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Application of the Coulomb Counting Method for Maintenance of VRLA Type Batteries in PLTS Systems

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Abstract. Almost all portable electronic devices such as cell phones, laptops, and remote-control toys use batteries as their power source. In certain cases, it was found that the battery could be damaged and short-lived. Damage to the battery is caused by using the battery that is less than the maximum. One example that can be taken in this regard is the battery connected to the PLTS system. Battery storage in PLTS can still be developed further so that the battery can work optimally and extend battery life. The case starts with conditioning the battery room temperature and the Depth of Discharge value which will shorten battery life. So to estimate this value we need a method, one of the methods that can be used is the Coulomb Counting method. This method is used to measure the value of the electric charge entering or leaving the battery. From the results obtained, the Coulomb Counting method can calculate the usage time of a 12V 200Ah VRLA battery with an average Depth of Discharge of Battery 1 DoD 39.02% DoD Battery 2 40.25% DoD Battery 3 41.92% DoD Battery 4 40.98% for 30 days. Conditioning is also carried out by maintaining the value of the depth of discharge of the battery so that it can maintain the value of Depth of Dis-charge with an average of each battery respectively 40.00%, 40.73%, 42.88% and 41.09%. From this conditioning, the estimated battery lifetime values were 3.77 years, 3.68 years, 3.45 years, and 3.64 years respectively.

1 Introduction

A battery is an energy source that can convert the stored chemical energy into electrical energy. Almost all portable electronic devices such as cell phones, laptops, and remote-control toys use batteries as their power source. With a battery, there is no need to connect a

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PLN source so that an electrical object can be supplied independently by the energy from the battery [1]. However, in practice batteries are often used not according to procedures that are in accordance with existing rules and cata-logs [2].

In previous studies, solar power plants with off-grid systems require batteries as energy storage generated from solar cells. The service life and service life of a battery are affected by several factors, therefore it is necessary to know how much the aver-age percentage level of Depth of discharge (DoD) of a battery is, as well as the number of daily cycles used by the battery during use [3]. So, it is necessary to review these parameters.

In view of these problems, of course, it is necessary to have a design for a place used to store batteries so that the battery can work optimally so that from an effective point of view, battery life can be maximized. Low discharge temperature not only causes a reduction in capacity but also increases the voltage degradation rate in the discharge curve. To get the best battery performance, generally the operating temperature is between 25 ℃ to 30 ℃ [4].

In previous research, it was explained that Depth of discharge is a value used to describe the amount of battery capacity that has been used. If a battery has a SoC value of 100%, then the DoD of the battery is 0%. DoD estimation is one of the important things in battery application, this value is needed to avoid damage to the battery system and maximize battery life. One way to estimate this value is the Coulomb counting method. Where in this method the estimated SoC and DoD values of a battery are calculated by calculating the electric current that enters or exits the battery [5] From some of these reviews, it is necessary to have a system that can condition battery storage and estimate DoD values using the Coulomb counting method on a battery.

2 Material and Method

This flowchart contains an explanation of the system from start to finish so that the stages of the system that will work in this research are identified:

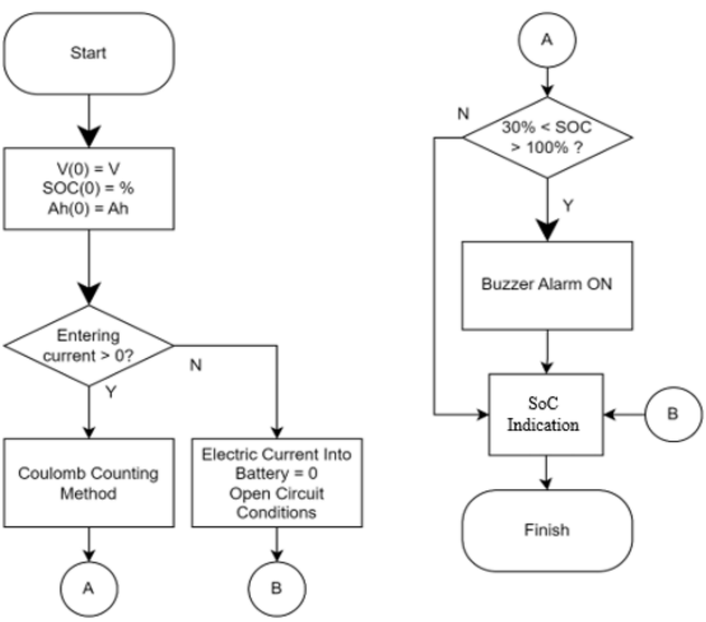

Fig. 1. Flowchart system State of Charge and Depth of Discharge Battery

From Fig. 1 it is explained that this research system works by conducting research on existing problems, then making tools that can perform conditioning and data collection so that they can be analyzed, and conclusions drawn. Starting from analyzing the Voltage and Current values so that the data can be processed into State of charge values when charging the battery or charging. Then two conditions will be indicated, namely when the circuit is closed and when the circuit is open. When the circuit is closed, the current will flow to the load and there will be a reading of the SoC value on the battery. If the SoC value on the battery is less than 30% or more than 100%, it will be indicated that the battery has reached a DoD value that exceeds the limit so that it will trigger an alarm to sound for certain conditions to be carried out on the battery.

Fig. 2 describes the workflow for conditioning the temperature and humidity of the battery room so that the battery can work optimally. in the picture begins with the reading of the room temperature parameters that are on the battery. Then, the temperature is entered into a certain range that is set at the optimal state of the battery. If the room temperature exceeds the specified point limit, the exhaust fan will turn on so that it can condition the room temperature back to optimal.

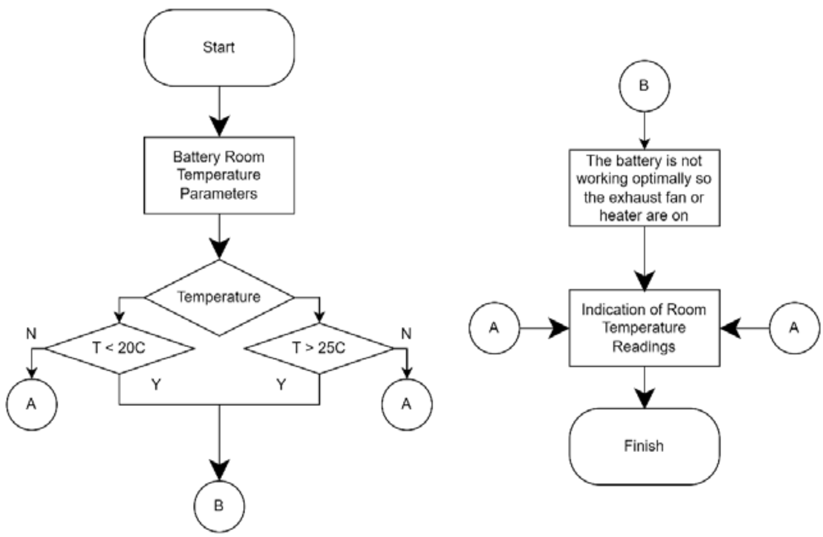

Fig. 2. The Workflow for Conditioning the Temperature and Humidity of the Battery Room

This system block diagram in Fig. 3 is a diagram that represents the system to be made. In the block diagram there are 3 important parts, namely Input, Process, and Output. Then there are also 2 other parts, namely the VRLA Nagoya 12V 200Ah battery as the research. On the input side, the battery will be connected to 3 sensors, namely a voltage sensor, a current sensor and a temperature sensor. Which functions to deter-mine the parameters needed in this study so that information is obtained for processing.

Then, the information obtained from the sensor is received by ESP32 in the Process section. This ESP32 is a microcontroller which later translates sensor readings and also forwards the information so that treatment can be carried out according to a predetermined set point.

In the output section, after everything has been processed by ESP32, this information is used to drive the existing conditioning system. Starting from bringing up the SoC value which will later be processed into DoD data to maintain the existing battery. Then there is also an emergency alarm that activates when the DoD value has reached the set point. There is also

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an exhaust fan and heater which are used to condition the battery environment so that the battery can work optimally.

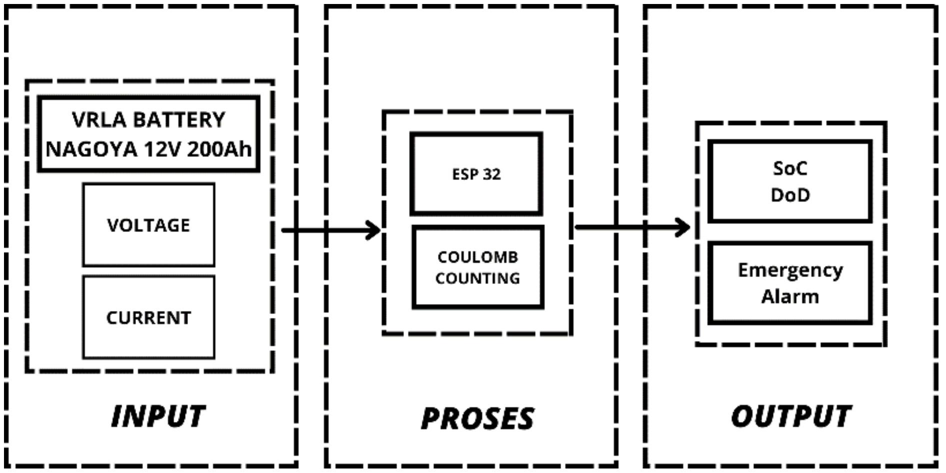

Fig. 3. Battery DoD SoC System Block Diagram

After conditioning the Depth of Discharge of the battery then proceed with estimating the lifetime of the battery (Fig. 4). In the diagram above to determine the estimated lifetime of the battery, measurements can be made on the average daily DoD of the battery. In addition, data is needed for the average daily cycle of the battery. After both data have been obtained, the lifetime calculation is performed by estimating the maximum number of cycles that can be obtained by the battery under certain conditions. Then, the estimated lifetime calculation can be carried out by taking into account both parameters, namely the average daily cycle and also the estimated maximum number of battery cycles.

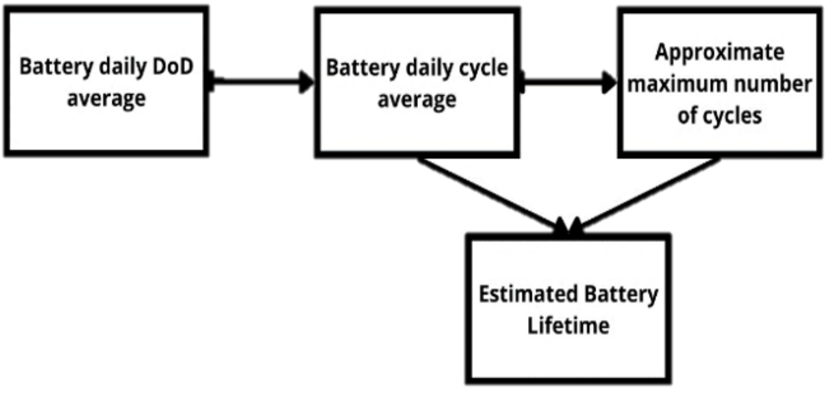

Fig. 4. Battery lifetime estimation method

3 Results and Analysis

3.1 Estimating the value of SoC using Coulomb Counting

On June 4, the SoC estimation was carried out on 4 batteries which was carried out for 24 hours with a span of 30 minutes for sending data, so the following graph is obtained. The graph shows a 1-day charge and discharge cycle on June 4. It can be seen in the graph of Fig. 5 that the battery charge and discharge levels become more linear so that the estimated SoC level is more predictable when the currents passing through the battery are the same.

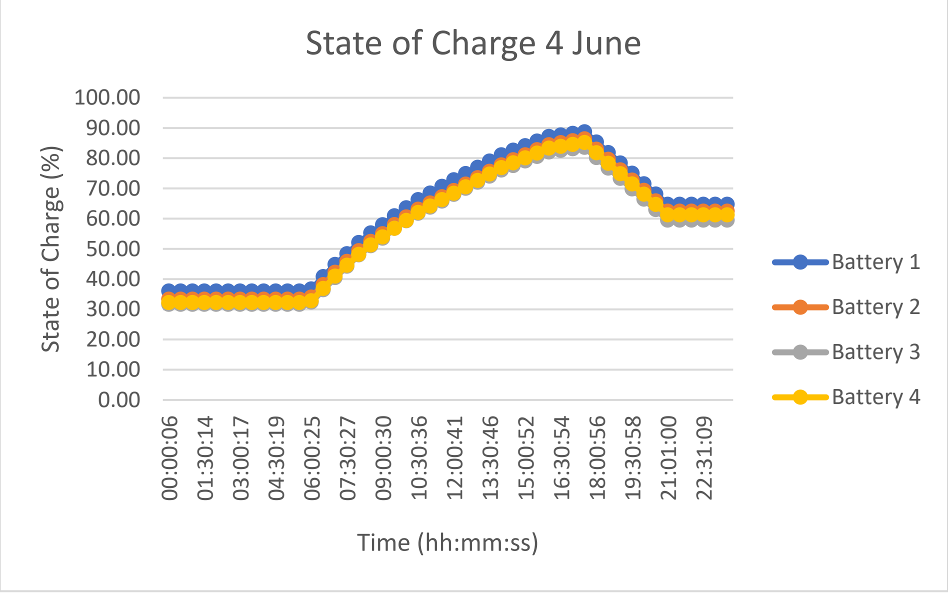

Fig. 5. State of Charge June 4th

It can be seen in Fig. 6 and Fig. 7 graphs of the increase and decrease in the battery SoC. From this graph, conditioning can be carried out to get the desired Depth of Discharge value for the battery to maintain battery lifetime. By using the current estimation method (Coulomb Counting), the rate of increase and decrease becomes more linear and predictable. When charging the battery, the SoC will increase according to the various charging currents. During discharge, the average current leaving the battery is 13.4A to 13.5A so the SoC will decrease by 3.4% every 30 minutes. How-ever, this method has drawbacks because the initial value for determining the SoC still uses the voltage as the initial reference for determining the SoC for each battery.

3.2 Battery Space Conditioning

In this study, battery room conditioning was carried out. It can be seen that at 17:30 to 22:31 the battery room was conditioned because at that time the battery was discharged, so the peltier and exhaust fans worked so that the temperature in the battery room could be reduced.

From Table 1, It can be seen that at 17:30 to 22:31 the battery room is conditioned because at that time the battery discharge occurs, so the peltier and exhaust fans work so that the temperature in the battery room can be reduced. When conditioning the battery room, the temperature of the battery room has decreased on the temperature sensor 1 to 25.30OC and the temperature sensor 2 to 25.80OC so that battery operation can be optimal (Fig. 8). When conditioning the battery room, the temperature of the battery room has decreased on the temperature sensor 1 to 25.30OC and the temperature sensor 2 to 25.80OC so that battery operation can be optimal.

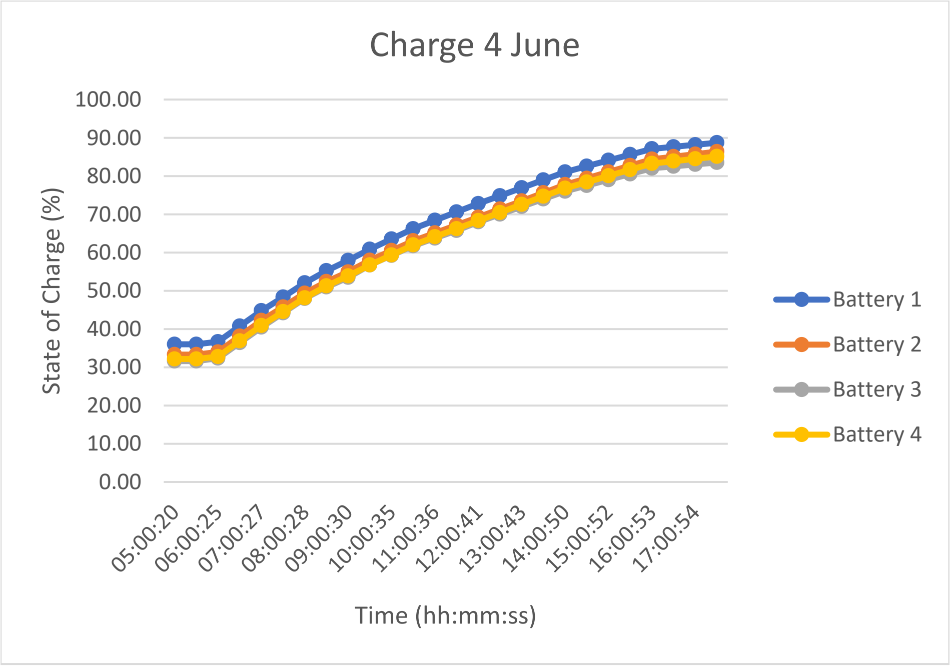

Fig. 6. Battery Charge June 4th

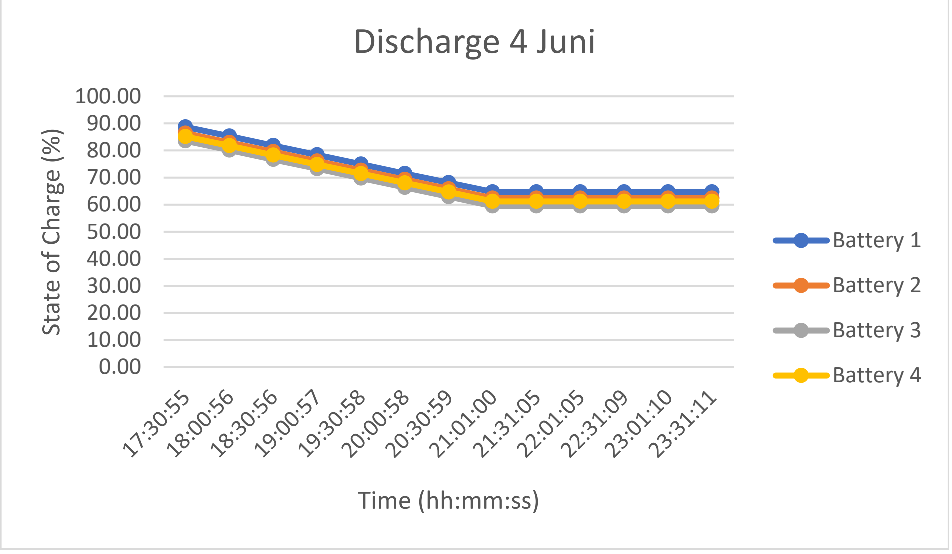

Fig. 7. Battery Discharge June 4th

Table 1. Room Temperature Conditioning

humidity 1 (%)	Temperature 1 (C)	Humidity 2 (%)	Temperature 2 (C)	Time
55.00	33.30	56.00	34.70	17:30:55
57.00	31.30	72.00	32.70	18:00:04
51.00	29.80	72.00	30.20	18:30:55
51.00	28.50	71.00	29.90	19:00:55
50.00	26.80	70.00	27.40	19:30:55
49.00	25.30	65.00	26.80	20:00:55
50.00	26.20	67.00	26.80	20:30:55
67.00	26.20	62.00	26.80	21:00:55
60.00	25.20	59.00	25.80	21:30:55
57.00	26.80	60.00	26.30	21:00:55
65.00	29.30	56.00	30.80	22:31:09
67.00	28.90	67.00	30.20	23:01:10
66.00	28.90	66.00	30.20	23:31:11

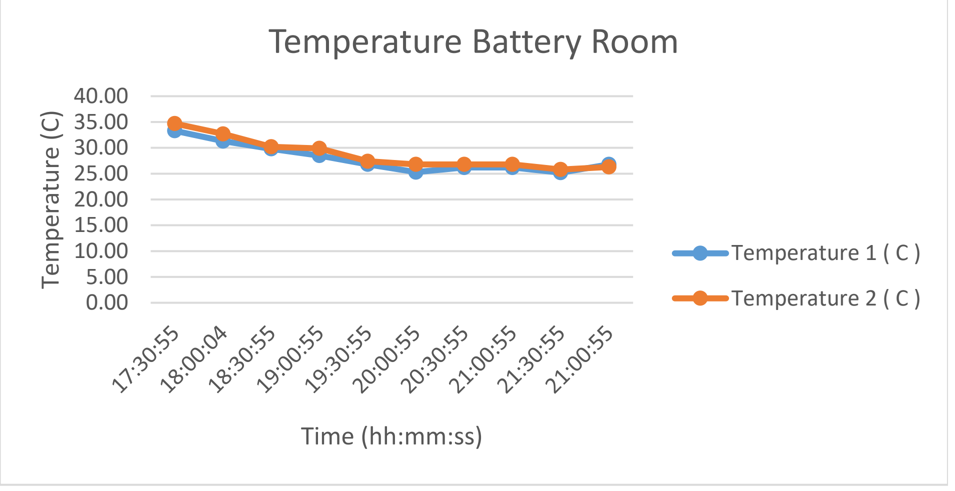

Fig. 8. Temperature Battery Room

3.3 Battery lifetime estimation

Battery lifetime is a necessary parameter to find out when a battery needs maintenance or replacement. It is important to keep the battery in optimal condition by adopting good maintenance practices.

3.3.1 Average Daily DoD of Battery

Based on the results of research that began on May 14, 2023 to June 14, 2023, the average daily DoD results for each battery were obtained. From Table 2 it can be seen that the results of the DoD estimation for the expansion from May 14 to June 14, so that we get a graph of the daily discharge of Battery. The average daily DoD results for each battery were obtained (Fig. 9). So that it can be determined the maximum cycle value that can be achieved from the battery. On 24th and 25th data could not be obtained due to technical problems with the existing control panel.

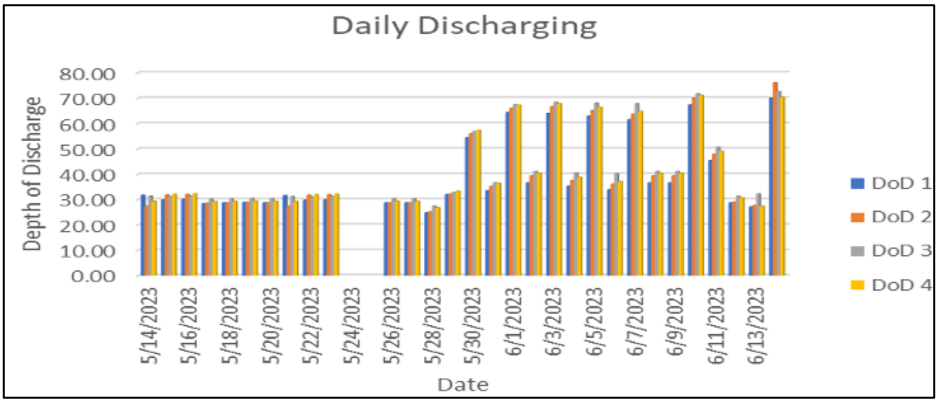

Fig. 9. Average daily DoD of battery

Table 2. Average daily DoD of battery

Date	DoD 1 (%)	DoD 2 (%)	DoD 3 (%)	DoD 4 (%)
5/14/2023	31.69	27.50	31.37	29.43
5/15/2023	29.88	31.82	31.17	32.14
5/16/2023	30.08	32.02	31.37	32.34
5/17/2023	28.59	28.59	30.20	29.23
5/18/2023	28.71	28.71	30.32	29.35
5/19/2023	28.91	28.91	30.52	29.55
5/20/2023	28.71	28.71	30.32	29.35
5/21/2023	31.56	27.37	31.24	29.30
5/22/2023	29.75	31.69	31.04	32.01
5/23/2023	29.95	31.89	31.24	32.21
5/24/2023	-	-	-	-
5/25/2023	-	-	-	-
5/26/2023	28.78	28.78	30.39	29.42
5/27/2023	28.71	28.71	30.32	29.35
5/28/2023	24.84	25.16	27.42	26.77
5/29/2023	32.06	32.28	32.86	33.28
5/30/2023	54.48	56.02	56.85	57.30
5/31/2023	33.49	35.22	36.58	36.38
6/1/2023	64.32	65.98	67.48	67.24
6/2/2023	36.60	39.32	41.04	40.37
6/3/2023	63.99	66.69	68.39	67.84
6/4/2023	35.31	37.60	40.54	38.83
6/5/2023	62.88	65.17	68.12	66.41
6/6/2023	33.93	36.13	40.30	37.17
6/7/2023	61.51	63.72	67.90	64.77
6/8/2023	36.60	39.32	41.04	40.37
6/9/2023	36.60	39.32	41.04	40.37
6/10/2023	67.31	70.01	71.71	71.16
6/11/2023	45.40	47.92	50.61	49.05
6/12/2023	28.71	29.03	31.29	30.65
6/13/2023	27.10	27.74	32.26	27.42
6/14/2023	70.00	76.13	72.58	70.32

Based on Fig. 9, the results show that when using the battery, the average DoD value for each battery is obtained, so that it is as follows.

DoD of Battery 1 = 39.02%
DoD of Battery 2 = 40.25%
DoD of Battery 3 = 41.92%
DoD of Battery 4 = 40.98%

So that it can be determined the maximum cycle value that can be achieved from the battery.

Table 3. Battery daily cycle

Date	Charging	Discharging
5/14/2023	1	1
5/15/2023	1	1
5/16/2023	1	1
5/17/2023	1	1
5/18/2023	1	1
5/19/2023	1	1
5/20/2023	1	1
5/21/2023	1	1
5/22/2023	1	1
5/23/2023	1	1
5/24/2023	0	0
5/25/2023	0	0
5/26/2023	1	1
5/27/2023	1	1
5/28/2023	1	1
5/29/2023	1	1
5/30/2023	0	1
5/31/2023	1	1
6/1/2023	0	1
6/2/2023	1	1
6/3/2023	0	1
6/4/2023	1	1
6/5/2023	0	1
6/6/2023	1	1
6/7/2023	0	1
6/8/2023	1	1
6/9/2023	0	0
6/10/2023	0	1
6/11/2023	1	1
6/12/2023	1	1
6/13/2023	1	1
6/14/2023	0	1

3.3.2 *Battery Daily Cycle (Cyc)*

To calculate and estimate the lifetime of the battery, data on battery charging and discharging cycles is required. This data will be used as a number to predict the lifetime of the existing battery.

From Table 3 it can be seen that the results of the battery daily cycle from May 14 to June 14, so that we get a graph of the daily discharge of Battery. the average daily DoD results for each battery were obtained. So that it can be determined the maxi-mum cycle value that can be achieved from the battery.

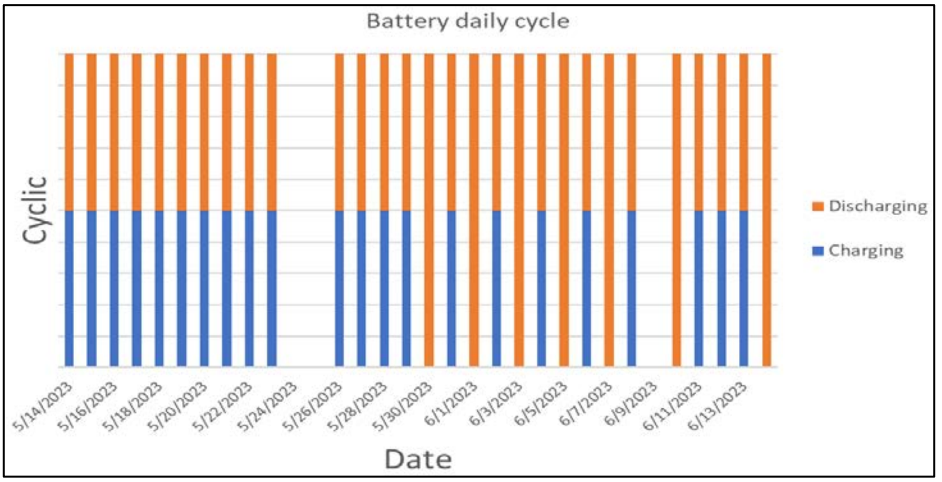

Fig. 10. Battery daily cycle

Judging from the Fig. 10, it can be seen the amount of charging and discharging on battery usage in PLTS. This data is used as a reference to see the average daily cycle that has been carried out by the battery.

$$\overline{Cyc} = \frac{\sum Charging}{\sum Discharging} \quad (1)$$

$$\overline{Cyc} = \frac{22}{29} \quad (2)$$

$$\overline{Cyc} = 0.758 \quad (3)$$

The average daily cycle of the 4 VRLA batteries is 0.758. So based on this daily cycle data, it will later be processed as data to get the durability or lifetime of the battery.

3.3.3 Battery Maximum Cycle (Cyh)

The maximum battery cycle can be obtained from data processing on average daily discharge of the battery so that the formula is obtained:

$Maximum\ Cycle\ = 296.69(DoD)^{-1.276}$

Then the maximum cycle results for each battery are obtained as follows :

$Maximum\ Cycle\ \ 1 = 296.69(DoD\ 1)^{-1.276}$

$Maximum\ Cycle\ \ 1 = 296.69(39.02\%)^{-1.276}$

$Maximum\ Cycle\ \ 1 =$ 896.15 cyclic

$Maximum\ Cycle\ = 296.69(DoD)^{-1.276}$

$Maximum\ Cycle\ \ 2 = 296.69(DoD\ 1)^{-1.276}$

$Maximum\ Cycle\ \ 2 = 296.69(40.25\%)^{-1.276}$

$Maximum\ Cycle\ \ 2 =$ 861.35 cyclic

$Maximum\ Cycle\ = 296.69(DoD)^{-1.276}$

$Maximum\ Cycle\ \ 3 = 296.69(DoD\ 1)^{-1.276}$

$Maximum\ Cycle\ \ 3 = 296.69(41.92\%)^{-1.276}$

$Maximum\ Cycle\ \ 3 =$ 817.81 cyclic

$Maximum\ Cycle\ = 296.69(DoD)^{-1.276}$

$Maximum\ Cycle\ 4 = 296.69(DoD\ 1)^{-1.276}$
$Maximum\ Cycle\ 4 = 296.69(40.98\%)^{-1.276}$
$Maximum\ Cycle\ 4 = 841.82$ cyclic

From the results of these calculations, it is obtained that the maximum number of cycles sequentially from Battery 1 to Battery 4 is 896.15 cycles, 861.35 cycles, 817.81 cycles, 841.82 cycles which will later be used to calculate the lifetime value of the existing battery

3.3.4 *Estimated Battery Lifetime*

Battery lifetime is the remaining battery life that can be used for several conditions. Estimates the number of battery lifecycles (battery life cycles) based on DoD level. In analyzing and estimating the number of cycles (cycles) based on the DoD level of the battery can be done.

$$Lifetime = \frac{Cyh}{CyC} \quad (4)$$

$$Lifetime1 = \frac{Cyh1}{CyC} = \frac{896.15}{0.758} \quad (5)$$
$$= 1182.255 \text{ day}$$

$$Lifetime2 = \frac{Cyh2}{CyC} = \frac{861.35}{0.758} \quad (6)$$
$$= 1136.34 \text{ day}$$

$$Lifetime3 = \frac{Cyh3}{CyC} = \frac{817.81}{0.758} \quad (7)$$
$$= 1078.90 \text{ day}$$

$$Lifetime4 = \frac{Cyh4}{CyC} = \frac{841.82}{0.758} \quad (8)$$
$$= 1110.58 \text{ day}$$

4 Conclusion

Based on data analysis and results obtained from the results obtained, the Coulomb Counting method can calculate the usage time of a VRLA 12V 200Ah battery with an average Depth of Discharge DoD Battery 1 39.02% DoD Battery 2 40.25% DoD Battery 3 41.92% DoD Battery 4 40.98% for 30 days. So that it can also predict battery life with room conditioning ±25°C battery becomes Battery 1 for 1182.25 days, Battery 2 for 1136.34 days, Battery 3 for 1078.90 days, and Battery 4 1110.58 days. It can be compared between the two methods that there are advantages to using voltage estimation where the SoC can be seen directly when measurements are made without waiting for the current and time that the battery has run, however, the estimated value from this voltage method is more difficult to estimate for increases and decreases. When using the coulomb counting method, the advantage obtained is that the estimate of the battery SoC is better estimated for subsequent use. This method cannot be used to initially determine the battery SoC and must use voltage as a reference.

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