JURNAL UPI

Journal of Mechatronics and Artificial Intelligence

JMAI JOURNAL OF MECHATRONICS AND ARTIFICIAL INTELLIGENCE

Homepage: http://ejournal.upi.edu/index.php/jmai/

Prototype of Monitoring System for Lithium-Ion Battery Charging and Discharging on UPS Using Atmega 328P

Dedi Riswandi[1], Andriana[1*], Irvan Budiawan[2]

[1] Prodi Teknik Elektro, Universitas Langlangbuana, Bandung, Indonesia
[2] Prodi Teknik Elektro, Universitas Jenderal Achmad Yani, Cimahi, Indonesia
*Corresponding author email: andriana6970@gmail.com

ARTICLE INFO

Article History:

Submitted/Received 23 May 2024
First Revised 31 May 2024
Accepted 01 Jun 2024
Publication Date 02 Jun 2024

Keywords:
Monitoring system,
Lithium-Ion,
Charging,
Discharging,
UPS,
Atmega 328P

ABSTRACT

An Uninterruptible Power Supplies (UPS), is required as a backup source of power in a railroad signalling power supply system. The battery is an essential part of a UPS. The battery functions to provide or supply electrical energy without having to be connected to electricity. Therefore, it is necessary to monitor battery conditions such as state of charge (SOC) to check battery capacity and depth of discharge (DOD) to calculate lost battery capacity. This research made a prototype of a battery monitoring system using IC ATMega328p as a microcontroller that will monitor the condition of the battery. Connecting the battery with the voltage divider circuit, the current sensor ACS712 as a current value reader at the time of charge and discharge. The results of the study showed that for the process of charging a new battery for 2 hours and 30 minutes using a 12 volt DC adapter with a current of 1.5 amperes, the current generated when the battery voltage reaches a maximum of 12,01 volts is 2,824 amperes and SOC 100%. Whereas the old battery filling took 1 hour and 30 minutes with a maximum battery voltage of 12,01 volts, 2,032 amperes, and a SOC of 100%. Whereas when the process is carried out using a battery discharge using a motor load of DC 10 volts, the time required for the discharging of the new battery is 14 hours and 30 minutes, with the current produced when the voltage of the battery reaches the minimum voltage of 8,98 volts, or 2,138 ampers, and DOD 0%.

1. Introduction

In Indonesia, the railroad business is now expanding significantly. With the development of the railway industry, experts who understand railway signaling systems are needed. The train signaling system is also the most important part that needs attention. The railway signaling system is an electronic system that connects several pieces of equipment on the railroad, such as signal lights, rail circuits, and interlocking systems, as controllers [1]. In railway signaling, there is a power supply source where the power supply system is used for train operations and must not be interrupted so that electrical energy can be utilized continuously while the signaling system is operating [2]. A UPS, or uninterrupted power supply, is required as one of the power supply sources in order to obtain a continuous source.

Uninterruptible Power Supplies (UPS) are devices that provide an alternative power supply when the voltage of 380 volts on PLN electricity is cut. The use of UPS is very important to prevent power failure as well as damage to the system and hardware used. A very important component of a UPS is the battery. Batteries are electrochemical cells that convert chemical energy directly into electrical energy. The battery functions to provide or supply electrical energy without having to be connected to the mains. Inside the battery is stored electrical power that can temporarily replace the main source. Normally, the battery capacity replaces the main power source for 15–30 minutes [3]. If the battery quality is poor, the time it takes to supply power to electronic equipment will be shorter. In fact, the function of the UPS is completely disrupted. As a result, when the mains power is cut off, the electronic equipment in use will stop immediately. Therefore, it is important to choose a device with optimal battery conditions. The UPS (uninterruptible power supply) panel is an important component in the electrical system that serves to provide backup power during a power outage. While it has significant benefits, it also has some drawbacks: it does not always have the ability to read the battery voltage per cell directly. Most UPSs used generally have batteries consisting of cells connected in serial and parallel to form a battery system. During normal operation, the UPS only monitors the overall voltage of the battery systems, not the voltage per cell separately.

From the factors that have occurred, an idea emerged to create a device capable of monitoring battery performance in order to minimize battery damage during charge or discharge. Some things that need to be considered when monitoring the battery are voltage, current, and status when charging or discharging. State of Charge (SOC) is one of the important parameters needed to ensure the charging status is safe, while Depth of Discharge (DOD) is an important parameter to ensure the discharge status is safe [4]. The state of charge or depth of discharge is the ratio of the remaining energy to the maximum energy capacity of the battery. State of Charge and Depth of Discharge values can be expressed in presentation form as 0%–100% [5]. The estimation of SOC and DOD has the function of protecting the battery and preventing it from overcharging or discharging [5-9].

With the right SOC and DOD values, it is expected to be a reference in operating the battery so that the battery can be operated safely (safe operating area) and support the performance of existing systems [10-12].

In this journal, the author makes a prototype of a charge and discharge monitoring system for lithium-ion batteries. In addition, this battery monitoring will have several indicators that will be displayed in real time using PLX DAQ software and a 16x2 LCD display, which will display voltage, current, capacity (mAh), and SOC or DOD values.

2. Methods

2.1. System Design

In this research, there are three processes involved in making a prototype battery monitoring system: charging, discharging pores, and acquiring voltage and current data. At the battery system design stage, the hardware is divided into several parts, namely: a 12 volt DC power supply equipped with voltage regulation, a microcontroller power supply, a battery sensor circuit used to calculate voltage values, and an LCD to display data. As for the design of the cell board system, there are 4 MOSFETs, FS44071A (Metal-Oxide-Semiconductor Field-Effect Transistor) and IC FM8254AAV, which are used to control battery charging and discharging and monitor battery conditions (figure 1).

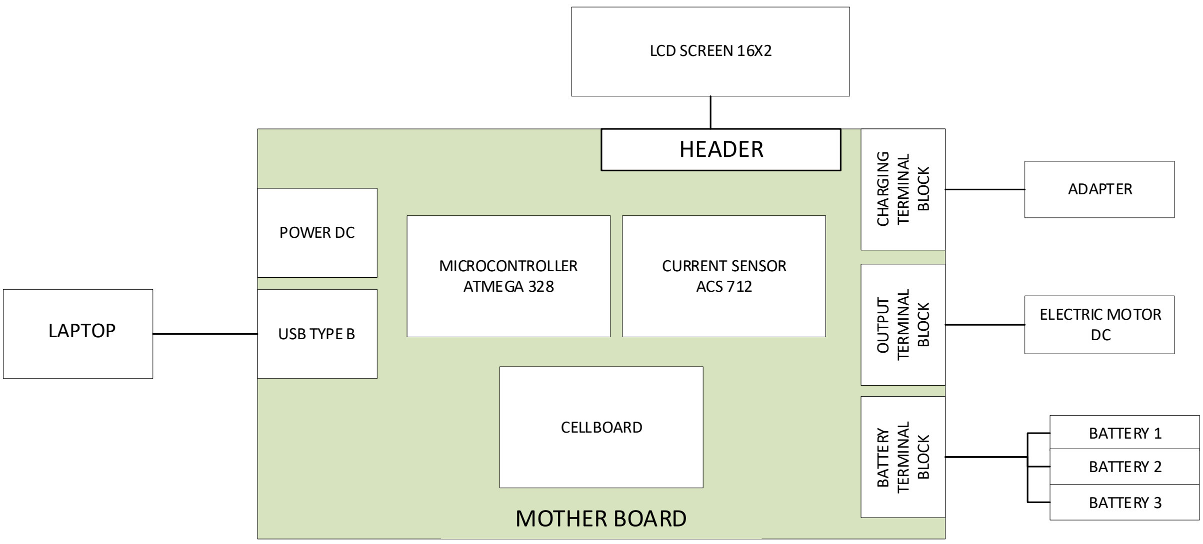

Figure 1: Schematics of the entire network.

2.1.1. Discharging Process

When the battery discharge cellboard detects that the battery needs to be used (power usage), another MOSFET will be turned on to control the discharge. The other MOSFET, FS4407A, will open so that power can flow from the battery to the device that needs power (figure 2).

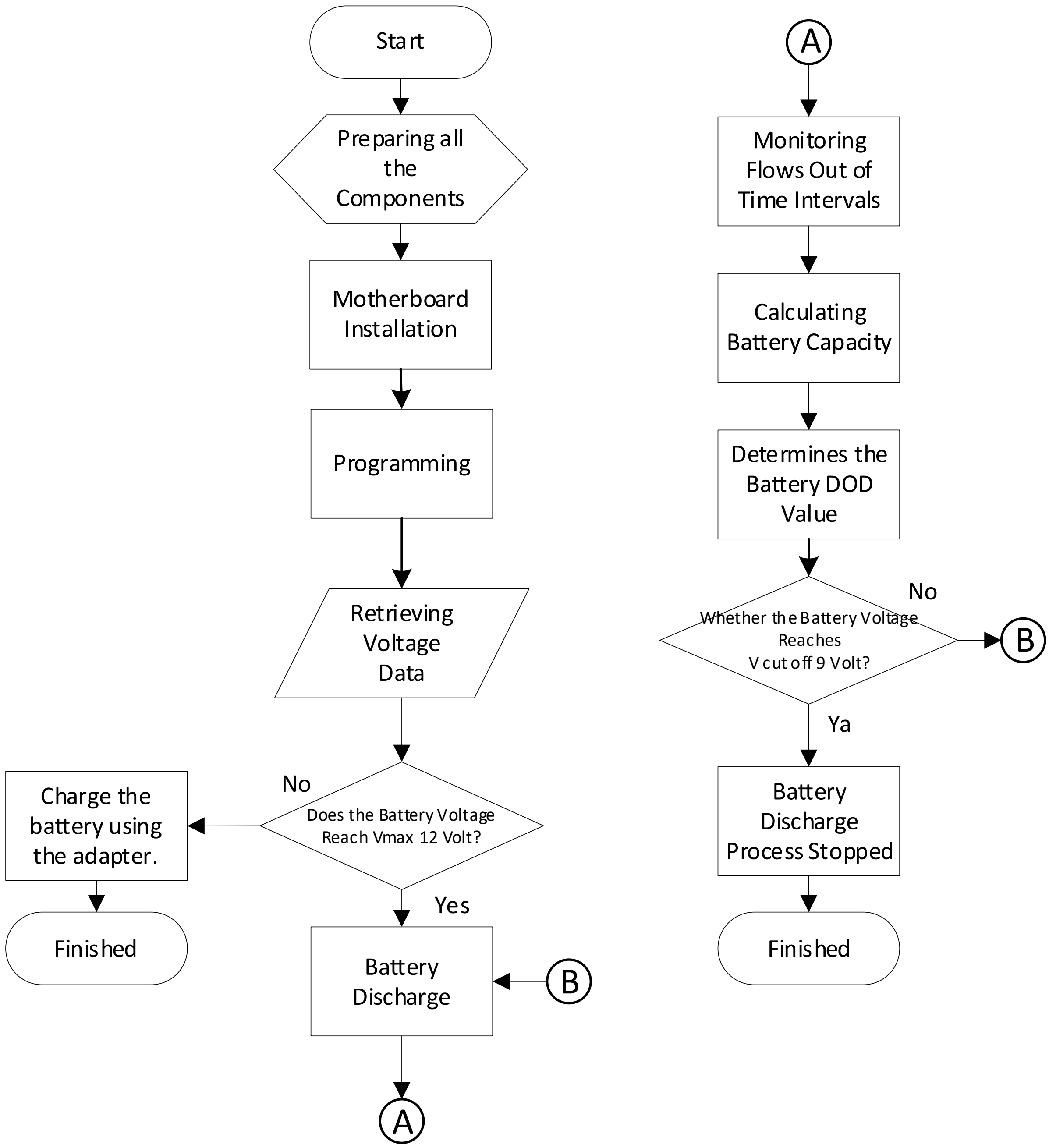

Figure 2: Discharging process flowchart.

2.1.2. Charging Process

When the battery charging BMS detects that the battery needs to be recharged, the FM8254AAV IC will give a signal to turn on the MOSFET that controls charging. MOSFET FS4407A will open (on) so that the current from the charging power source (charger) can charge the battery (figure 3).

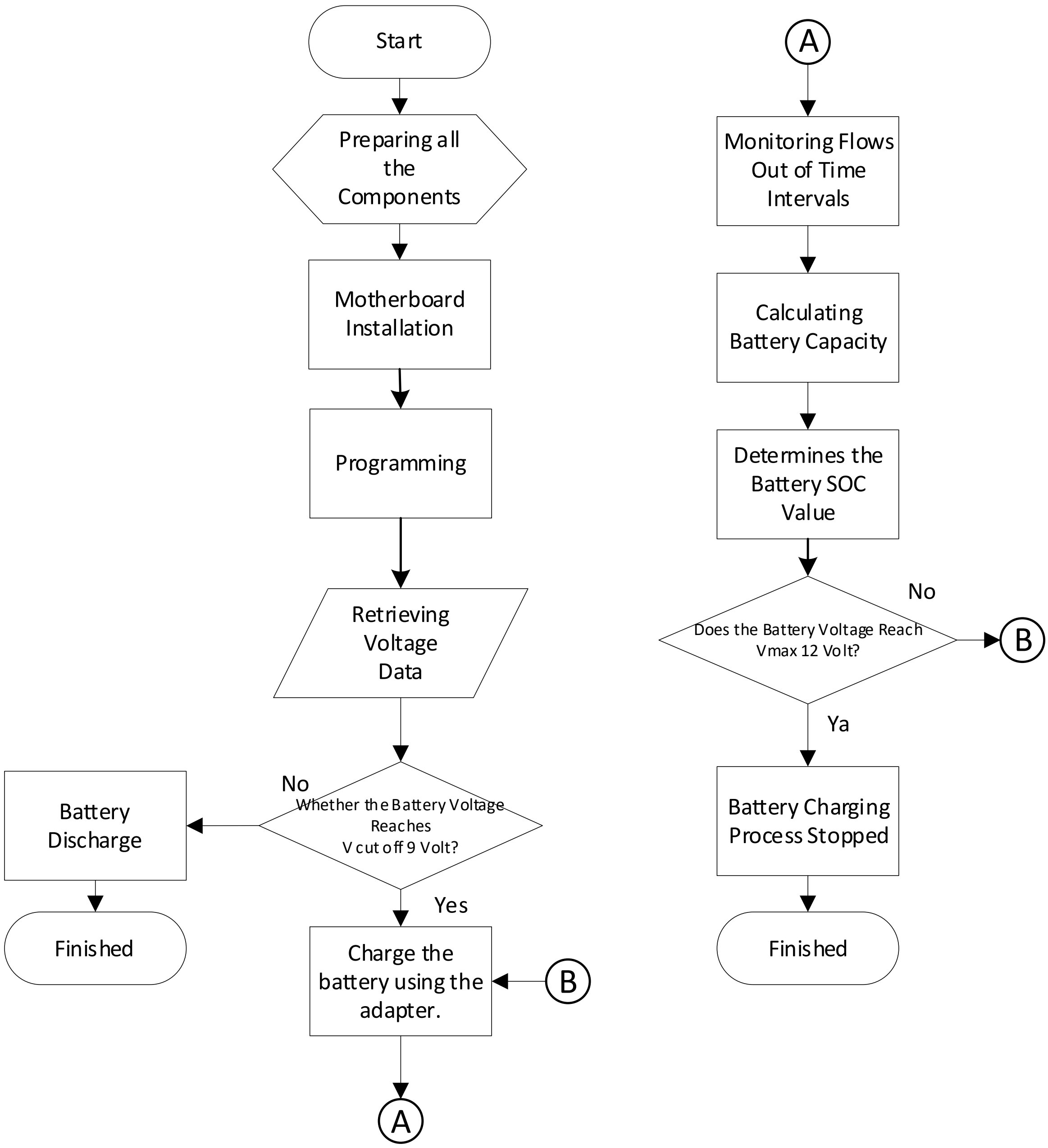

Figure 3: Charging process flowchart.

3. Result and Discussion

3.1. Experiment Using Old Batteries

In this experiment, there are two processes, namely charging and discharging. From Table 1, the charging and discharging processes for several voltage values of each battery are as follows:

Table 1: Old battery trial data.

OLD BATTERY											
CHARGE						DISCHARGE					
VB1	VB2	VB3	VTOTAL	Amper	soc	VB1	VB2	VB3	VTOTAL	Amper	soc
3,81	4	3,98	11,79	2,455	93%	3,86	4,2	3,96	12,01	2,798	100%
3,81	4,03	3,96	11,79	2,481	93%	3,86	4,2	3,96	12,01	2,771	100%
3,83	4	3,98	11,82	2,428	93%	3,86	4,2	3,96	12,01	2,613	100%
3,81	4,03	3,96	11,79	2,507	93%	3,86	4,2	3,96	12,01	2,692	100%
3,83	3,98	3,98	11,79	2,375	93%	3,86	4,2	3,98	12,04	2,587	100%
3,83	3,98	4	11,82	2,402	93%	3,86	4,2	3,96	12,01	2,507	100%
3,83	4	3,98	11,82	2,481	93%	3,86	4,2	3,96	12,01	2,56	100%
3,83	3,98	4	11,82	2,455	93%	3,86	4,17	3,96	11,99	2,56	99%
3,83	4	3,98	11,82	2,507	93%	3,86	4,17	3,96	11,99	2,507	99%
3,81	4	3,98	11,79	2,428	93%	3,86	4,2	3,93	11,99	2,745	99%
3,83	3,98	3,98	11,79	2,402	93%	3,86	4,2	3,93	11,99	2,534	99%

From Figure 4 below, it can be seen that by using the battery, the time required to carry out the charging process is 1 hours 30 minutes. During these 1 hours 30 minutes, the minimum voltage is 9.06 volts with a SOC value of 1%, and the battery is able to carry out the charging process up to a voltage of 12.21 volts with a SOC value of 100%. From Figure 4 below, it can be seen that by using the battery, the length of time required to perform the discharge process is 9 hours 40minutes. During these 9 hours 40 minutes, the minimum voltage at which the battery is able to perform the discharge process until the load cannot rotate is 8.98 volts with a DOD of 0%.

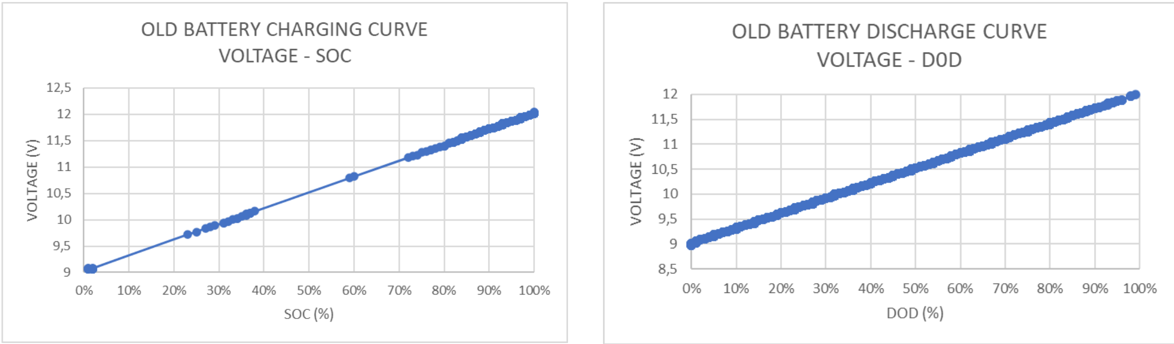

Figure 4: Charge – discharge curve of an old battery.

3.2. Experiment Using a New Battery

In the experiment using a new battery, table 2 shows several voltage values on each battery.

Table 2: New Battery Trial Data

NEW BATTERY											
CHARGE						DISCHARGE					
VB1	VB2	VB3	VTOTAL	Amper	SOC	VB1	VB2	VB3	VTOTAL	Amper	DOD
3,15	3,22	3,34	9,72	1,109	23%	4,03	4,13	4,08	12,23	6,097	100%
3,20	3,22	3,34	9,77	1,082	25%	4,05	4,08	4,1	12,23	6,097	100%
3,20	3,25	3,39	9,84	1,188	27%	4,05	4,08	4,1	12,23	6,097	100%
3,22	3,27	3,37	9,86	1,188	28%	4,05	4,1	4,08	12,23	6,097	100%
3,25	3,27	3,37	9,89	1,24	29%	4,05	4,1	4,08	12,23	6,097	100%
3,25	3,3	3,39	9,94	1,32	31%	4,05	4,13	4,08	12,26	6,097	100%
3,25	3,32	3,37	9,94	1,267	31%	4,08	4,08	4,08	12,23	6,097	100%
3,30	3,27	3,39	9,96	1,346	32%	4,05	4,08	4,1	12,23	6,018	100%
3,30	3,3	3,42	10,01	1,346	33%	4,05	4,08	4,13	12,26	6,071	100%
3,30	3,32	3,42	10,03	1,24	34%	4,05	4,1	4,08	12,23	6,018	100%
3,30	3,32	3,42	10,03	1,24	34%	4,05	4,1	4,1	12,26	6,018	100%
3,32	3,32	3,42	10,06	1,267	35%	4,05	4,13	4,08	12,26	6,018	100%

When viewed from the graph in Figure 5, the time taken for the charging process was 2 hours and 30 minutes, from a minimum voltage of 9.06 volts with a SOC value of 1% to a maximum voltage of 12.01 volts when charging with a SOC value of 100%. As for the discharge process for 114 hours and 30 minutes, the minimum voltage produced is 8.98 volts with 0% DOD.

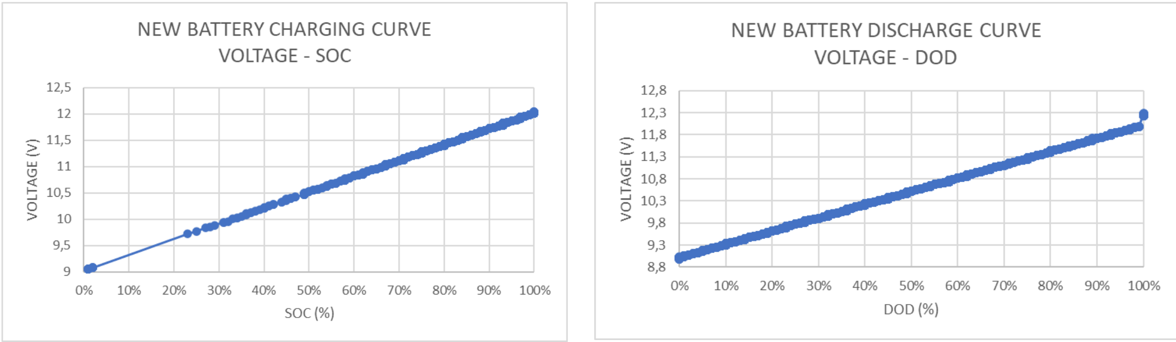

Figure 5: Discharge curve of a new battery.

4. CONCLUSION

Based on the results of the study, it can be concluded that an optimized charger will charge the battery quickly in the early stages but slow down as it approaches full capacity to prevent overcharging, which can damage the battery and lead to decreased capacity and poor safety. By using a new battery, the time required for the charging and discharging processes is longer than using an old battery. This is because the capacity of the new battery is greater at the time of inspection compared to the old battery that has already undergone degradation of usage. At full charge, using a new battery takes 2 hours and 30 minutes, while using an old battery takes 1 hours 30 minutes. During the discharge process, using a new battery takes 14 hours and 30 minutes, while using an old battery takes 14 hours. Monitoring the charging process, when the SOC is 1%, the current generated is 1.109 amperes and will continue to increase until the SOC touches the maximum value of 100% and the current generated is 2.085 amperes. This happens because the more the SOC value increases, the greater the current value aims to protect the battery. When discharging a DC motor load using an old battery, when the voltage is 9.06 volts, the time required is 9 hours 40 minutes, and the DC motor load can no longer rotate. Whereas when using a new battery with the same voltage of 9.06 volts, the time required is 14 hours and 30 minutes, and the DC motor load can still rotate to continue the discharge process until the DOD reaches a value of 0%.

References

[1] R. Pradana, A. Surya Wibowo, and A. Sugiana, "Perancangan Dan Simulasi Sistem Persinyalan Kereta Api Secara Nirkabel Design and Simulation Railway Signal System Wirelessly," vol. 8, no. 5, pp. 4397–4408, 2021.

[2] D. Serrano-Jiménez, L. Abrahamsson, S. Castaño-Solís, and J. Sanz-Feito, "Electrical railway power supply systems: Current situation and future trends," Int. J. Electr. Power Energy Syst., vol. 92, pp. 181–192, 2017.

[3] X. Fan et al., "Battery technologies for grid-level large-scale electrical energy storage," Trans. Tianjin Univ., vol. 26, pp. 92–103, 2020.

[4] K. W. E. Cheng, B. P. Divakar, H. Wu, K. Ding, and H. F. Ho, "Battery-management system (BMS) and SOC development for electrical vehicles," IEEE Trans. Veh. Technol., vol. 60, no. 1, pp. 76–88, 2011, doi: 10.1109/TVT.2010.2089647.

[5] J. Loukil, F. Masmoudi, and N. Derbel, "A real-time estimator for model parameters and state of charge of lead acid batteries in photovoltaic applications," J. Energy Storage, vol. 34, p. 102184, 2021.

[6] N. Rahmadani, M. Musaruddin, M. N. A. Nur, H. T. Mokui, and A. N. Aliansyah, "Analisis Prakiraan Kebutuhan Energi Listrik di Kabupaten Kolaka Utara menggunakan Metode Dkl 3.2, Regresi Linear dan Software Leap," J. Fokus Elektroda Energi List. Telekomun. Komputer, Elektron. dan Kendali), vol. 8, no. 2, pp. 101–109, 2023.

[7] F. Yang, S. Zhang, W. Li, and Q. Miao, "State-of-charge estimation of lithium-ion batteries using LSTM and UKF," Energy, vol. 201, p. 117664, 2020.

[8] H. Tian, P. Qin, K. Li, and Z. Zhao, "A review of the state of health for lithium-ion batteries: Research status and suggestions," J. Clean. Prod., vol. 261, p. 120813, 2020.

[9] Đ. Lazarević, M. Živković, Đ. Kocić, and J. Ćirić, "The utilizing Hall effect-based current sensor ACS712 for true RMS current measurement in power electronic systems," Sci. Tech. Rev., vol. 72, no. 1, pp. 27–32, 2022.

[10] M. Santoso, Z. M. A. Putra, A. T. Nugraha, F. Najudah, and R. Firdiansyah, "Enhancing Measurement Quality of Voltage Divider Circuit and ACS712 DC Current Sensor in PPNS Baruna 01 Crewboat Solar Power Plant," in E3S Web of Conferences, 2024, vol. 473, p. 1009.

[11] A. A. Arefin, A. S. N. Huda, Z. Syed, A. Kalam, and H. Terasaki, "ACS712 based intelligent solid-

state relay for overcurrent protection of PV-diesel hybrid mini grid," in 2020 IEEE Student Conference on Research and Development (SCOReD), 2020, pp. 59–62.

[12] L. J. Bradley and N. G. Wright, "Optimising SD saving events to maximise battery lifetime for ArduinoTM/Atmega328P data loggers," IEEE Access, vol. 8, pp. 214832–214841, 2020