The Method of Constant Current - Constant Voltage (CC – CV) for SECA Electric Car Battery Charging with Fuzzy Logic Controller

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Abstract. Electric cars are a solution to overcome the depletion of fossil fuels and environmental impacts. An electric car is a type of electric vehicle that uses a battery as the primary energy source. In charging, the battery is prone to overcharging, so a charging system is needed to maintain battery performance to avoid damage to the battery. In this study, researchers have tested a SECA electric car to charge the battery using a method of constant current - constant voltage (CC - CV) that applies a constant current at the initial stage and a constant voltage till the battery has charged fully. The battery type is a lead acid battery with 12V, 30Ah capacity. The analysis of this battery charging system has been proven by the fuzzy logic controller (FLC) as the current and voltage controller based on its rule base to get higher performance improving the charging system. Charging the battery with this system is expected to maintain battery lifetime by avoiding overcharging the battery during the charging process.

Keywords: Electric Car · Battery Charging · CC – CV Method · Fuzzy Logic Controller

1 Introduction

Energy is a need that cannot be separated from human daily life. The depletion of fuel energy is caused by internal combustion engine vehicles that use fossil fuels and are not environmentally friendly. This has led to the need for environmentally friendly vehicles that use alternative and rechargeable energy [1]. An electric car is a solution to replace fossil fuel vehicles because they get a supply of electric power from a rechargeable battery to drive the motor and other instruments in the car [2].

Batteries are devices for storing electrical energy. Energy storage become a primary component of an alternative renewable energy. The energy capacity will decrease after the battery is used as a power source and be able to return to full capacity after the battery is recharged [3].

The battery charger is fundamental to filling the energy in electric car batteries. The current and voltage values have adjusted to the specifications of the battery charged. A

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charger can affect the time, battery charging status, and battery performance [4]. If the voltage and current of the DC power source are too high, it will destroy the battery cells so that overcharging can occur an excessiveness heating of the battery and shorten its lifetime. However, if the DC power source is too low, the battery will not be charged.

One of the things to overcome these problems is to apply a method called the constant current-constant voltage (CC-CV) system when charging the battery. The constant current has implemented at the beginning of the battery charge cycle. When the battery voltage has reached the maximum value voltage value, the charger will shift to constant voltage (CV) charging mode and continue to charge the battery in that mode until the battery is charged fully [5].

In this study, researchers have performed a test for charging a SECA electric car battery with a constant current-constant voltage system that has charged a lead acid battery with 12 V, 30 Ah capacity. This system has performed to charge the battery with a constant current at the beginning of the charging process and a constant voltage till the battery charging reaches a certain voltage and can stop charging automatically when the battery voltage has reached the upper limit. The battery charger has been connected to the charger to charge the battery. The current and voltage issued by the charger have regulated according to the CC-CV system. Then, the fuzzy logic controller method has used to be analyzed the voltage and current data during the charging process.

2 Literature Review

2.1 Battery Charging

Charging is a process where the battery will be powered by a power source which current and voltage values have adjusted to the specification of the battery charged. The battery has to be charged to be used continuously. Throughout the process of charging, the voltage on the battery will increase to its maximum voltage. Battery power capacity is decreasing along because of electricity in electrical loads, especially in electric vehicles. If the battery capacity is low, the battery needs to recharged using a charger [6].

The lead acid battery has six cells where the battery charging voltage set between 13.2 V–14.7 V for a 12 V for general battery, the charging current is determined to be 10%–40% of the battery capacity (Fig. 1).

Fig. 1. Battery Charging Process

2.2 Constant Current-Constant Voltage

CC-CV is combination of constant current (CC) and constant voltage (CV) methods. This filling method is also known as the two-step method, as it combines the two methods. For the charging process, the current and voltage of the charger be determined before charging. The working principle of charging with the CC-CV method is that at the beginning of battery charging will be charged with CC first until it reaches the maximum battery voltage. The initial period is chosen charging the battery with a high current, because it is the time when the battery will have the least negative impact on the battery (such as heat), so the battery will be safer and last longer to use. After that it will proceed to CV mode until the battery is full. Filling CC-CV is better than filling in CC or filling in CV only [7].

The CC-CV method allows for fast charging without the risk of overcharging and is suitable for various types of batteries. By using this method, the battery will charge to its full capacity [8]. The fuzzy logic controller uses voltage and current variations as controller input variables and battery voltage as charging output variables. The battery voltage will increase according to the given charging voltage and current. By implementing this strategy, the battery will be fully charged according to its capacity and avoid being overcharged.

2.3 Overcharge

Overcharge is defined as charging with a current and voltage that is too large or excessive to the battery continuously even though the battery is fully charged. As for the consequences caused by overcharging the battery becomes damaged and reduces battery life. Damage to the battery caused by overcharging is caused because each battery cell on the positive plate will get pressure caused by high temperatures during the overcharging process [9].

2.4 Fuzzy Control System

The Fuzzy Control System or Fuzzy Logic Controller (FLC) is a control system with the uncertainty that utilizes the concept of fuzzy sets in its design. FLC supports membership between 0 and 1 [10]. Some of the advantages of fuzzy logic are: (1) there is no need for a mathematical model of the plant to be controlled; (2) a decision-making mechanism that is embedded in the control as a basic rule of control; (3) it is more appropriate to use in systems that are difficult to define which can be controlled by operators without knowing the system's dynamic characteristics [11] (Fig. 2).

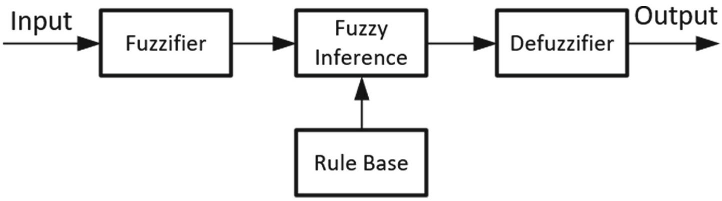

Fig. 2. Fuzzy Logic Controller Concept

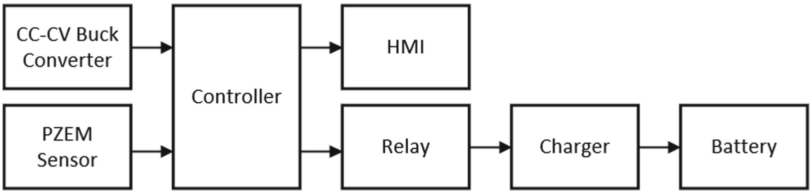

Fig. 3. Charging Battery System Block Diagram

In this research, the parameters used as inputs are current and voltage parameters. These two variables processed through three steps are fuzzification, inference mechanism, and defuzzification. It will produce a status indicating the battery capacity/State of Charge (SoC) of the battery charged.

3 Equipment Design

The design aims to produce equipment with proper functions as intended (Fig. 3).

CC-CV Buck Converter as a regulator of the amount of current and voltage setpoint on battery charging. The PZEM-017 sensor detects the value of the voltage and current in the charger and battery based on the setpoint of the system controlled. The NodeMCU ESP8266 controller controls the process of reading input into the desired output. Relay as a switch to connect and disconnect electric current to control charging process by PZEM-017 sensor as the input. Then, a battery charger is used for charging lead acid batteries. The HMI will display the value of voltage, current, and temperature when charging the battery (Fig. 4 and Table 1).

After the data has been collected through measurements on the system using predetermined instruments, the next step is to process the data. Data processing has been used to facilitate the making of analysis. The method of data processing used in this research is the fuzzy logic controller method using software (Fig. 5, 6 and 7).

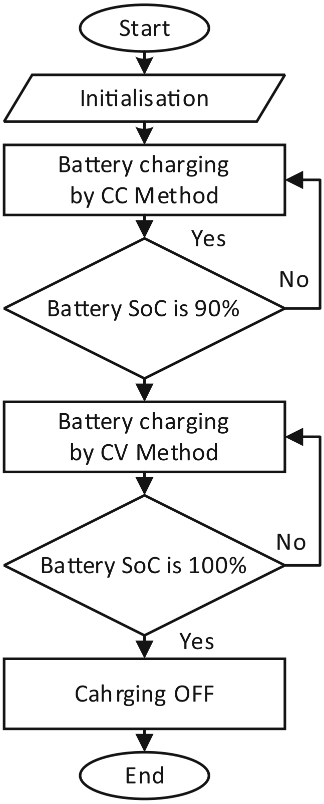

Fig. 4. Charging Battery System Flow Chart

Table 1. Rule Base of CC. CV Method

No	Imput		Output
	Voltage (V)	Current (I)	
R1	LOW	HIGH	LOW
R2	MEDIUM	HIGH	LOW
R3	HIGH	MEDIUM	MEDIUM
R4	HIGH	LOW	HIGH

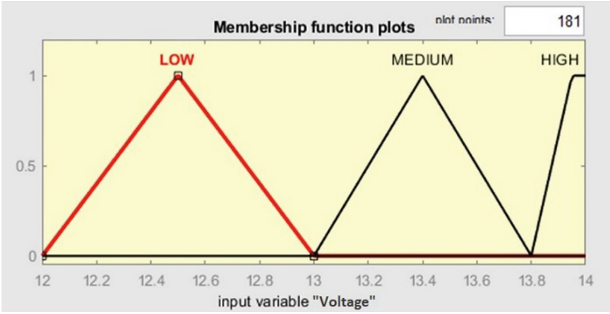

Fig. 5. Voltage Membership Function

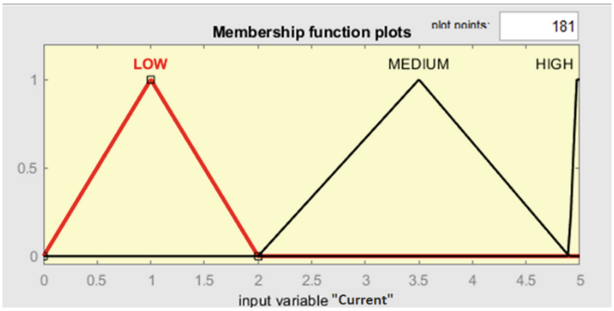

Fig. 6. Current Membership Function

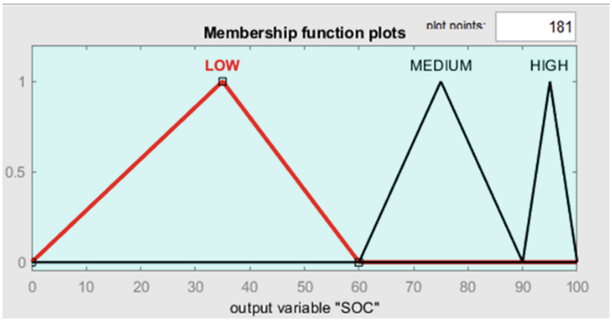

Fig. 7. SoC Membership Function

4 Discussion

At the time of data collection, the researchers tested the voltage and current that worked when charging the battery to find out how the CC-CV system worked. In battery charging process, if the voltage and current flowing at the time of battery charging exceeds the capacity, the battery will be overcharged which can cause damage to the battery.

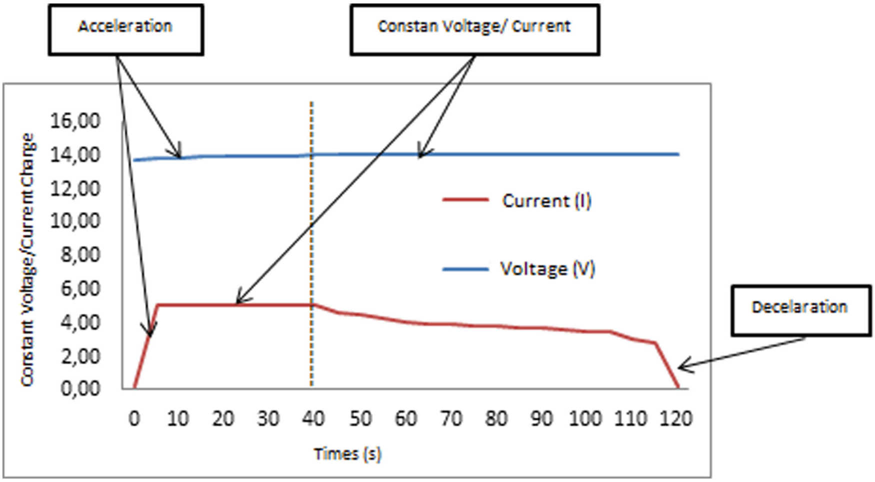

Fig. 8. Voltage and Current Graph During Battery Charging Process

Battery charging data, in the configuration of voltage and current value of charging during the process of battery charging, will be processed and the data obtained from the battery charging process is shown in Fig. 8.

From Fig. 8, it can be explained that during the charging process the 12 V, 30 Ah of the lead acid battery charging occurs with a constant current of 4.9 A–5 A and a constant voltage charging of 14 V. The current generated in this battery charging did not pass the maximum current for charging the battery.

Then, the charged battery can avoid the overcharged due to excessive current. The measured voltage of the battery at the beginning of charging is 13.54 V with 80% battery SoC. Meanwhile, when the battery voltage is measured at 13.8V or 100% with a charging current of 0.20 A, which indicates the lead acid battery has fully charged, the time estimated for the battery charging process is occurred in about 120 s.

When the measurement results are at 0th to 40th seconds, occurred constant current (CC) charging about 4.9 A. In the 40th to 50th seconds occurred the transfer from CC to CV controlled by the microcontroller then, at the 50th seconds continued with 14.00 V–13.99 V constant voltage charging (CV) and the battery voltage is 13.8 V when the battery is charged full.

When the SoC of the battery is 100%, the microcontroller will activate the relay connected to the charger. Thus, charging the battery will automatically stop and can avoid overcharge due to excessive voltage on battery charging. The graph of the state of charge (SOC) during charging of the battery is shown in Fig. 9.

In this test, the microcontroller will initialize the program set and then instruct the PZEM module to detect the charging voltage and current. After waiting for the voltage and current calculation process carried out by PZEM, the microcontroller will read the data, then calculate for the charging voltage and current based on the value read by the sensor with the setpoint.

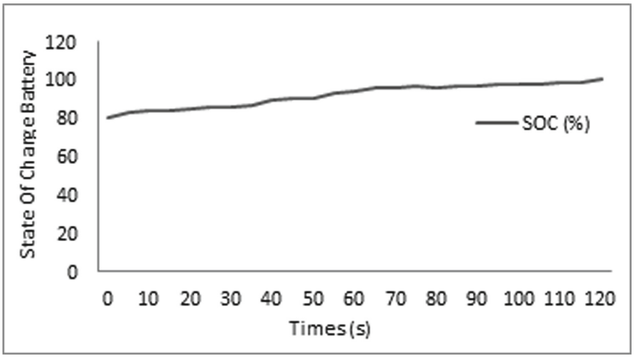

Fig. 9. SoC Graph During Battery Charging Process

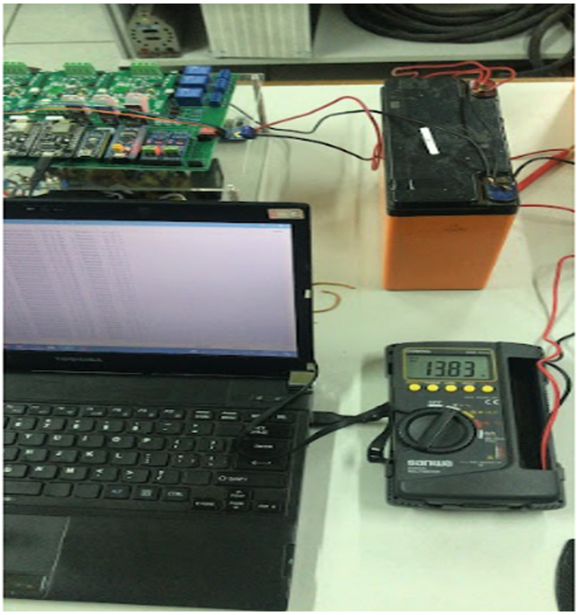

Fig. 10. Testing During Battery Charging Process

When the SoC battery is 90%, the microcontroller will activate the circuit on the CC-CV Buck Converter to change the CC mode to CV. When the SOC of the battery is 100%, the microcontroller will activate the relay connected to the charger. Thus, charging the battery will automatically stop and can avoid overcharging the battery (overcharge) (Fig. 10).

5 Conclusions

Based on the results of the study for the CC-CV system for charging electric car batteries using the FLC method, it drawn as following conclusions:

(1) the magnitude of the current and voltage when charging battery is influenced by the CC-CV circuit on the CC-CV buck converter that produces a constant current of 4.99–5 A at the beginning of charge process and a constant voltage of 14V when the battery SOC reaches 90% which is regulated using NodeMCU ESP8266 microcontroller.
(2) the amount of charging current in this study does not exceed the maximum current (12 A) so, the charged battery does not experience overcharge due to excessive current.
(3) this charging system can automatically off charging when the battery 100% fully charged, so it can maximize the voltage of the battery charged and prevent the battery from being overcharged due to overvoltage.

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