen when the load management system is run. To be clear, the following can be seen as the circuit of all components connected to the Arduino Mega 2560 Microcontroller.

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The testing process is carried out when the PV system is on before being loaded with 8x100watt incandescent lamps, which are assumed to be household loads. Before being loaded, the system will read the output of the Photovoltaic and Battery modules, which are used as working parameters of the Solid State Relay. All sensor readings from the measured values can be displayed on the Arduino serial monitor.

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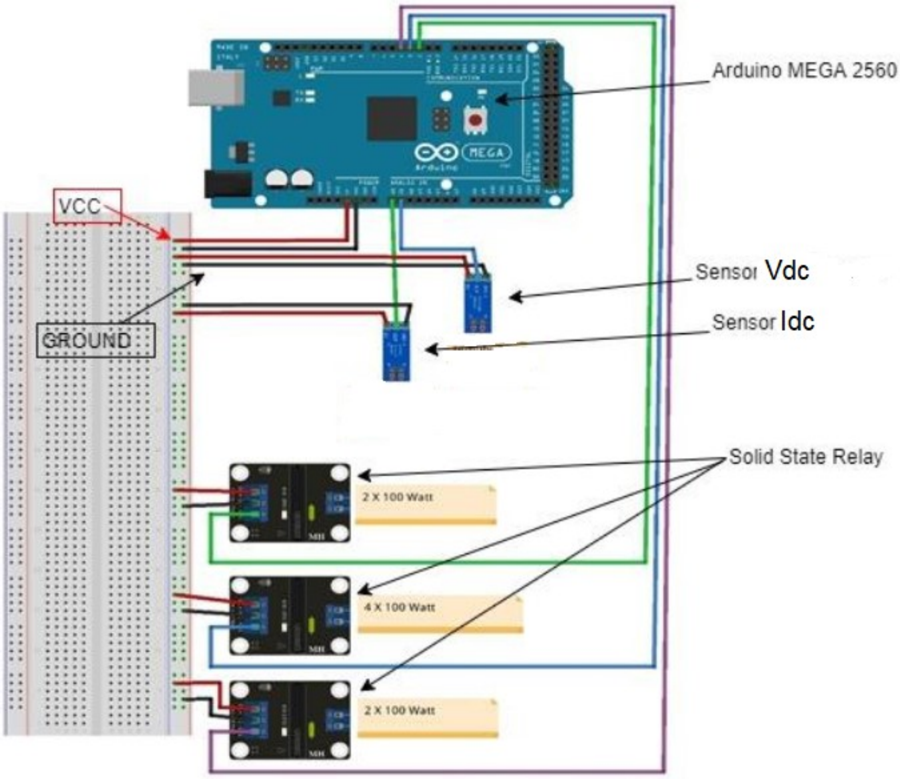

Fig 1. Wiring diagram of PV loading system using Arduino Mega 2560

The Arduino Mega 2560-based load management system uses several sensors and solid-state relays that do not require a library to read data. DC Current and DC voltage sensors can directly communicate with Arduino. At the same time, the solid-state relay can be directly connected to the Arduino, which is connected to the digital pin available on the Arduino board. It shows how the Arduino program's initial declaration can recognize sensors (DC Current and DC Voltage Sensors).

Furthermore, the Arduino program code uses a 9600 baudrate as an Arduino introduction and data transfer speed to be connected to an application or device other than the Arduino application positioned in the Void Setup function. The function of this program is as the main command and initial command that will not be read repeatedly by the Arduino.

```
void setup() {
  Serial.begin(9600);
  pinMode(relayPin1, OUTPUT);
  pinMode(relayPin2, OUTPUT);
  pinMode(relayPin3, OUTPUT);
  Serial.println ("PV management systemd");
  Serial.println ("\tICh(A)\tVBat(V)\tBebanMax(W)");
}
```

The void data_olah function contains data processing commands that will be used when the void loop function is run to measure the value of each sensor used.

```
void data_olah() {
  nilaiadc = analogRead(analogPincurrent);
  tegangan = (nilaiadc / 1024.0) * 5000;
  Ipv = ((tegangan - teganganoffset) / sensitivitas);

  value = analogRead(analogPinvoltage);
  VModul = (value * 5.0) / 1024.0;
  VBat = VModul / (R2 / (R1 + R2));

}
```

The Void Loop function contains different variables that are adjusted to the readings on each sensor used. The calculations in each of these variables can be displayed on the serial monitor as needed. The command on the void loop will be read repeatedly by Arduino for a period (delay) that can be determined as required.

III. SYSTEM TESTING

The output of the PV system, in this study, uses a sensor as a parameter for selecting the load line. Photovoltaic current and battery voltage readings use the sensor as a medium. The ACS712 30A sensor reads the photovoltaic current, and the DC voltage sensor reads the battery voltage. This DC Voltage Sensor uses the working principle of a voltage divider. Using 30k for R1 and 7.5k for R2, this

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module can reduce the input voltage up to 5 times the source voltage. The maximum voltage rating on this sensor is 25V.

The standard voltage on Vout as the input voltage limit on the Arduino is 5V so that it can read the voltage on the battery up to 25 Vdc. The PV rooftop output current reading is obtained from the ACS712 30A sensor reading. This sensor is a module to detect the amount of current flowing out of the PV module. The ACS712 sensor can measure a maximum of positive and negative currents ranging from -30A to 30A. This sensor works with a power supply of 5V and has a middle value (0A).

A DC voltage sensor calibration with a DC current sensor is performed by comparing manual measurements using a multimeter to get the measurement results used as load-line displacement parameters.

TABLE 1. DC VOLTAGE SENSOR MEASUREMENT RESULTS

No	Multimeter (Vdc)	Sensor (Vdc)	Error (%)
1	24.75V	24.35V	1.6
2	24.95V	24.40V	2.2
3	24.50V	23.46V	4.1
4	24.76V	23.88V	3.5
5	23.34V	23.12V	0.8

From Table 1, it can be seen that the results of measurements made with a DC voltage sensor have errors/differences from the results of measurements with a Multimeter. The error obtained varies from 0.8% to 4.1%.

TABLE II. DC CURRENT SENSOR MEASUREMENT RESULTS

No	Multimeter (Idc)	Sensor (ACS712)	Error (%)
1	15.13	15.42	1.2
2	12.51	12.67	0.6
3	10.17	10.45	1.1
4	7.82	7.96	0.5
5	4.54	5.02	2

From Table 2, it can be seen that the results of measurements made with a DC current sensor have errors/differences from the results of measurements with a Multimeter. The error obtained varies from 0.5% to 1.2%.

A. Sket Program design

The design mechanism of the operation and loading management of the PV system can be seen in Fig. 2, where the parameters (charging current and battery voltage) that are used as input will affect the output (maximum load channel selection) that the system can serve. Determination of high load, medium load and low load depends on the combination of charging current (Ich) readings and battery terminal voltage (VBat). When the charging current drops but the battery capacity is still large which VBat more than 24.89 V, the high load option is still maintained. When the charge current drops and the battery capacity is medium between 22.3V and 24V, the loading option will switch to medium load. If the charging current drops lower and the battery terminal voltage is lower than 22.3 V, then the low load option will be selected.

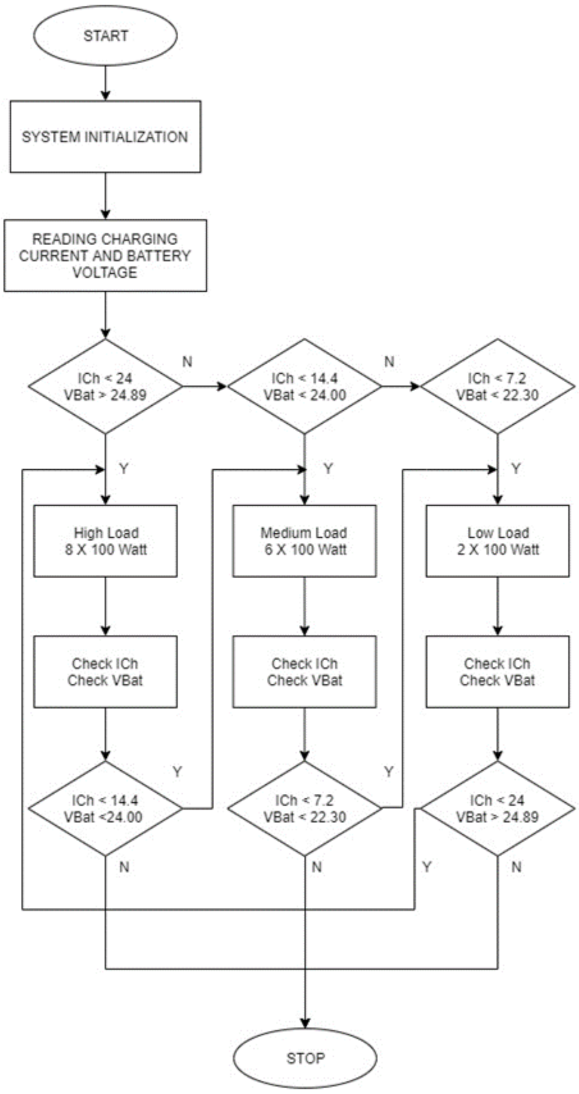

Fig 2. Mechanism of PV loading management system

The loading mechanism is realized using a solid-state relay as a switching switch from low, medium, or high loads. The electricity source from the PLN grid is chosen as the last option when the PV power source is no longer available. The test was carried out using eight incandescent light points of 100 W each. The loading levels were adjusted so that the maximum load was low at 200W, 600W medium, and 800W high.

IV. RESULT AND DISCUSSIONS

The load management system aims to regulate the load that can be fed or served by the system based on the availability of Photovoltaic Current and Voltage in the PV system battery. Several variables that will be monitored and used as load channel selection parameters are DC current and DC voltage. All data can be viewed and recorded in real-time on a Personal Computer using CoolTerm software. More details can be seen in Fig. 3.

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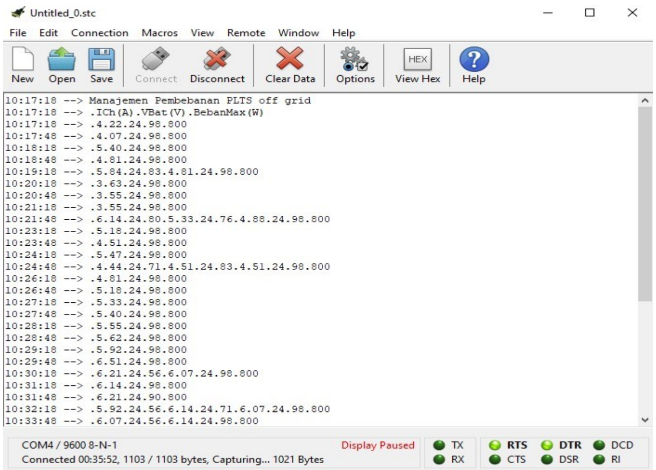

Fig 3 CoolTerm display

In collecting data from this load management system, it is carried out under fluctuating weather conditions and conditions. Solar panels are placed on the roof of the Electrical Engineering Department Building, Andalas University. On average, solar panels begin to harvest solar energy actively, converted into electrical energy starting from 7.00 WIB to 18.00 WIB. Weather conditions significantly affect the availability of energy that can be converted into solar panels. Therefore, the average data collection starts at 10.00 WIB until 15.00 WIB.

The data retrieval process was carried out on June 21, 2021, using a serial monitor facility connected to CoolTerm software, which can display and record data in the form of txt. After testing and recording the data in txt form, it will be processed in Ms. Excel to create a graphic display that can be seen in the following fig. 3.

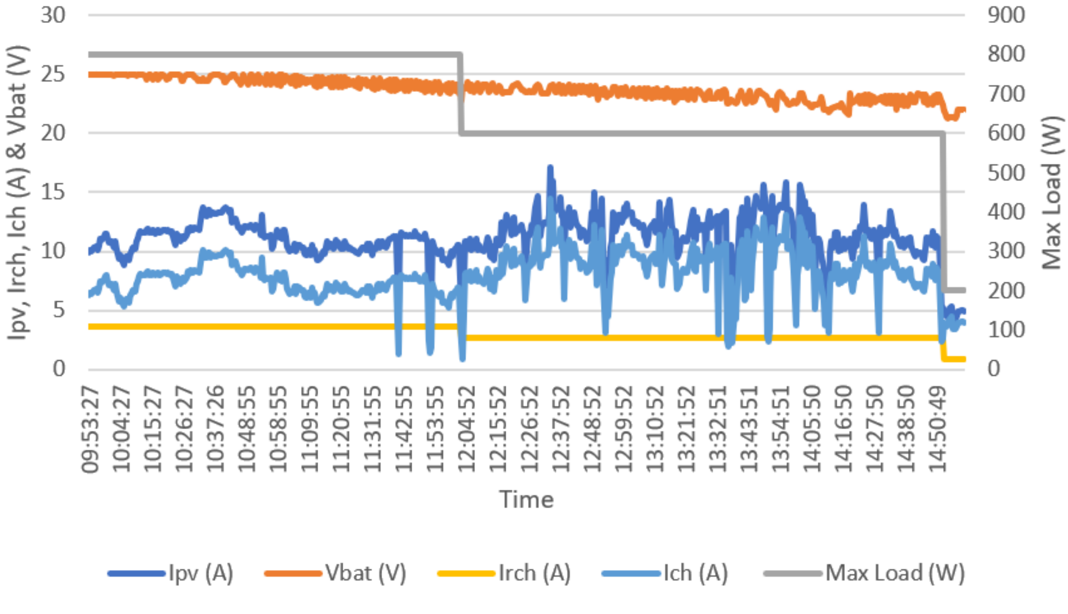

Fig 4. Graph of PV loading management testing under the clear sky weather condition

From Fig. 4, it can be seen that the change in the maximum load that the system can serve decreases as the photovoltaic current rises and falls. Looking at the graph, Ipv fluctuations affect Vbat, which causes a decrease in the maximum load that the system can serve. At 12.02 WIB, Ipv was seen at 10.21 A, and Vbat was at 23.75V. This indicates that the maximum load that the system can serve is a medium load line (600W). The decision to move the maximum load line from the high load line to the medium load line occurred because the Ipv decreased to 5.1 A from 7.92 A and the voltage drop from 24.15 V to 22.78 V on the battery, so the system moved the high load line to the medium load line. The graph above shows how the recharging current occurs along with the loading carried out by the system; the charging current is estimated from the difference between Ipv and Irch.

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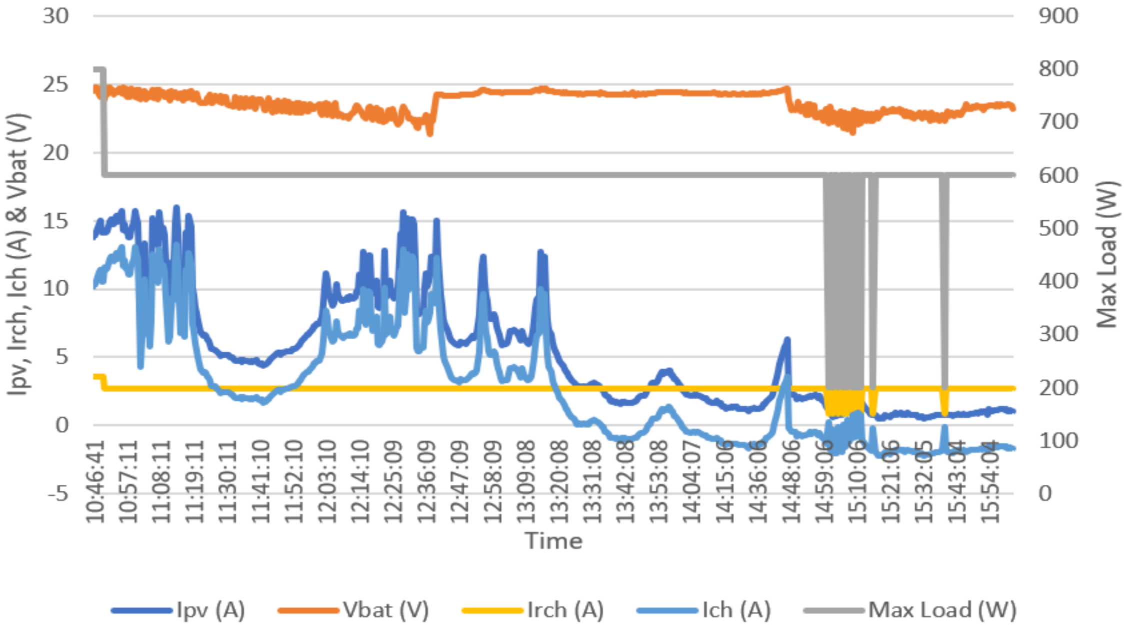

Fig 5. Graph of PV loading management testing under the cloudy weather condition

It can be seen in Fig. 5, which is shown by the graph, that the maximum load that the system can serve seems to decrease when the weather conditions start to become cloudy and cloudy. Ipv conditions are very fluctuating, resulting in a decrease in battery voltage, which then causes a reduction in the ability to serve maximum loads. At 15.00, the load shifts from the medium load line to the low load line when the Ipv condition is 1.11A and Vbat is 22.14V. Continuous switching occurs because the voltage increases in the battery when the medium load line switches to the low load line. There is a decrease in battery voltage when the low load line changes to the medium load line. Conditions during recharging significantly affect this so that the displacement is very extreme.

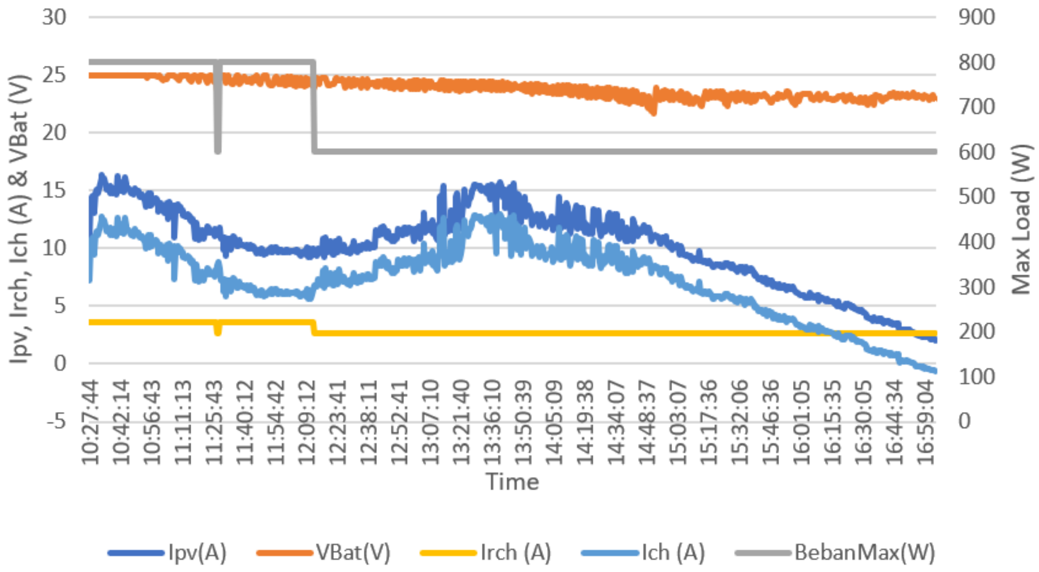

Fig 6. Graph of PV loading management testing during the weather tends to be sunny to cloudy

The graph shown in Fig. 6 illustrates the system's performance when the weather conditions tend to be sunny to cloudy. This is demonstrated by the Ipv, which tends to be above 8A. This condition impacts the system's ability to serve high to medium loads while simultaneously charging the battery. This can be seen from Irch, which is always smaller than Ipv, allowing the system to serve the load while simultaneously charging the battery as an energy storage medium. The decrease in the ability to serve the maximum load occurred along with the reduced absorption of sunlight which experienced the lowest point of Ipv at 2.22A.

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V. CONCLUSION

This solar PV loading management system has been designed according to sunshine conditions. The PV loading mechanism has been built using four solid-state relays to switch from low, medium, or high loading options. The electricity source from the PLN grid is chosen as the last option when the PV power source is no longer available. The test was carried out using eight 100 W incandescent bulbs. The test results showed that weather conditions could increase the fluctuation of PV output power. The maximum load that the system can serve depends on the photovoltaic current and battery capacity. The test results show that the instability of PV current affects the Vbat, which causes a decrease in the maximum load that the loading management system can serve. The decision to move the maximum load from the high load limit to the medium load limit as well as low load occurred because the Ipv decreased as well as the battery voltage decreased and reach the setting values.

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