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# Design of Optimal Charging System on Lead-Acid Calcium Battery for UNY 2020 Electric Car

**I Siswanto[1*], F Arifin[2], H Prabowo[3], R Asnawi[4], Tafakur[1], A Syafiq[1], S Kurniawan[2]**

Department of Automotive Engineering, Universitas Negeri Yogyakarta, Indonesia
Department of Electronics Engineering, Universitas Negeri Yogyakarta, Indonesia
Department of Mechanical Engineering, Universitas Negeri Yogyakarta, Indonesia
Department of Electrical Engineering, Universitas Negeri Yogyakarta, Indonesia

Email: ibnusiswanto@uny.ac.id

**Abstract.** The battery is a very important component as a source of energy to drive an electric car. The capacity of using the battery adjusts to the load supplied. The use of batteries in addition to supplying loads is a storage of electrical energy. Methods of storing electrical energy in batteries can use a generator or power supply. This paper discusses the optimal charging system design for lead-acid-calcium batteries in the UNY 2020 electric car. The proposed charging system uses constant current (CC) and constant voltage (CV) based on the 3-stage charging process used. In the design, the characteristic curve of voltage, current, state of charge (SoC) is obtained. The design simulation results show the battery performance during the charge and discharger cycle process for 75 times with the bulk stage, absorption stage, and float stage.

## 1. Introduction

The battery is a supporting component as an energy source for various electronic applications, one of which is an electric car. This component has characteristics that adapt to the sealants used in it such as lead-acid, lithium, and nickel-cadmium. Each material has good resistance from voltage, current, capacity, to battery life [1].

The battery usage application focuses on energy sources in electric cars. Where the large battery storage capacity adapts to the large electric motor power used. The larger the electric motor used, the larger the battery capacity required. The battery capacity greatly affects the operating life of the electric motor. The larger the battery capacity used, the longer the operation of the electric motor [2]. The greater the battery capacity used, the longer the battery charging process will take. This of course will be a drawback from using electric vehicles. It is necessary to develop a fast charging process on the battery.

This research uses a battery which is applied to the UNY electric car. Where is the UNY electric car specification using 4 lead-acid batteries with the type of calcium alloy batteries. The battery has better specifications than using lead-acid normally. So that, seen from the characteristics of battery endurance, it has much better capabilities. Batteries of this type are widely used for energy source applications in electric vehicles, including electric motors and electric cars.

The results of this study are the fast-charging simulation results for lead-acid calcium batteries with an optimal charging process. The optimal charging stage is simulated and analyzed to see the fenomena that occurs in the voltage, current, and SoC of the battery. The simulation in this study uses 3 stages with constant current (CC) and constant voltage (CV) electronic systems.

## 2. Prepare of research

Determining the design used so that the optimal battery charging manufacturing process is carried out by reviewing some of the existing literature.

### *2.1 Battery lead-acid calcium*

The lead-acid battery is a battery that has many drawbacks, both in terms of the charging process and serious problems. Of course, this is a very big concern in optimizing the lead-acid battery [3]. Optimization of this battery can be done in the charging process or for the discharging process by limiting the current flowing in the battery [4], [5].

The lead-acid battery component consists of several layers of copper and zinc which are energized by an electric current that comes from a chemical liquid [6], [7]. The magnitude of the resulting current will greatly affect the chemical reaction and cause sulfation in both electrode reports. Of course, excessive sulfation will reduce the life and performance of the battery. Equations 1 to 3 show the chemical reaction in the battery.

$$Pb(s) + HSO_4^-(aq) \rightarrow PbSO_4(s) + 2H_2O(l) \tag{1}$$

$$PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) \rightarrow PbSO_4(s) + 2H_2O(l) \tag{2}$$

$$Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow PbSO_4(s) + 2H_2O(l) \tag{3}$$

When the electrons accumulate, these chemical particles create an electric field that attracts hydrogen ions and displaces sulfate ions. Hydrogen ions filter the charged electrodes from the solution limiting further reactions unless the charge is allowed to flow out of the electrodes.

The net energy released per mole (207 g) $Pb(s)$ converted to $PbSO_4(s)$, is ca. 400 kJ, corresponding to the formation of 36 g of water. The total molecular mass of the reactants is 642.6 g / mol, so theoretically a cell can produce two distant charges (192,971 coulombs) of 642.6 g of reactant, or 83.4 amperes hour per kilogram (or 13.9 Ah / kg for a 12 volt battery). For a 2 volt cell, this yields 167 Wh / kg of reactant, but in practice, lead-acid cells only produce 30-40 watt-hours per kilogram of battery, due to the mass of water and other elements. part.

To reduce the sulfation process, it is necessary to limit the current flowing in the battery both in the charging and discharging processes. Current limiting affects the plate sulfation process on the battery. The greater the current that is flowed during the charging process, the faster the sulfation process in the battery.

### *2.2 Lead-acid calcium charge method*

The battery charge and discharge rates are regulated by the C-rate [8]–[11]. Battery capacities are usually rated at 1C, meaning that a fully charged 1Ah battery should provide 1A for an hour. Discharging the same battery at 0.5C will deliver 500mA for two hours, and at 2C yielding 2A for 30 minutes. The loss on quick release reduces discharge time and this loss also affects charge time. Table 1 shows the effect of the C-rate on charging time.

**Table 1.** Effect of C-rate on charging time

| **C-rate** | **Time (min)** |
|---|---|
| 5C | 12 |

| | |
|---|---|
| 2C | 30 |
| 1C | 60 |
| 0.5C or C/2 | 120 |
| 0.2C or C/5 | 300 |
| 0.1C or C/10 | 600 |
| 0.05C or C/20 | 1200 |

To get a sufficiently good capacity reading, manufacturers typically rate lead-acid calcium batteries at a very low 0.05C, or 20 hours of discharge. Even at this slow discharge rate, lead-acid calcium rarely reaches 100% SoC because the battery is overvalued. The manufacturer provides a capacity offset to adjust for differences if discharged at a higher than specified C level.

### *2.3 Step of Charge*

There are 3 steps for the charging process especially for lead-acid calcium batteries. Where are these steps such as the bulk stage, absorption stage, and float stage. Figure 1 shows the 3 charging conditions for a lead-acid calcium battery.

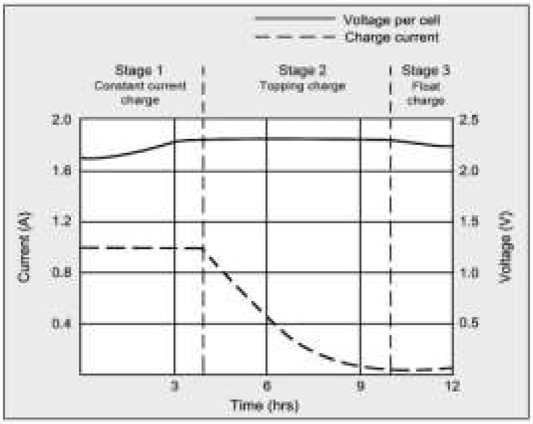

**Figure 1.** Three steps for charging a lead-acid battery

#### *2.3.1 Bulk stage.*

In the bulk stage process, the battery is supplied with a constant current. Of course, the amount of current that flows must be adjusted to the C-rate of the battery to be charged. The amount of C rate determines the length of the charging process to maintain the age and performance of the battery.

The bulk process is carried out using the constant current method. The attainment of the current value is used to fulfill the constant current by using the constant current model. In the charging process, the recommended current is to meet the C-rate value on the battery body.

Bulk charge time is carried out until the SoC of the battery reaches 80%. Where at 80%, the current is smaller than the amount during the charging process.

#### *2.3.2 Absorption stage*

The absorption process is a process of keeping the tension constant. This process uses constant voltage (CV) [12]. The voltage is kept constant so that the charging current is smaller. In the simulation, the absorption process is carried out when the battery SoC reaches 80% and above.

#### *2.3.3 Float stage.*

The float stage is a constant charging process when the SoC on the battery reaches 99%. At the float stage, the current flowing is close to 0 and the charger voltage is close to the open-circuit voltage on the battery.

## 3 Methodology

Figure 2 shows the research methodology used.

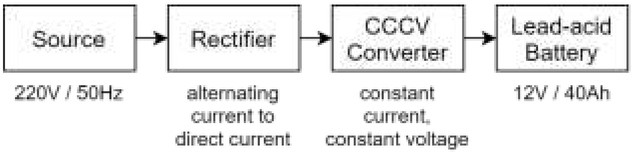

**Figure 2.** Methodology

Charging the lead-acid battery cannot be done using the fast charging method. So that it allows the charging process to be carried out based on the C-rate characteristics of the battery used. In this paper model, the battery uses Delkor 80D26R. Table 2 shows the battery specifications used. With the characteristics of C0.05, which means that the battery charging process is most efficient if it is charged for 1200 minutes with a current of 3.5A. The current magnitude value is obtained by formula (1).

$$I_c = C_{Batt} \times C_{rate} \tag{4}$$

Where, $I_c$ is the current during the charging process, $C_{Batt}$ is the battery capacity, $C_{rate}$ is the battery charge level. The smaller the C-rate value, the smaller the current required during the charging process.

**Table 2.** Battery technical specifications

| Parameter | Value |
|---|---:|
| Model | NX110-5 |
| Lead Material | 99.85 - 99.97 % |
| Calcium Material | 0.03 - 0.15 % |
| CCA | 560 A |
| Vrate | 12 V |
| RC | 110 min |
| Capacity | 70 Ah |
| C-rate | 0.05C |

### *3.1 Design of simulation*

The simulation design uses constant voltage and constant current methods.

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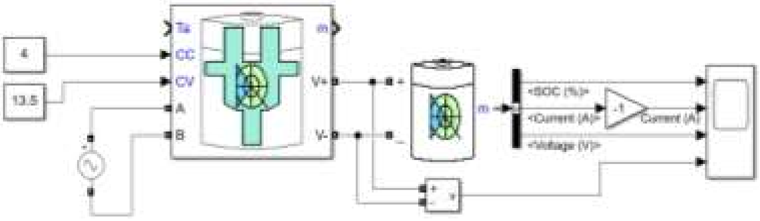

**Figure 3.** Simulation of lead-acid calcium battery with CCCV

Where to reach the bulk stage, the charging method uses a constant current. As for the absorption state, the charging method uses constant voltage [3], [13]. If the battery condition has reached the float stage, then the voltage value is the same as the battery value and the aris value is close to 0A. The parameters on the battery charger can be seen in Table 3.

**Table 3.** Battery charger parameters.

| Parameter | Value |
|---|---|

| | |
|---|---|
| Input type | 1-phase AC |
| Vpeak | 311 V |
| Frequency | 50 Hz |
| Charging mode | Constant Current – Constant Voltage |
| Bulk current | 60 V |
| Float voltage | 18 V |
| Set point CC | 4 A |
| Set point CV | 13.5 V |

*3.2 Preparing test*

There are 2 methods of testing the lead-acid calcium battery charging process. Namely by looking at the parameters of the charging process (voltage, current, SoC, power), and seeing the depth of discharger (DOD) process.

## 4 Result and Discussion

Figures 4 to 6 show the characteristics of the lead-acid calcium battery during the charging process. Where there are 4 parameters that are observed such as SoC (%), current (A), voltage (V), and power (W). Charging time shows the time in seconds (s). Each test based on the C-rate has a different charging time.

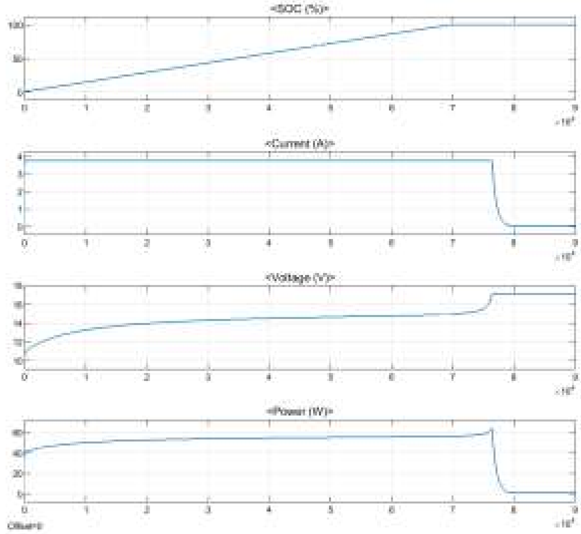

**Figure 4.** Lead-acid calcium battery when charging 0.05C

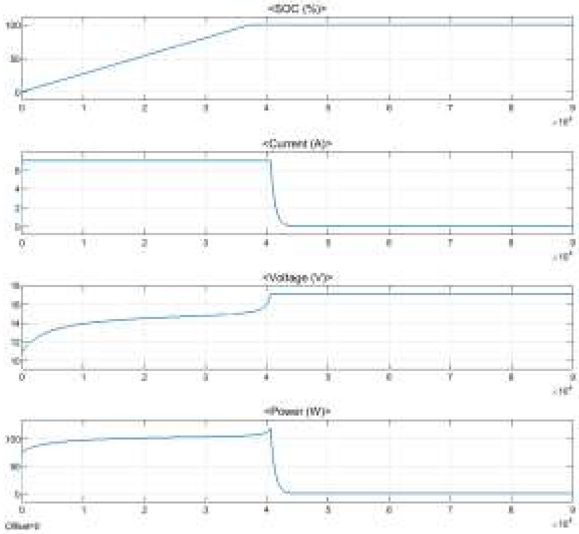

**Figure 5.** Lead-acid calcium battery when charging 0.1C

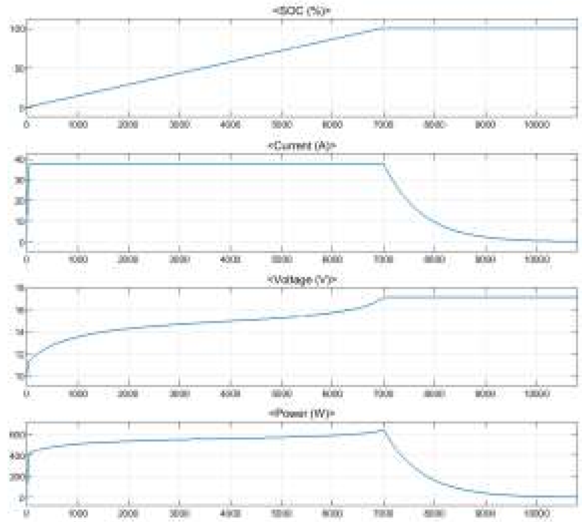

**Figure 6.** Lead-acid calcium battery when charging 0.5C

Figure 4 shows a lead-acid calcium battery in the charger using a current of C/20. Where the value of the current flowing for the charging process is very small. So that the time achieved from 0% SoC condition to reach 100% is very long, namely for 68,400s or for 19 hours. Whereas in Figure 5 shows a lead-acid calcium battery in the charger using a current of C/10. Where the current flow value for the charging process is faster than when using the C/20. So that the time achieved from 0% SoC conditions to reach 100% faster is for 36,000s or as long as 10 hours.

Figure 6 shows when a lead-acid calcium battery is charged using a current of C/2. Where the value of the current flowing for the charging process is very small. So that the time achieved from 0% SoC condition to reach 100% is very long, namely for 6.912s or 1 hour 55 minutes.

Figures 7 to 9 show a battery charge and discharge test for 60,000s. Where in Figure 7 shows the charger and discharger using C/20. The charging process tends to be longer. Figure 8 shows the charger and discharger using C/10, the charging process tends to be faster. While Figure 9 shows the charger and discharger using C/2, the charging process is very fast.

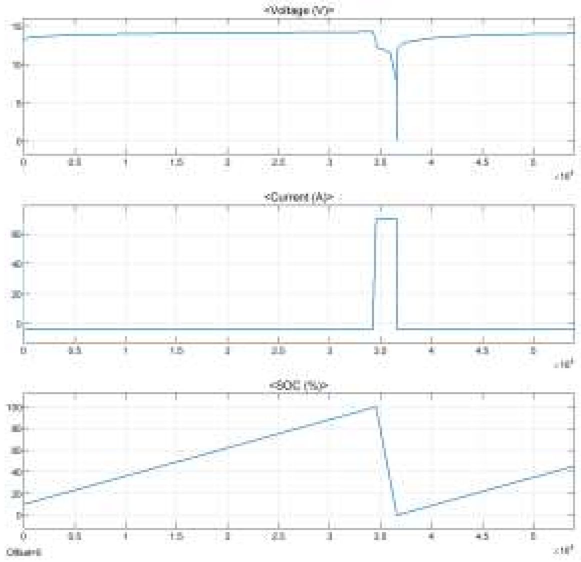

**Figure 7.** Characteristics of the lead-acid battery when charging 0.05C and discharging 3.75A

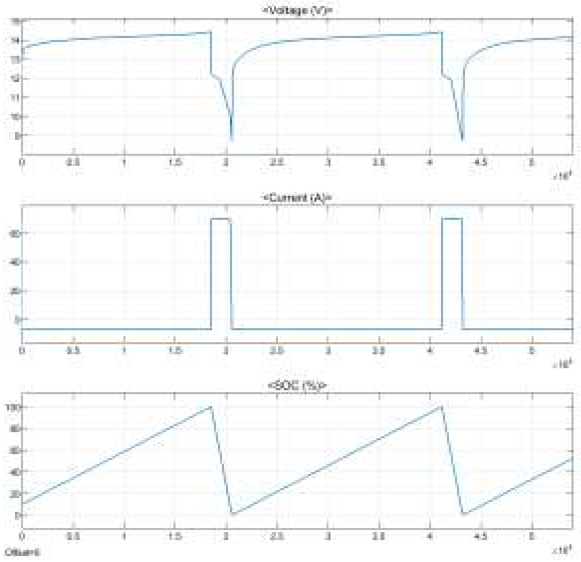

**Figure 8.** Characteristics of the lead-acid battery when charged at 0.1C and discharging at 7A

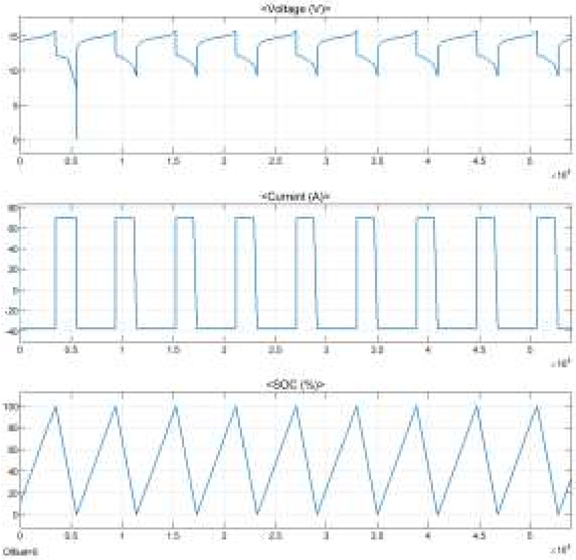

**Figure 9.** Characteristics of the lead-acid battery when charging at 0.5C and discharging at 37.5A

## 5 Conclusion

The results show the charging and discharging process carried out on the battery. Simulation 1 shows the lead-acid battery simulation process based on an existing model. Simulation 2 shows the simulation process using the lead-acid calcium battery datasheet model. While in simulation 3 shows the process of charging and discharging the lead-acid calcium battery datasheet model as much as 1000 times. Based on the simulation results, the design of a fast-charging system based on the steps of the charging process greatly determines the time and age of battery usage. The next research focuses on developing a battery management system (BMS) for lead-acid batteries.

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