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Li-Ion battery discharge study

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Abstract. The production of energy from renewable sources remains another challenge. Efficient storage of electricity is one of the current problems in electricity. This paper studies three ways to discharge a Li-Ion battery with a capacity of 4.2V, connected to three circuits with different resistance values. for data acquisition were used USB 6008 (program was written in LabView using NI-DAQmx) from National Instruments.

Keywords – Li-ion Battery, USB 6008, LabView, resistors

1. INTRODUCTION

Storing electricity can be a real challenge, because it is a whole process in conserving and conserving this energy. The tendency to obtain electricity is to obtain energy using renewable sources, for example obtaining electricity using photovoltaic panels (PV) on board ships, in the maritime environment[1]. This way of producing electricity substantially reduces CO2 emissions, so it can reach the proposed goal globally, namely reducing CO2 emissions and obtaining electricity from renewable sources. It is important that this time of electricity production can also be obtained on board a ship. Maritime transport accounts for 90% of global transport, and if it were possible to produce electricity on board ships, while transporting goods from renewable energy sources, it would implicitly reduce CO2 emissions.[1]–[4]
In this paper we will present experiments for discharging Li-ion batteries. This battery model was chosen because it is one of the best battery models (low cost and easy maintenance),[5] but also for the fact that this battery model is a new generation one, which is constantly being improved[6]. To perform the measurements, we programmed a data acquisition system from National Instruments using LabView software.[2], [7]

2. RESEARCH PLATFORM STRUCTURE

The research purpose was to study the feasibility of using a charged Li-Ion battery at maximum capacity and then connected to three electrical circuits with different characteristics. The first objective was to choose the battery model (Table 2.1).[8]

Table 2.1 - Li-Ion battery characteristics.

Item	Specification
Nominal discharge capacity	2,000mAh Charge, 1A, 4.20V, CCCV 100mA cut-off; Discharge: 0.2C, 2.5V discharge cut-off
Nominal voltage	3.6V
Standard charge	CCCV, 1A, 4.20 ± 0.05 V, 100mA cut-of
Rapid charge	CCCV, 4A, 4.20 ± 0.05 V, 100mA cut-off
Charging time	Standard charge 180min / 100mA cut-off Rapid charge: 50 min (at 25°C) / 100mA cut-off
Discharge cut-off voltage End of discharge	2.5V

The research platform is composed of three main parts:

a. Li-Ion Battery and battery charger,
b. Data acquisition system – LabView and USB 6008 from National Instruments,
c. Breadboard and resistors.

A. Specification of battery are related in Table 2.1
B. *Data acquisition system* - To record the battery discharge data in the three experimental circuits, we used from National Instruments module USB 6008 - hardware part which programmed using LabView software. Module USB 6008 is programmed to behave like a voltmeter and connects in parallel to the battery terminals.
   a. *Module NI USB 6008*

The data acquisition card is composed from an analog to digital converter and a 32-bit counter with a full-speed USB interface (Figure 2.1 - Block Diagram USB 6008).
The NI USB-6008 provides connection to eight analog input (AI) channels, two analog output (AO) channels, 12 digital input/output (DIO) channel. The experiment with battery required only one analog input channel (we used AI-01) (Figure 2.2)[1], [9]

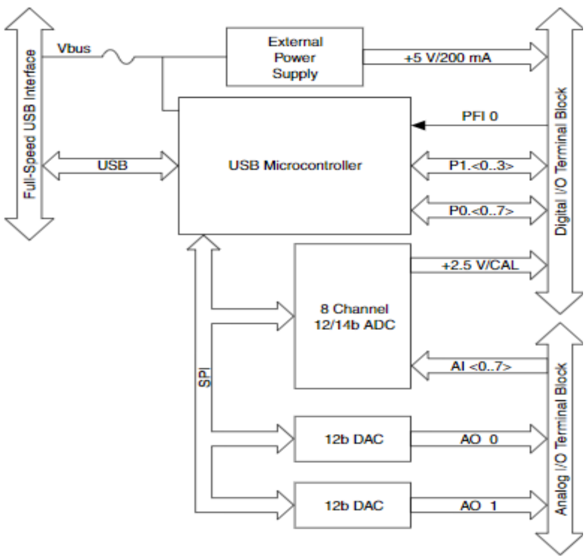


Figure 2.1 - Block Diagram USB 6008

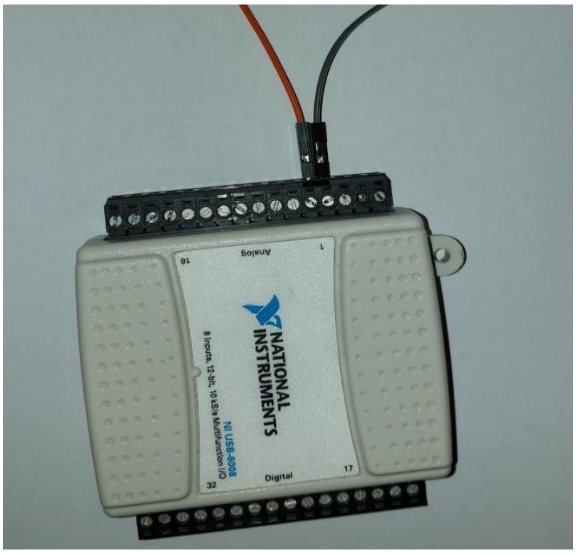


Figure 2.2 – USB 6008

   b. *Data Acquisition Program -LabView* – For data acquisition the program was written in LabView using NI-DAQmx like in Block diagram (Figure 2.3).

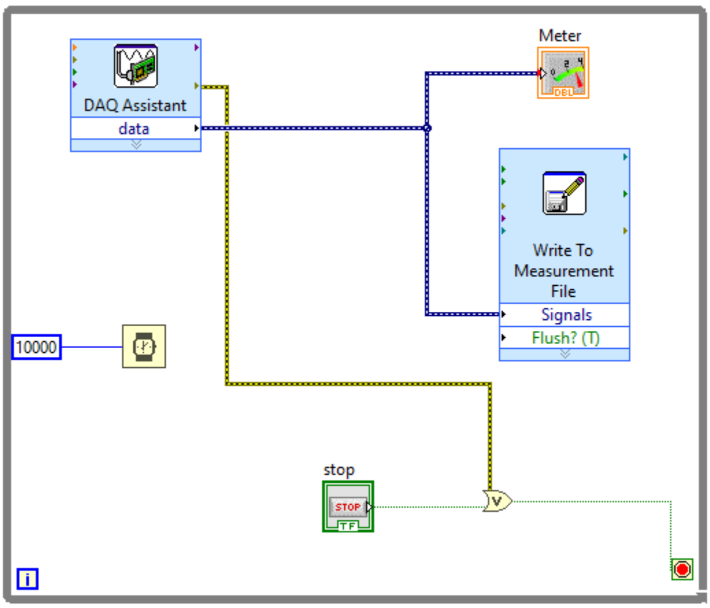


Figure 2.3 – Program block diagram

Block diagram detailed:

- *While loop* – repeat and execute the code until the stop button is pressed or the program has an error,
- *OR* – the logical component that stops running the program when the STOP button is pressed or an error occurs,
- *Wait (ms)* - Waits the specified number of milliseconds and returns the value of the millisecond timer,
- *Meter* – Help us to see in real time the voltage value.
- *Write to measurement file* – receive data from *DAQ Assistant* and writes the voltage values,
- *DAQ Assistant* - is the interface between USB-6008 module and LabView programming language. It converts the battery voltage output in dynamic data which can be processed by LabView virtual instruments. It measures voltage between -10 and 10 V DC. The block diagram behind this component is shown in Figure 2.4.

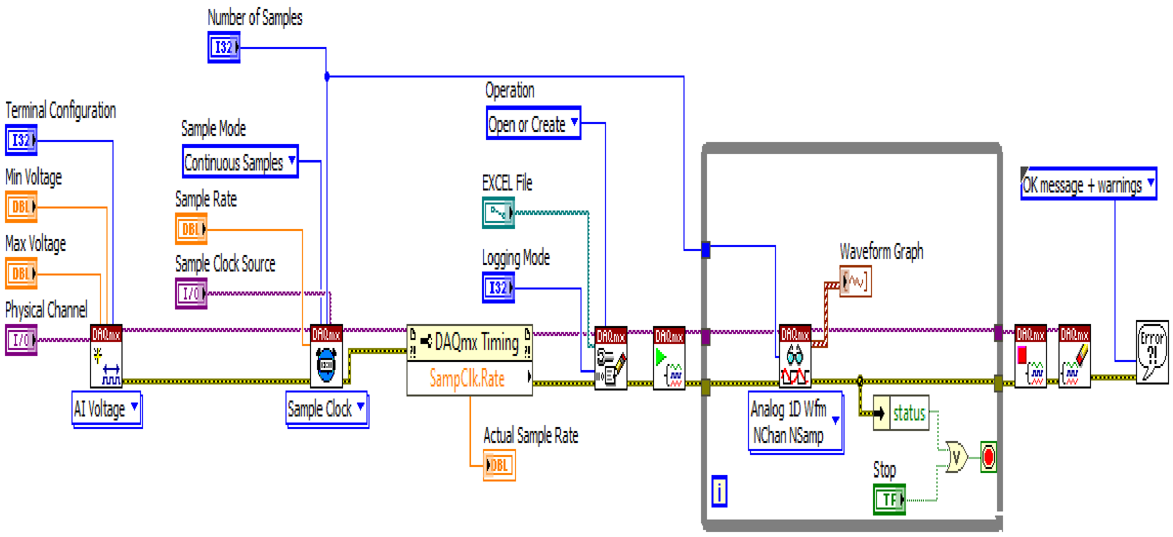


Figure 2.4 – DAQ Assistant block diagram

C. *Breadboard and resistors* - The experimental circuits were made using breadboard like in Figure 2.5.

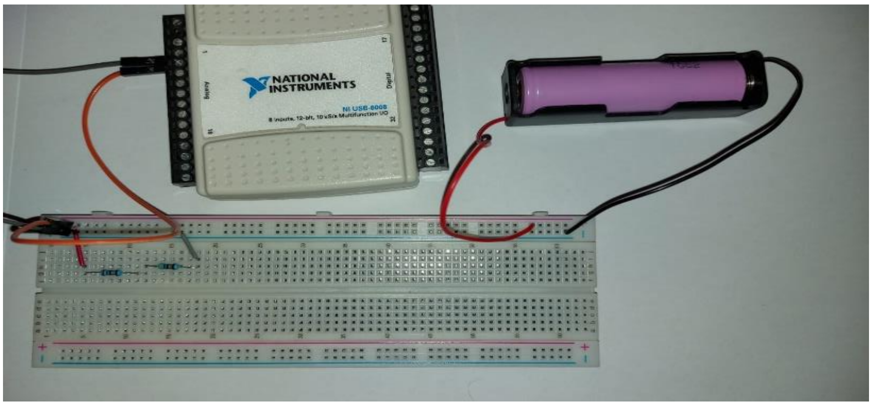


Figure 2.5 – Breadboard and resistors

3. EXPERIMENTAL PART

The experimental part consisted in connecting the battery to three resistive circuits with different values (120Ω, 13.75Ω, 69Ω). USB 6008 and software LabView recorded the voltage values and put it in a excel file.

A. The first experiment.

In this experiment was used several resistors of different values, connected in parallel, the equivalent resistance of the circuit was 120 Ω. Figure 3.1 shows the circuit diagram – made with the help of the falstad program. The recorded values are represented in the graph in figure 3.2.

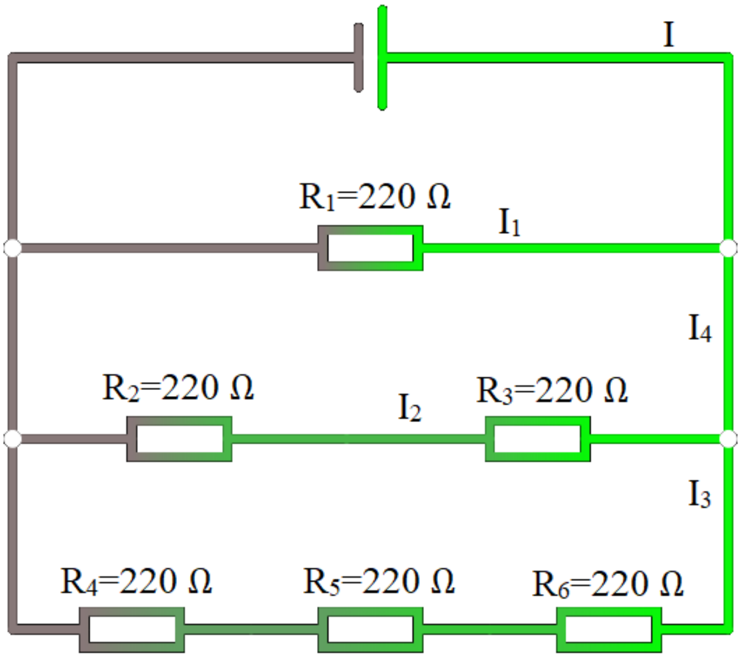


Figure 3.1 – Electrical diagram for the first circuit

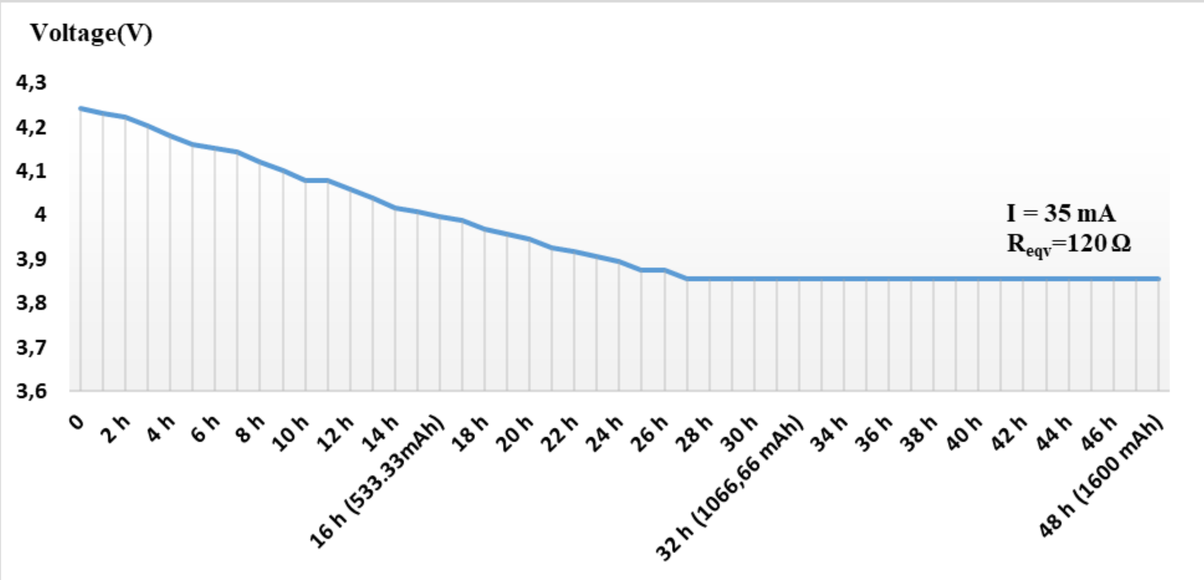


Figure 3.2 - Graph of the first experiment

For this circuit we have the following physical sizes:

$$\begin{cases} R_{eqv} = 120\ \Omega \\ E = 4.2\ V \\ I = 35\ mA \\ I_1 = 19.09\ mA \\ I_2 = 9.54\ mA \\ I_3 = 6.36\ mA \\ P_1 = 80.18\ mW \\ P_2 = 40.091\ mW \\ P_3 = 26.72\ mW \\ P_{eqv} = 147\ mW \end{cases}$$

In this circuit the current and energy consumption are quite low, so after 48 hours I stopped the experiment and decided to reduce the equivalent resistance by about 10 times. It can be seen that the voltage drops quite quickly from 4.2V to 3.9V, but it is established between 3.9V and 3.8V.

B. The second experiment

For this experiment was used a 4.2V Li-ion battery and an equivalent resistance of 13.75 Ω. Figure 3.3 shows the circuit diagram – made with the help of the falstad program. The recorded values are represented in the graph in figure 3.4

It can be seen that the battery voltage drops quite quickly from 4.2V to 3.9V, but between 3.9V and 3.5V the battery voltage stabilizes and remains constant. From 3.5V to 2.5V it drops almost instantly, and at 2.5V the circuit has been disconnected, because the manufacturer advises us not to drop the battery voltage below 2.5V.[8]

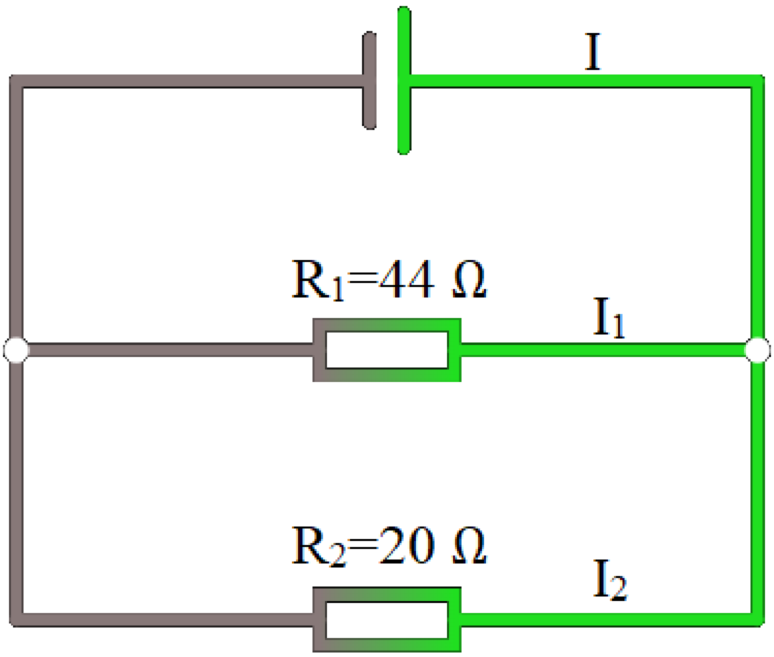


Figure 3.3 - circuit diagram

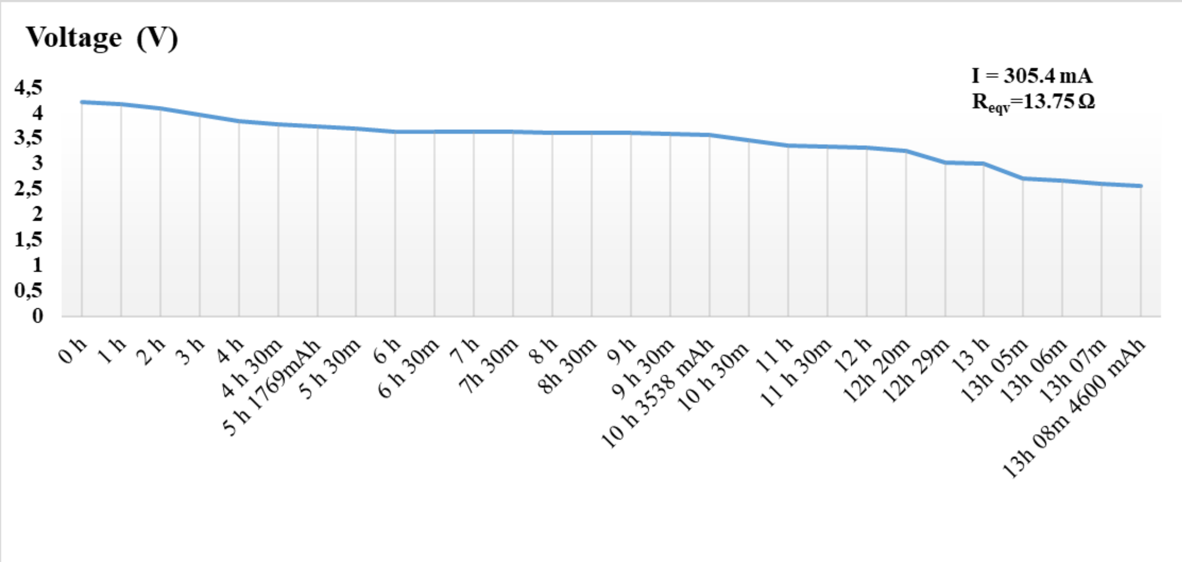


Figure 3.4 - Graph of the secund experiment

For this circuit we have the following physical sizes:

$$\begin{cases} R_{eqv} = 13.75\ \Omega \\ E = 4.2\ V \\ I = 305.4\ mA \\ I_1 = 95.4\ mA \\ I_2 = 210\ mA \\ P_1 = 400.9 mW \\ P_2 = 882 mW \\ P_{eqv} = 1282.9 mW \end{cases}$$

C. The third experiment

For this experiment was used a 4.2V Li-ion battery and an equivalent resistance of 66.8 Ω (approximately the average value of the resistances of the two previous experiments). Figure 3.5 shows the circuit diagram – made with the help of the falstad program. The recorded values are represented in the graph in figure 3.5.

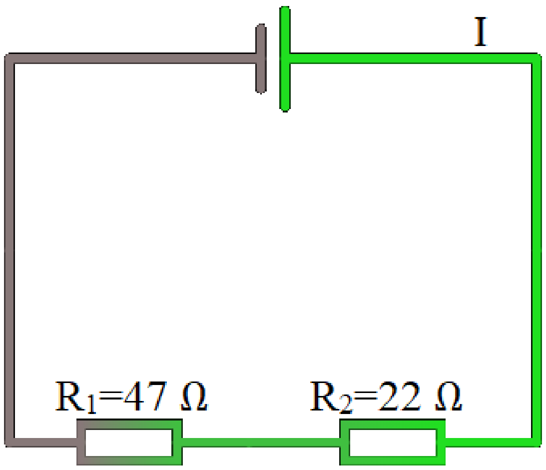
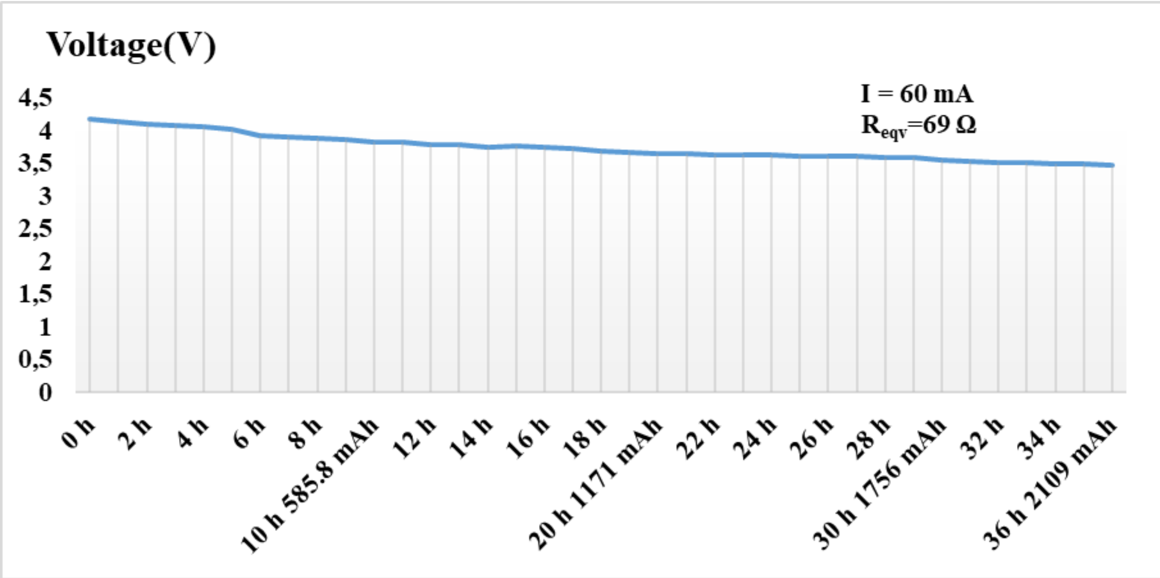


Figure 3.5 - circuit diagram



For this circuit we have the following physical sizes:

$$\left\{\begin{aligned} R_{eqv} &= 69\ \Omega \\ E &= 4.2\ V \\ I &= 60\ mA \\ P_1 &= 81.5\ mW \\ P_2 &= 174.14\ mW \\ P_{eqv} &= 255.64\ mW \end{aligned}\right.$$

It can be seen that this time too the battery voltage has stabilized between 3.9V and 3.5V.

4. CONCLUSIONS

From the three experiments we can deduce that this type of battery stabilizes its voltage between 3.9V and 3.5V. We can also say that this type of battery has three stages in the discharge process, as follows:

1) The first stage is between 4.2V and 3.9V. - The battery discharge process occurs quite quickly.
2) The second stage is between 3.9V and 3.5 V - The battery discharge process is slow.
3) The third stage is between 3.5 and 2.5V. - The battery discharge process is extremely fast. It is recommended to avoid this stage and discharge below 2.5V.[8]

Based on this study, it was possible to create a battery diagram (Figure 4). It follows that in the near future, this study will be much more elaborate, also the charging regime of these types of batteries will be studied.

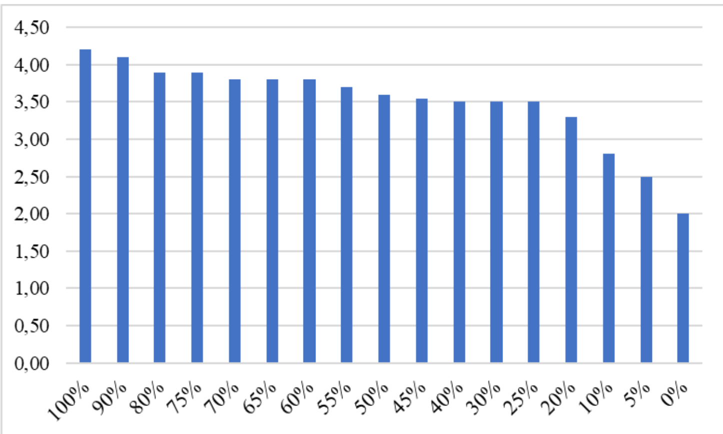


Figure 4 – Battery diagram

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