IoT based Lithium-ion Battery Pack Performance Monitoring

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Keywords: Battery Pack, Blynk, Internet of Things, Lithium-ion.

Abstract: Lithium-ion batteries are the latest battery technology that claims to have a long lifetime. However, if using a lithium-ion battery exceeds the state of health voltage, the lifetime of the lithium-ion battery will decrease faster. In order to have a long lifetime, the lithium-ion battery requires a continuous, real-time, and mobile monitoring system for battery electrical parameters. In this study, we created an IoT-based battery electrical monitoring system applied to a lithium-ion battery pack with a capacity of 60 Ah, 12 Volt. This monitoring system can monitor the current, voltage, power, and battery capacity data through the LCD on the panel and smartphone every minute. As a result, during charge and discharge, the monitor system that has been created successfully monitors all electrical data on the battery pack. The battery pack can supply 57Watt AC load at discharge for 7 hours and 50Watt DC load for 9 hours. When charging, the battery pack takes 24 hours with a charging current of 2 A. If the battery condition is low, the system will notify via smartphone. In addition, electrical parameter data is well recorded through the Blynk application and google spreadsheet.

1 INTRODUCTION

Lithium-ion batteries are the latest battery technology claimed to have a long lifetime and minimal maintenance (Scrosati & Garche, 2010). So that lithium ion batteries are widely used as energy storage for electric cars (Xiong et al., 2017)(Berecibar et al., 2016) or renewable energy power plants (Diouf & Pode, 2015)(Wu et al., 2015). However, lithium ion batteries must always be in the state of health to avoid critical safety, reliability, and decreased performance of Li-ion batteries. (Lu et al., 2013)(Xiong et al., 2018). Some large-scale batteries generally use a battery management system (BMS) to manage the charge discharge process (Lin et al., 2019)(Carkhuff et al., 2018). However, the current BMS design has not monitored battery performance in real time and mobile. BMS does not yet have the feature to connect with Internet of Things (IoT) technology. IoT-based monitoring system aims to increase scalability, cost-effectiveness and flexibility in monitoring (Vermesan & Friess, 2014).

Researchers have implemented an IoT-based battery monitoring system, including a cloud-based condition monitoring platform (Adhikaree et al., 2017), cloud-based fault diagnosis (Kim et al., 2018), dan android phone (Menghua & Bing, 2017). The three studies present fairly complex programming algorithms.

This article proposes to monitor the performance of IoT-based battery packs with a simple programming algorithm, using the Blynk platform. One of the advantages of using the Blynk platform is the ease of connectivity between field devices (sensors) and microcontrollers, ease of programming, and stability in the internet network to minimize data loss. The Blynk platform is applied to monitor the condition of the battery packs that have been made in previous studies (Wiguna et al., 2021).

With an IoT-based monitoring system on the battery pack, the battery pack's current, voltage, power, and capacity can be monitored and recorded in real time. If the battery pack condition is outside the specified range, the system will notify the smartphone owner.

Dwiyaniti, M., Kusuma, L., Tohazen, ., Nadhiroh, N. and K., S.
IoT based Lithium-ion Battery Pack Performance Monitoring.
DOI: 10.5220/0010950800003260
In *Proceedings of the 4th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2021)*, pages 668-673
ISBN: 978-989-758-615-6; ISSN: 2975-8246

2 RESEARCH METHODOLOGY

The research method used is the design or experimental method. The components of this research consist of a voltage sensor, a current sensor, an ADC module, an internet-connected NodeMCU, and an LCD as shown in the general overview of the study (Figure 1).

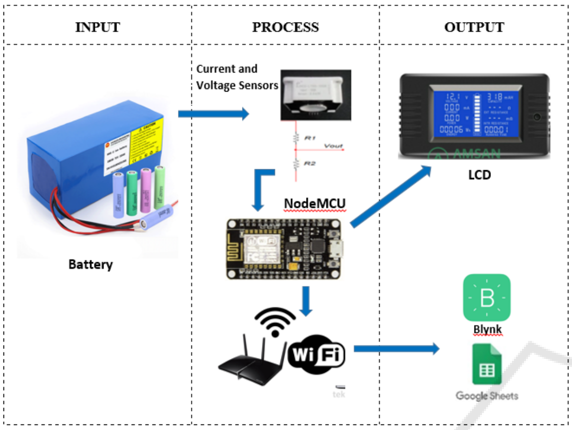


Figure 1: Monitoring system of the battery pack performance.

The stages of the research:

1. Design the monitoring system.
2. Microcontroller programming and IoT platform. The microcontroller used is NodeMCU ESP8266 with Arduino IDE software and Blynk for the IoT platform. The parameters displayed on Blynk are the voltage, current, power, total battery capacity and the voltage graph. In addition, the data is recorded on a google spreadsheet where the data will be updated automatically every 1 minute (figure 2).
3. Do the test for the battery performance monitoring system.
   The goal is to determine battery performance in real-time, and the data can be monitored and appropriately recorded. The tests carried out are (1) discharge the battery pack with AC and DC loads, (2) charging the battery pack, (3) sending and displaying data on Blynk and google spreadsheets, (5) fault conditions or low battery.

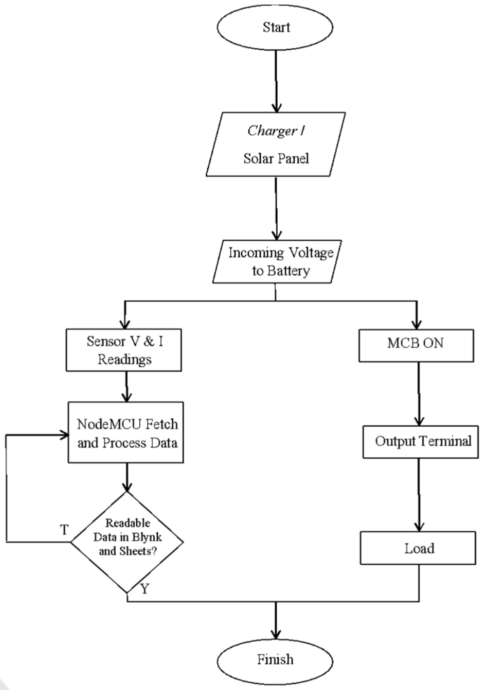


Figure 2: Battery pack flowchart.

3 RESULTS AND DISCUSSION

3.1 Discharging Battery Pack with AC and DC Load

This test is a battery discharge test using an AC load and a DC load alternately. The total AC load used was 57W, consisting of 9 W lamps, 18 W lamps, 5 W lamps and 25 W fans. To convert the DC voltage of the battery pack into AC, we use an inverter, as shown in Figure 4.

Figure 3: Discharge test circuit with AC load.

The discharging test with AC load has been carried out until the battery capacity indicator on the

LCD remaining 20%. This testing process takes 7 hours. According to the specifications, the designed battery pack has a capacity of 60 Ah. While the AC load current used is:

$$I = \frac{P}{V} \quad (1)$$

$$I = \frac{57\,W}{12\,V} = 4{,}75\ A$$

So that by calculation this battery can be used:

$$t = \frac{60\,Ah}{4{,}75\,A} = 12{,}6\ hours$$

However, this test can only be used for up to 7 hours because it was only tested until the battery capacity indicator shows 20%. In addition, the inverter was suspected to be the cause of the large current consumption so that the battery discharge becomes faster.

The test is complete when the battery capacity is at 20% to keep the battery condition safe. SOC calculation, the lowest battery voltage is 9.91. So the test is stopped when the voltage is 10.38 V or when it is already 20%.

$$\text{SOC} = \frac{V_{latest} - V_{min}}{V_{max} - V_{min}} \times 100\ \% \quad (2)$$

$$\text{SOC} = \frac{10{,}38 - 9{,}91}{12{,}24 - 9{,}91} \times 100\ \% = 20{,}17\ \%$$

While discharge testing using the DC load was two lamps of 25 W, the total load was 50 W. The test circuit is shown in Figure 4.

Figure 4: Discharge test circuit with DC load.

Testing using a DC load are carried out until the battery capacity indicator on the LCD shows 15%. This testing process takes 9 hours and 30 minutes. According to the specifications, this designed battery pack has a capacity of 60 Ah. While the DC load current used is:

$$I = \frac{P}{V} \quad (3)$$

$$I = \frac{50\,W}{12\,V} = 4{,}16\ A$$

by calculation, this battery can be used:

$$t = \frac{60\,Ah}{4{,}16\,A} = 14{,}4\ hours$$

However, this test can only be used up to 9 hours 30 minutes because it is only tested until the battery capacity indicator shows 15%.

The test is complete when the battery capacity is at 15% to keep the battery condition safe. SOC calculation, the lowest battery voltage is 9.91. So the test is stopped when the voltage is 10.27 V or when it's already 15%.

$$\text{SOC} = \frac{V_{latest} - V_{min}}{V_{max} - V_{min}} \times 100\ \% \quad (4)$$

$$\text{SOC} = \frac{10{,}27 - 9{,}91}{12{,}24 - 9{,}91} \times 100\ \% = 15{,}45\ \%$$

The test results using an AC load and a DC load are shown in Figures 5, 6 and 7.

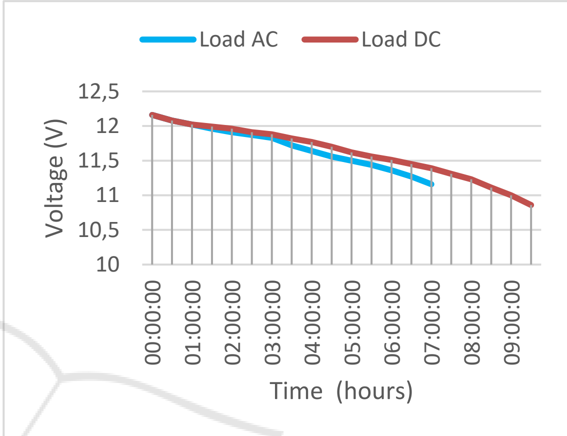


Figure 5: Voltage versus Time on AC and DC Load Discharge Test.

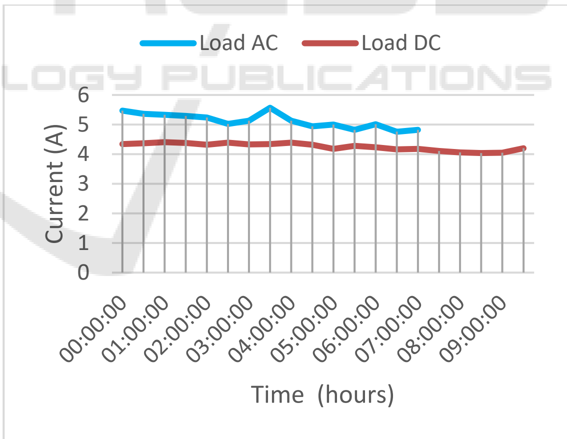


Figure 6: Current versus Time on AC and DC Load Discharge Test.

Figure 5 shows a graph of the voltage value versus the time of the total battery output. These data show that the longer the running time, the voltage value decreases from 12.16 V to 11.27 V when using an AC load and the voltage drops from 12.16 V to 10.86 V on DC load. The difference in voltage drop on AC and DC loads occurs due to different SOC level settings. However, the voltage drop that occurs is still in the standard battery pack range, which is at least 9.91 V.

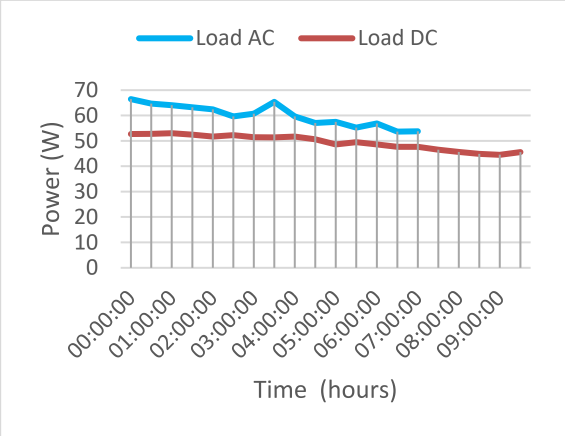


Figure 7: Power versus Time on AC and DC Load Discharge Test.

Figure 6 shows a graph of the current value versus the time of the total battery output. Based on Figure 6, the current flowing from the battery pack to the load tends to be stable because the load is constant. The current is greater than the calculation result at the AC load because there is an additional current from the inverter. While at DC load, the load current that occurs is following the calculation. At 4 o'clock there is a sudden increase in current due to a change in AC load, the lamp breaks. After replacing the lamp, the current returns to normal .

Figure 7 shows a graph of the power value versus the time of the total battery output. Based on figure 7, the power consumption corresponds to the load. The AC power consists of 2 loads, the lamp load is 57 W, and the rest is the inverter. While on DC power, only 50 W lamp. Power consumption also tends to decrease due to a decrease in battery pack voltage

3.2 Charging Battery Pack

After completing the discharge test, the next test is to charge the battery pack using a 2 A adapter. The adapter is connected to the battery pack through the charging socket located on the door of the battery pack panel (figure 8).

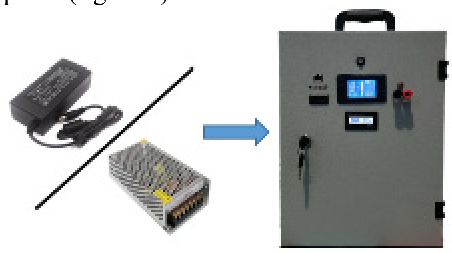


Figure 8: Charge test circuit.

Based on calculations with a constant charging current of 2A, the charging process from null to full takes time:

$$t = \frac{60\ Ah}{2\ A} = 30\ hours$$

Nevertheless, in this test, the battery pack charging process was 23 hours. It happened because the charging process starts when the battery capacity condition is 20% instead of zero. The test results are shown in Figures 9, 10, and 11.

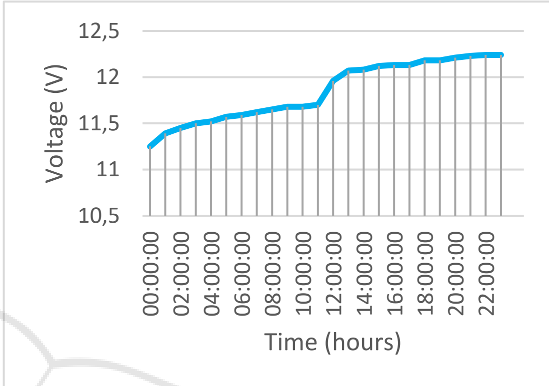


Figure 9: Voltage versus Time on Charge Test.

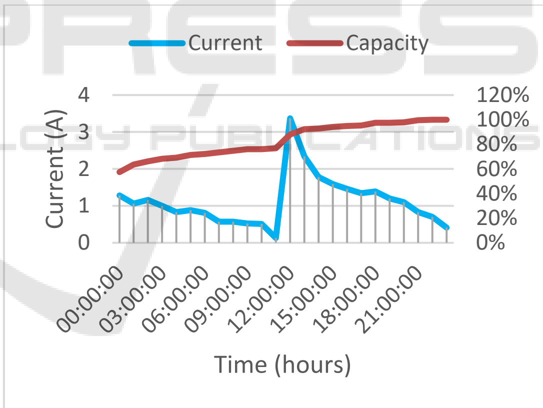


Figure 10: Current capacity versus Time on Charge Test.

Based on figure 9, the battery charging process is successful. The voltage continues to rise from 11.25 V to a full battery pack of 12.24 V, and the voltage increase tends to be constant ± 0.2V. At 12.00, there is a significant change in voltage. The cause of this is the replacement of the 2A adapter with a 4 A power supply.

Figure 10 shows the current charging and capacity battery pack. The current charging condition is inversely proportional to the battery pack capacity. The charging current decreases as the battery capacity increases. This condition is the same as the

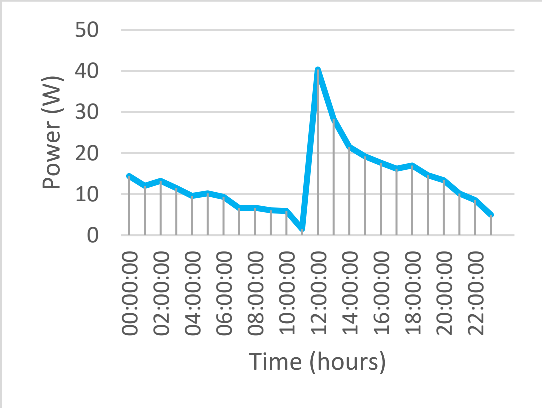


Figure 11: Power versus Time on Charge Test.

characteristics of battery charging. At 12.00, there is a significant change in current of around 3.4 A. It happened to cause the replacement of the 2A adapter with a 4 A power supply. However, this condition is still safe because the battery pack can accept up to 4.19 A currents.

The charging current strongly influences the power at the time of charging. The smaller the current, the smaller the power generated, as shown in figure 11.

3.3 IoT-based Performance Monitoring Results

3.3.1 Monitoring Results through the Blynk Application

1. Display on the Blynk application

The data on the charging and discharging process can be viewed with the Blynk application on a smartphone. Figure 12 shows the Blynk display when connected.

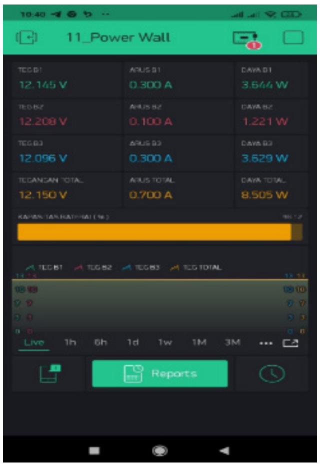
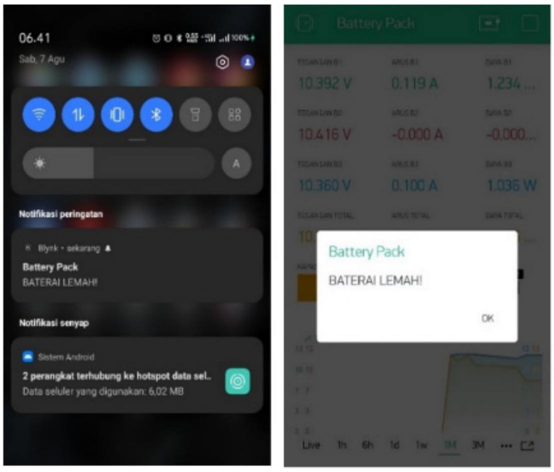


Figure 12: Blynk Display.

2. Notifications when the battery is low

When the remaining battery capacity is 20%, the Blynk app will give a "Low Battery!" notification on a smartphone, as in Figure 13.



(a) (b)

Figure 13: (a) Notification display on the smartphone notification bar and (b) notification display when opening the Blynk app.

3.3.2 Google Sheets Monitoring Results

Figure 14 is a display on a google spreadsheet in which data contain the results of sensor readings from the tool. The data displayed in the google spreadsheet are the date, time, voltage, current, and power values of each battery pack, the total battery output on the device, and the battery capacity value or state of charge (SOC) of the total battery output. The data in the google spreadsheet will be updated automatically every 1 minute.

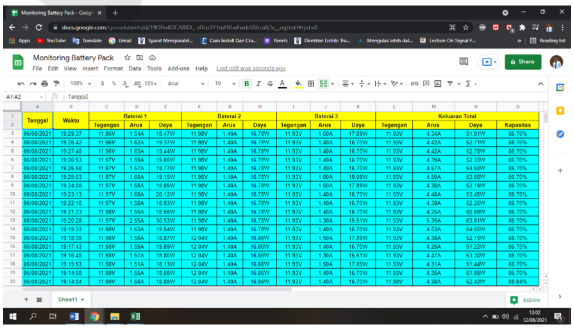


Figure 14: Monitoring view via a google spreadsheet.

4 CONCLUSIONS

The monitoring system of the performance battery pack based on IoT has been functioning correctly by displaying data on the current, voltage, power, and capacity of the battery pack and recording the data in a google spreadsheet. However, the charging and discharging process takes a long time because it depends on the load; the system built on this battery pack can be monitors and records data for analysis purposes. For further research, this battery pack system can be used to store energy from solar panels.

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support provided by the vocational higher education strengthening program Teknik Otomasi Listrik Industri Study Program and a research grant from UP2M PNJ.

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