

# SMART BATTERY MANAGEMENT SYSTEM FOR SOLAR-POWERED FRESHWATER LOBSTER CULTIVATION USING SCC TECHNOLOGY

## *SISTEM INTELIGENT DE MANAGEMENT A BATERIEI PENTRU CULTIVAREA HOMUSULUI DE APĂ DULCE CU FUNȚIONARE SOLAR CU TEHNOLOGIA SCC*

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**Abstract:** *Freshwater lobster farming faces challenges such as poor water quality, which increases mortality, and unreliable power sources for monitoring systems. This study developed an eco-friendly solar power system integrated with a Battery Management System (BMS) using Solar Charge Controller (SCC) technology. The system uses three sensors—voltage, DHT11 temperature, and AC712 current sensors—to monitor battery conditions. A relay activates a DC fan when the battery temperature exceeds 25°C. Testing showed the battery charges in 10 hours and provides over 25 hours of continuous operation. The results demonstrate that the power system ensures reliable energy management and consistent device performance.*

**Keywords:** solar power system; battery management system (BMS); solar charge controller (SCC); freshwater lobster farming; real-time monitoring and control

**Rezumat:** *Creșterea homarului de apă dulce se confruntă cu provocări precum calitatea slabă a apei, care crește mortalitatea și surse de energie nesigure pentru sistemele de monitorizare. Acest studiu a dezvoltat un sistem de energie solară ecologic integrat cu un sistem de management al bateriei (BMS) folosind tehnologia Solar Charge Controller (SCC). Sistemul folosește trei senzori — tensiune, temperatură DHT11 și senzori de curent AC712 — pentru a monitoriza starea bateriei. Un releu activează un ventilator de curent continuu atunci când temperatura bateriei depășește 25°C. Testele au arătat că bateria se încarcă în 10 ore și oferă peste 25 de ore de funcționare continuă. Rezultatele demonstrează că sistemul de alimentare asigură un management fiabil al energiei și o performanță constantă a dispozitivului.*

**Cuvinte cheie:** sistem de energie solară; sistem de management al bateriei (BMS); controler de încărcare solară (SCC); Creșterea homarului de apă dulce; Monitorizare și control în timp real

## 1. Introduction

In aquaculture, sustainable energy management plays a crucial role in ensuring the smooth operation of IoT-based systems [1], [2]. Freshwater lobster (*Cherax quadricarinatus*) farming, like other forms of aquaculture, relies heavily on maintaining stable environmental conditions to optimize growth and reduce mortality [3], [4]. Effective management of parameters such as water temperature, dissolved oxygen (DO), and pH is essential, requiring continuous operation of aerators, pumps, and feeding systems powered by reliable energy sources [5], [6]. However, the uninterrupted operation of these systems is challenged by the limitations of conventional power systems, especially in off-grid environments.

The integration of solar-powered energy systems offers a sustainable solution to these challenges, ensuring that operations continue seamlessly without relying on conventional electricity sources [7]. Central to this is the implementation of a Solar Charge Controller (SCC), which regulates the power flow from solar panels to batteries. Proper battery management is essential for aquaculture systems, as poorly managed batteries degrade faster, reducing their lifespan and increasing operational costs. By employing SCC technology, the system can prevent overcharging and deep discharging, which are two major causes of premature battery failure. Optimizing battery performance not only extends the lifespan but also ensures energy availability during critical periods, such as at night or during cloudy weather.

The integration of Battery Management Systems (BMS) with SCC in lobster farming provides an intelligent way to monitor power consumption, battery health, and charge-discharge cycles. This ensures that essential systems, such as water aeration and feeding, continue to function without interruption. As IoT devices become more prevalent in aquaculture, a robust power management strategy is necessary to support real-time monitoring and automation. Additionally, renewable energy solutions align with global sustainability efforts by minimizing the carbon footprint of aquaculture operations.

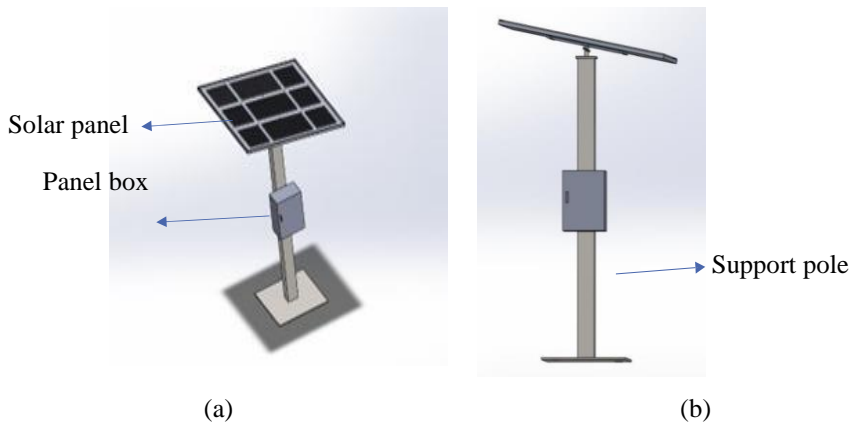
This study aims to develop a battery management strategy for freshwater lobster farming systems powered by solar energy. By focusing on extending battery life through optimal charge control with SCC, this research contributes to the long-term sustainability of aquaculture operations. The

outcome of this study will help farmers reduce maintenance costs, enhance operational reliability, and promote environmentally friendly practices [8], [9], [10].

## 2. Materials and Method

### 2.1. Physical design of solar panels

In figure 1 is the design of a portable solar panel, there is a control panel box measuring (20 cm × 40 cm × 40 cm). In the panel box there are components and microcontrollers used in the system. The panel width is (160 cm x 100 cm) with a pole height (150 cm). The solar panel used is a monocrystalline type with an efficiency of 21.42%.



**Figure 1.** Physical design of solar panels: (a) front view, (b) side view

Based on Figure 1 shows the entire body prototype component of the solar panel frame that can withstand the load of the solar panel of 8 kg and a 50 Ah battery weighing 15 kg. On this solar panel frame there is also a support that functions as a retainer and adjuster of direction/angle. In the implementation of the solar panel iron frame, there is a panel box that will be placed under the solar panel or more precisely attached to the iron side of the solar panel support.

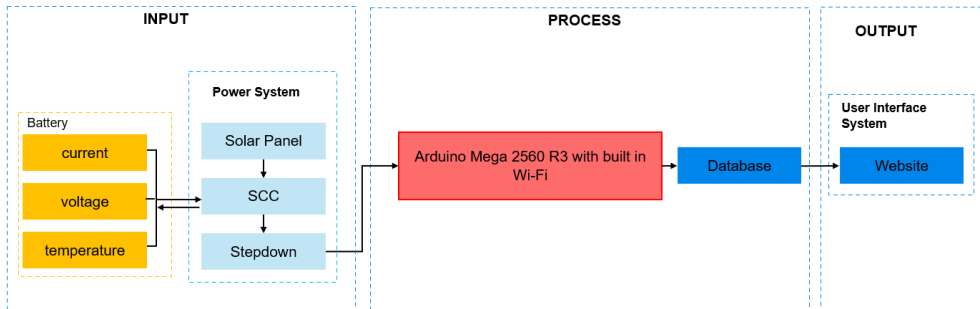
### 2.2. The Battery Management System (BMS)

The BMS is designed with two main research scopes, namely: (1) battery parameter monitoring system and (2) battery protection system. With

these functions, the BMS ensures optimal performance, safety, and longevity of the battery.

### 1) Battery parameter monitoring

Battery parameter monitoring (as showed in Figure 2) is a system used to monitor the power capacity of the battery and monitor usage over time.



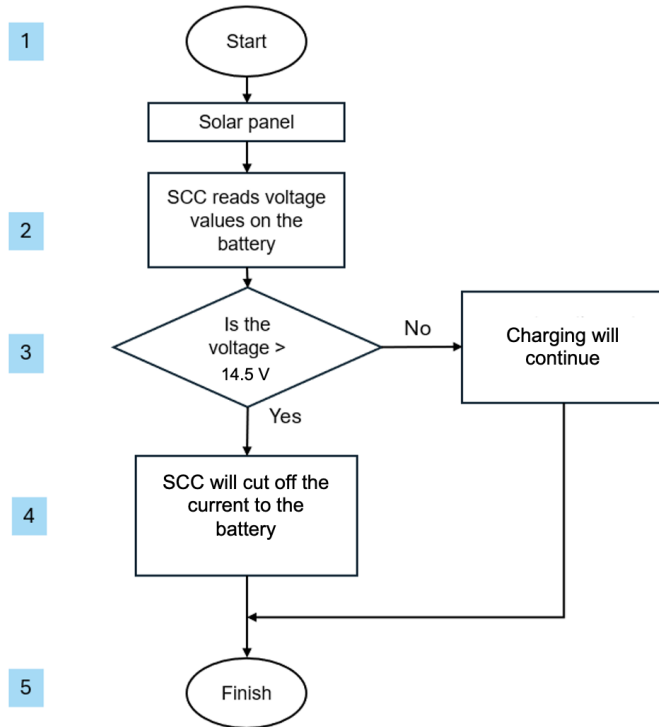
**Figure 2.** Battery monitoring system

The real-time of monitoring in figure 2 allows users to check battery capacity remotely without having to come directly to the location. This is very useful for lobster farmers who are not always in the field, because they can monitor battery conditions periodically through the monitoring website. Although the SCC can display battery parameters such as current, voltage, and temperature, the SCC cannot send data to the website. Therefore, the use of sensors is very necessary to facilitate data transmission and function as a backup system when the SCC is damaged. The battery monitoring system is made referring to the IoT (Internet of Things) concept.

### 2) Battery protection system

The battery protection system in this system consists of 2 parameters, namely protection from overcharged & over discharging and then protection from overheating. More complete information is shown in Figure 3, Figure 4 and Figure 5.

Figure 3 shows a flow diagram of the battery voltage protection system so that the risk of overcharging can be minimized. The following is an explanation of the performance of this subsystem:



**Figure 3.** Flowchart of voltage protection system on battery (overcharging on battery)

### 1) System Start

The system starts by initializing its processes, powered by the solar panel. The solar panel is the primary source of energy for the system, generating electricity that charges the battery.

### 2) Voltage Reading

The SCC reads the voltage values on the battery. The SCC continuously monitors the battery voltage to ensure that the battery is functioning within the optimal range for the system to operate efficiently.

### 3) Check Battery Voltage Level

The SCC checks if the voltage from solar panel to the battery is greater than 14.5V:

a. If the voltage is greater than 14.5V, this means the charging process from solar panel to battery charge is sufficient, and the system moves to the next step.

b. If the voltage is 14.5V or below, the charging is continued.

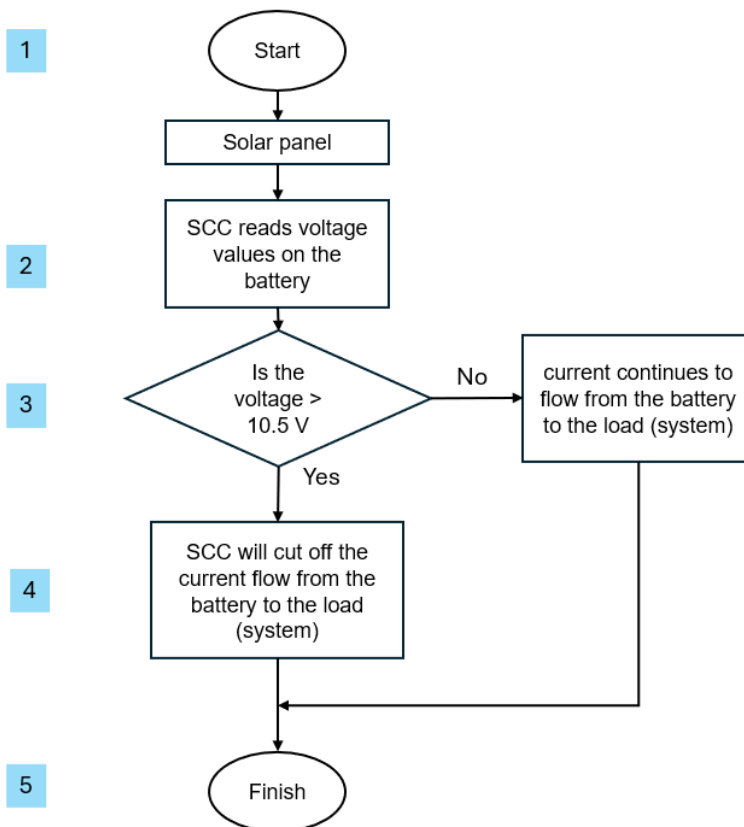
4) Cut-Off Power Flow (If Voltage > 14.5V)

If the battery voltage exceeds 14.5V, the SCC determines that the battery is sufficiently charged. To protect the battery from overcharging, the SCC cuts off the current flow from solar panel the battery. This ensures that the battery is not overcharged, and that energy is properly managed.

5) Finish

After the voltage check and current flow management, the system cuts off power to prevent overcharging.

Next, the flowchart of the over discharging process (power supply from the battery to the load/system) is shown in Figure 4 below.



**Figure 4.** Flowchart of voltage protection system on battery (over discharging on battery)

Figure 4 shows a flow diagram of the battery voltage protection system so that the risk of over discharging can be minimized. The following is an explanation of the performance of this subsystem:

1) System Start

The system starts by initializing its processes, powered by the solar panel. The solar panel is the primary source of energy for the system, generating electricity that charges the battery.

2) Voltage Reading

The SCC reads the voltage values on the battery. The SCC continuously monitors the battery voltage to ensure that the battery is functioning within the optimal range for the system to operate efficiently.

3) Check Battery Voltage Level

The SCC checks if the voltage on the battery is greater than 10.5V:

a. If the voltage is greater than 10.5V, this means discharging process to the load is sufficient, and the system moves to the next step.

b. If the voltage is 10.5V or below, the system continues to allow the current to flow from the battery to the connected load (the system), ensuring that power is delivered to the components.

4) Cut-Off Power Flow (If Voltage > 10.5V)

If the battery voltage exceeds 10.5V, the SCC determines that the battery is sufficiently discharged to handle the load. To protect the battery and system, the SCC cuts off the current flow from the battery to the load. This ensures that the battery is not overcharged, and that energy is properly managed.

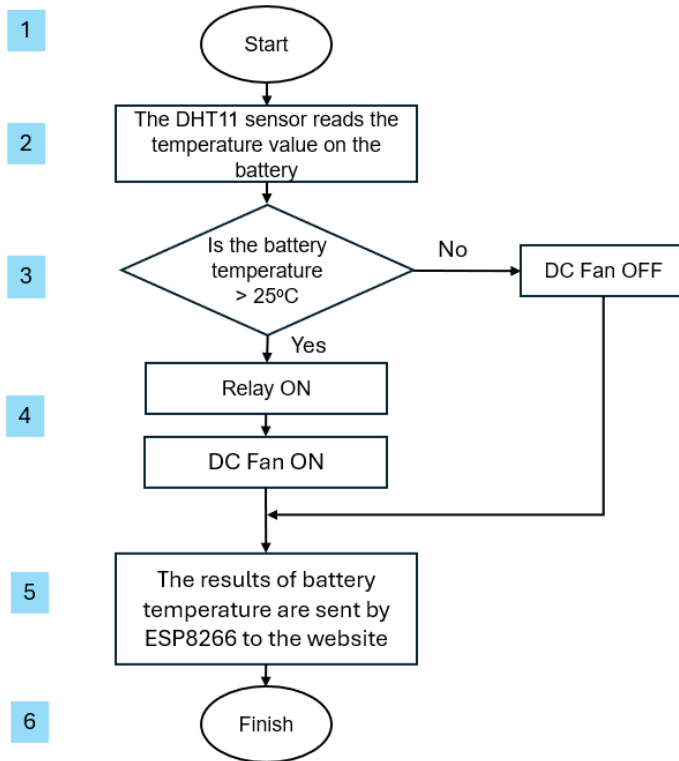
5) Finish

After the voltage check and current flow management, the system either cuts off power to prevent overcharging or continues to supply power to the load if the voltage is within safe limits.

Figure 5 shows a flow diagram of the battery temperature protection system so that the risk of overheating can be minimized. The following is an explanation of the performance of this subsystem:

1) System Start

The system begins its process with the initialization step.



**Figure 5.** Flowchart of temperature protection system on battery

## 2) Read Battery Temperature

The DHT11 sensor is activated to read the battery temperature. This sensor continuously monitors the temperature to ensure it remains within optimal operating limits.

## 3) Check Battery Temperature

After the sensors take the measurements, the system checks if the battery temperature exceeds 25°C.

a. If the temperature is greater than 25°C, the system moves to the next step to activate cooling mechanisms.

b. If the temperature is 25°C or below, the system bypasses the cooling mechanism and turns the DC fan OFF

## 4) Turn ON the DC Fan (Cooling)

If the battery temperature exceeds 25°C, the system turns the relay ON, which triggers the DC fan. This helps cool the battery and maintain its performance.

#### 5) Send Battery Temperature Data

The system sends the temperature data and other relevant sensor readings to a web platform via the ESP8266 module. This step enables remote monitoring of the battery's temperature.

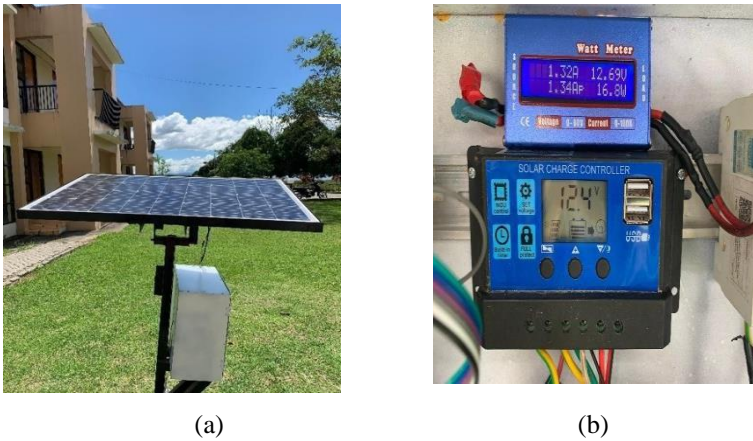
#### 6) Finish

The system completes the process by ensuring that the readings and any actions taken are logged and monitored online. The system can continue monitoring or repeat the process in a loop to provide continuous feedback and temperature control.

### **3. Result and Discussion**

#### **3.1. Implementation of Solar Panel System**

The electrification system plays an important role in freshwater lobster cultivation to provide a stable and efficient electricity supply to support the operational activities of the cultivation [11], [12]. In the electrification system designed for freshwater lobster cultivation, solar panels are used as the main power source for the entire system, utilizing renewable energy to reduce dependence on conventional electricity networks. The energy generated by the solar panels is managed by a SCC, which plays a role in ensuring optimal charging to the battery and protecting against the risk of overcharging and over discharging. This system is also equipped with a watt meter to monitor energy consumption in real time and a Miniature Circuit Breaker (MCB) which function as protection against excess current that can damage equipment. The battery functions to store the energy generated, so that it can be used when sunlight is not available. In addition, a step-down is used to lower the voltage according to system needs. The SCC is then connected to the entire load through the available load port, ensuring efficient and safe power distribution to all devices used in lobster cultivation. The solar panels are arranged on hollow iron as shown in Figure 6 (a) below to support the load of the solar panels weighing 8 kg and the battery weighing 15 kg and the implementation of the Watt Meter in Figure 6 (b).



**Figure 6** (a) Implementation of solar panels, (b) implementation of Watt meters and SCC on batteries

Table 1 below is the data of the results of voltage monitoring tests using voltage sensors.

*Table 1. Results of voltage sensor tests with a multimeter*

Data to-	Voltage Sensor (V)	Multimeter (V)	Difference	% Error	Load Type
1	3.60	3.61	0.002	0.2%	Lithium ion battery
2	3.60	3.61	0.002	0.2%	
3	3.60	3.61	0.002	0.2%	
4	3.65	3.61	0.011	1.1%	
5	3.60	3.61	0.002	0.2%	
6	3.60	3.61	0.002	0.2%	
7	3.64	3.61	0.008	0.8%	
8	3.64	3.61	0.008	0.8%	
9	3.64	3.61	0.008	0.8%	
10	3.60	3.61	0.002	0.2%	
11	3.60	3.61	0.002	0.2%	
12	3.60	3.61	0.002	0.2%	
13	3.60	3.61	0.002	0.2%	
14	3.60	3.61	0.002	0.2%	
15	3.60	3.61	0.002	0.2%	
16	3.60	3.61	0.002	0.2%	
17	3.60	3.61	0.002	0.2%	
18	3.60	3.61	0.002	0.2%	
19	3.60	3.61	0.002	0.2%	
20	3.60	3.61	0.002	0.2%	
Average Error			0.00335	0.335%	

Based on Table 1, it shows that the sensor can work well and has a relatively small error percentage of 0.335% compared to the standard multimeter measuring instrument. Good voltage sensor performance will be very necessary in monitoring the battery charging and discharging process. The battery discharging process aims to find out how long the battery needs to meet the load needs when the solar panel cannot be used. And vice versa, the charging process aims to find out how long it takes to fill the battery capacity from solar energy (solar panels) so that it can be used for the discharging process to the load (lobster cultivation system). The charging and discharging data can be seen in Table 2 below:

*Table 2. Results of battery charging and discharging process tests*

Time observation	Battery voltage during charging and discharging	
	Day 1 (V)	Day 2 (V)
09:00 AM	11.92	12.01
10:00 AM	11.72	12.51
11:00 AM	11.93	12.08
12:00 AM	12.81	13.18
01:00 PM	12.78	13.21
02:00 PM	12.58	12.98
03:00 PM	12.81	11.5
04:00 PM	12.78	11.67
05:00 PM	12.58	12.44

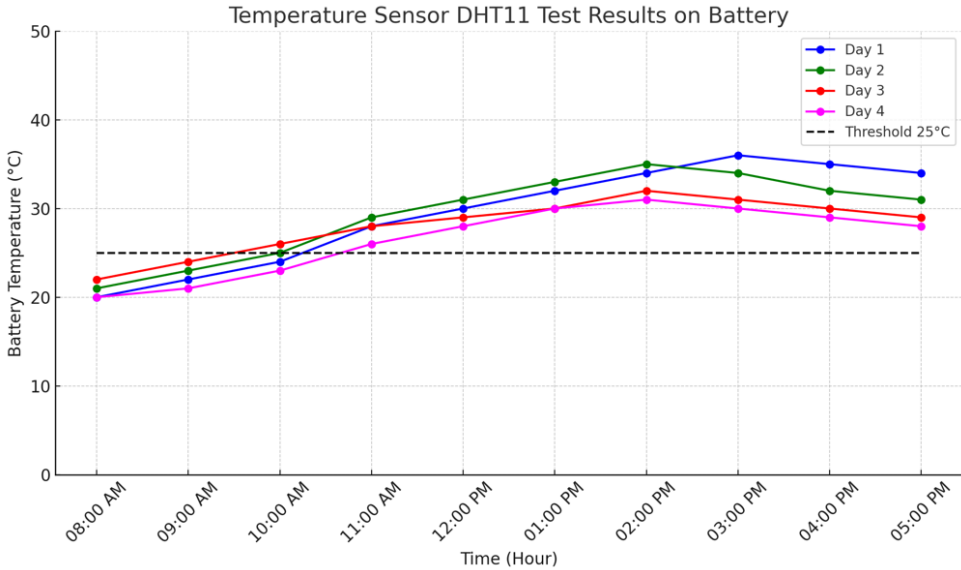
In Table 2, the test was carried out from 09:00 AM to 05:00 PM, which is the time when the solar panel can charge the battery, and the battery can supply power to the load. When the discharging process takes place, the battery voltage tends to be stable and only decreases slightly. This happens because the charging process continues even though discharging is being carried out. Therefore, the data shows that the charging and discharging processes can be carried out simultaneously.

This shows the performance of the BMS is quite good in the charging and discharging process. Thus, it is expected that the battery life will be more durable than without using this BMS system.

Furthermore, the data from the temperature control and monitoring tests using the DHT11 sensor on the battery are shown in Figure 7.

The formula for finding the percentage error is shown in the following equation 1 [11], [12]:

$$Error = \left| \frac{\text{standard measuring instrument reading} - \text{sensor reading}}{\text{standard measuring instrument reading}} \right| \times 100\% \quad (\text{eq. 1})$$



**Figure 7.** DHT11 temperature sensor testing graph on the battery.

Based on Figure 7 and using equation 1 above, the percentage of sensor error compared to the multimeter is 1,535% and the accuracy is 98.465%.

These results show that this system is successful in keeping the battery temperature at its set point, so that the impact of overheating can be suppressed, and battery health can be better maintained.

In this study, a smart BMS has been developed for solar-powered freshwater lobster cultivation using SCC technology. While the system has demonstrated its effectiveness, there are still opportunities for further improvements and optimizations.

One potential avenue for future research is the integration of a passive cooling system for the battery using phase change materials (PCM). Particularly, organic PCM materials could be explored due to their energy efficiency and eco-friendliness. Passive cooling solutions could help regulate battery temperature more effectively without additional energy consumption, thereby enhancing system sustainability and extending battery lifespan.

By incorporating an effective passive cooling system, the overall efficiency and sustainability of solar-powered BMS applications can be significantly improved, making them more suitable for long-term deployment in aquaculture and other renewable energy-based applications.

## Conclusions

1. The solar panel system used can produce an average power of 50.93 watts, with an average voltage of 13.99 volts and a current of 3.58 amperes during testing for 7 days.

2. This system successfully supports 24-hour uninterrupted operation. The charging and discharging processes run well. When the voltage from the solar panel to the battery exceeds 14.5 V, the SCC will cut off the flow to the battery to prevent overcharging of the battery, and then when the battery voltage reaches a value greater than 10.5 V, the SCC will cut off the flow from the battery to the load so that there is no excessive discharge that can shorten the battery life.

3. The management system also managed to keep the battery temperature at its set point, which is 25°C. When the sensor reads a temperature greater than 25°C, the fan will turn on to lower the battery temperature so that the potential for battery damage due to overheating can be minimized.

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### Acknowledgements

1. This research was funded by the Directorate of Research, Technology, and Community Service, Directorate General of Higher Education, Research, and Technology, Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia under contract number 103/E5/PG.02.00.PL/2024.
2. Thanks to LPPM Institut Teknologi Del.
3. The authors also would like to express their gratitude to the reviewers and the editorial team of Energy Environment Efficiency Resources Globalization Journal for their valuable feedback and suggestions, which have helped improve the quality of this manuscript.

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