Design Lead Acid Battery Charging System Using Ant Colony Optimization (ACO) Algorithm

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Abstract. This research shows the design of Smart Charging (SC) using Ant Colony Optimisation (ACO) algorithm for charging 12V 30Ah lead acid battery. This research aims to propose a new energy charging method for electric vehicle batteries using a smart charging system. The new solution to determine the State of Charge (SOC) in the battery charging system will come from a combination of mathematical solutions and artificial intelligence algorithm modelling. The Ant Colony algorithm designs the best current pattern gradually and iteratively until it produces a 5-stage current pattern (10A, 5A, 3A, 2A, and 0A). This algorithm allows the charging device to charge a 12V 30Ah lead acid battery with a stable current of 1.4 A for 25 minutes with a SOC of 73%.

Keywords: Smart Charging, Battery, Ant Colony Optimization (ACO)

1 Introduction

The use of petroleum fuels leads to increased CO2 greenhouse gas emissions to 417.2 ppm in 2022, and 22.9%[1] of the total emissions are produced by fossil fuelled vehicles, therefore one of the efforts to reduce petroleum consumption is the implementation of electric car technology because electric cars do not produce emissions (CO2) to meet the transportation needs of the community.[2] The most commonly used electric car is the Battery Electric Vehicle (BEV). A BEV is an electric car that uses 100% pure battery power.[3], [4] Among other types of electric cars, BEVs have the highest power efficiency. The most widely used battery type for BEVs [5][6] is lead acid which has the advantage of being included in a secondary battery or can be recharged (charge).[7] [8]Battery charging is the process of recharging the battery so that the battery can be used again. The charging system used to charge the battery is the thing that most affects the condition of the battery's lifetime.[9] Based on the charging speed, charging consists of 3 levels. Level 1 (slow charging), level 2 (semifast charging, level 3 (fast charging). The developing technology in the charging process is fast charging, the methods often used are Constant Current (CC), Constant Voltage (CV), Constant Current-Constant Voltage (CC-CV), Pulse Charging (PC), and Reflex Charging

N. L. Husni et al. (eds.), *Proceedings of the 8th FIRST 2024 International Conference on Global Innovations (FIRST-ESCSI 2024)*, Advances in Engineering Research 261,
https://doi.org/10.2991/978-94-6463-678-9_20

(RC).[10]Battery charging using the CC-CV method produces an unstable or fluctuating current, [11] This can cause the battery temperature to increase and can cause damage to the battery. In addition, the battery charging time with this method is also still an obstacle because during the CV stage will result in a longer charging time. to overcome the unstable current and reduce the length of charging time, this study applied the Ant Colony (AC) algorithm. [12], [13] On the Smart Charging (SC) system. Smart charging is a technology used in charging batteries more intelligently and efficiently. The concept involves the use of additional algorithms to optimise the charging process. The AC algorithm is an algorithm inspired by the nature of ant colonies to find the best and fastest way to find food based on the level of pheromones on the road. This algorithm is applied to the SC system, so it is expected that charging can determine the best charging current pattern. In addition, the Ant Colony algorithm in this charging system can control the battery charging current, to prevent overcharging which can cause excessive heat in the battery.

2 Overview

The process of charging lead acid batteries has been carried out by many previous researchers, as described in several previous publications.[14] Charging is the process of supplying an electric current to a battery, so that the battery can replenish its energy and can be used again as before. The amount of electric current applied depends on the battery capacity and charger technology.[15] For lead acid batteries with a capacity of 12 V, the charging voltage is set between 13.2 V and 14.7 V, or at least one volt above the battery capacity. The charging voltage should not be too high or low, if the voltage is too high, the battery cells will be electrolysed, therefore the charging of lead acid batteries is influenced by the method used.[16]

The Constant Current (CC) method is one of the methods used for charging batteries by using a constant current during battery charging, until the battery voltage is fully charged (maximum). [19]

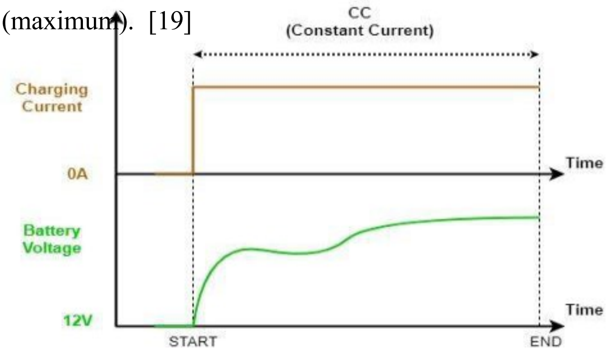

Fig. 1. Charging using the Constant Current (CC) method

The Constant Voltage (CV) method is a battery charging technique where the charging voltage is kept constant, usually using a power supply. The working principle of this method is that the charging current will be high at the beginning and the current gradually drops when the battery has taken the voltage on the charger. [18][19]

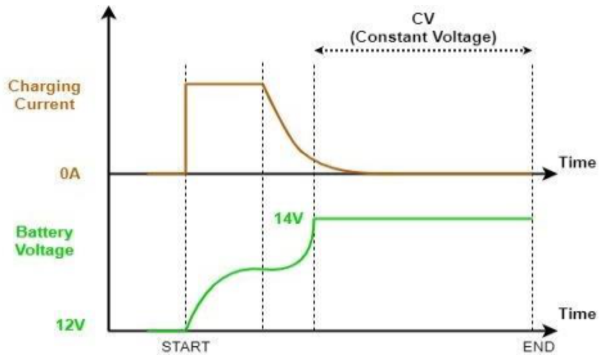

Fig. 2. Charging using the Constant Voltage (CV) method

The CC-CV method or commonly called the two step method is a combination of Constant Current and Constant Voltage charging techniques. The working principle of this method is that at the beginning of charging the battery until it reaches the maximum battery voltage (preset voltage), CC mode is used. After the battery is full the method switches to CV mode.[20]

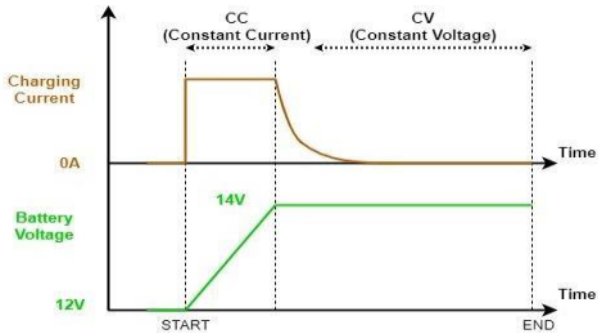

Fig. 3. Charging using the Constant Current-Constant Voltage (CC-CV) method

Although the CC-CV battery charging method is generally effective and widely used for charging lead acid batteries and some other types of batteries, there are some drawbacks associated with the current instability that can occur causing the battery temperature to become uncontrollable and can result in damage - to the battery.[21] This research applies the Ant Colony Optimisation algorithm. [22] to set a safe current pattern for Lead Acid batteriesNext, the ant colony (AC) algorithm used to identify the parameters is thoroughly studied. To initiate the route search, pheromone updates as well as state transition probabilities are used.[23] Finally, a real case of a battery exchange station is used to verify the suggested model in both identification and simulation. The results show that the model is appropriate and accurate.

3. Methodology

3.1. System Design

The design methodology or System Design will explain the stages of designing the ACO algorithm. These stages follow the framework that has been designed so that this design can be done in a structured manner and get maximum results. In the diagram of the research stages below is the framework of this research in charging lead Acid batteries.

Before a system is built, a system is designed through a series of activities that can be carried out individually or in groups. The system developed is intended to meet user needs in terms of handling, obtaining, and processing the information needed.

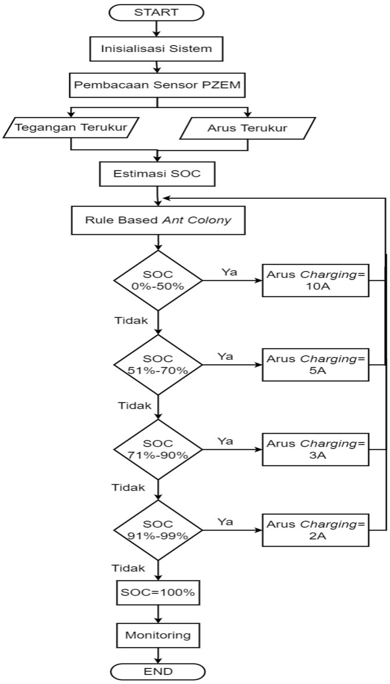

Fig. 4. Smart Charging Process Flowchart

The flowchart of the Attack Colony algorithm begins with the initialization of all paths that ants can take to reach food. These lines show the variations in battery charging current for the SOC range of 0% to 100%, as well as the time required to charge with those current values. A number of m ants will be randomly placed at each point of different current magnitudes to calculate the initial pheromone level of each path. The pheromone levels will be updated through evaporation and the addition of pheromones, which will then be eliminated using a probabilistic method, so that only paths with high pheromone levels will be chosen by the ants as the flow variant.

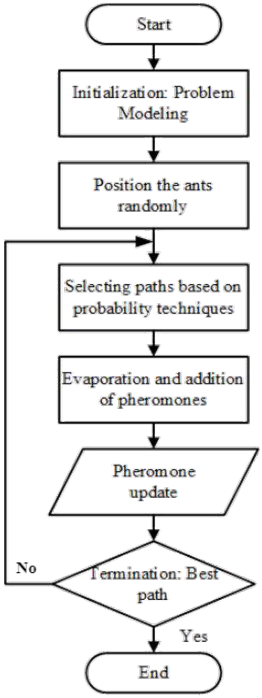

Fig. 5. ACO Flowchart System

In the block diagram of this smart charging system design, two devices are used: the charging device, which functions as the power charging supplier consisting of a power circuit and a CC-CV buck converter, and the second device, the microcontroller, which functions as the charging distributor for 4 batteries and employs the ACO algorithm approach to obtain the charging pattern based on the SOC levels of each battery, consisting of 4 microcontrollers and 4 sensors. All components are designed to form a single smart charging program that can charge 4 batteries simultaneously with the ACO algorithm approach in its charging pattern, allowing the batteries to charge quickly and safely.

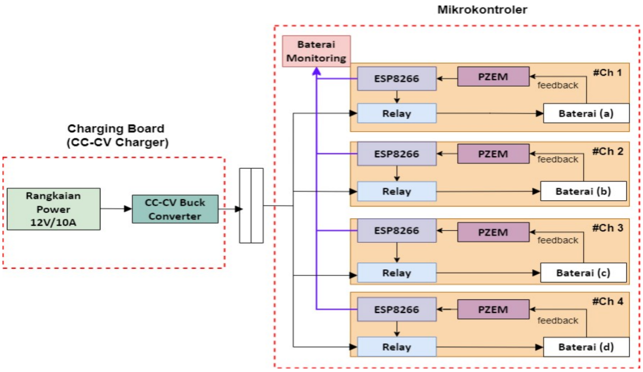

Fig. 6. Block Diagram Charging Control

This Smart Charging uses the Internet of Things (IoT) system so that it can be connected to access control and monitoring of charging by users through android devices and laptops. Can be seen in the following picture.

Fig. 7. Smart Charging ACO connect via IoT system

3.2. Testing and Analyzing

System testing is the process of executing a software system that determines whether the software system meets system specifications and runs on the desired output. Figures 8, 9, and 10 are the results of charging using the ACO algorithm. In Figure 5, the battery charging current is stable and does not fluctuate, so the battery charging current will not jeopardize the condition and lifetime of the battery. The current in the charging process is also adjusted to the current pattern of the Ant

Colony algorithm design. In testing the charging system with the Ant Colony algorithm, the microcontroller will initialize the program that has been set and then instruct the PZEM module to detect the battery voltage. After waiting for the voltage calculation process carried out by PZEM, the microcontroller will read the data and then calculate the battery SOC estimate. After the SOC estimation is obtained, the system will flow the amount of current based on the designed Ant Colony algorithm. When the initial SOC shows 73%, the measured battery voltage is 1.4 A.

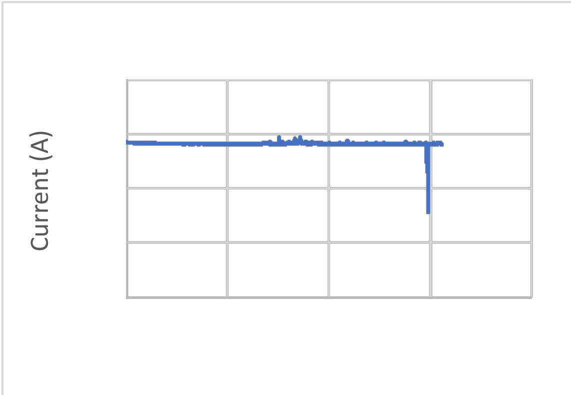

Fig. 8. Current of The Charging

Fig. 9. Current of The Charging

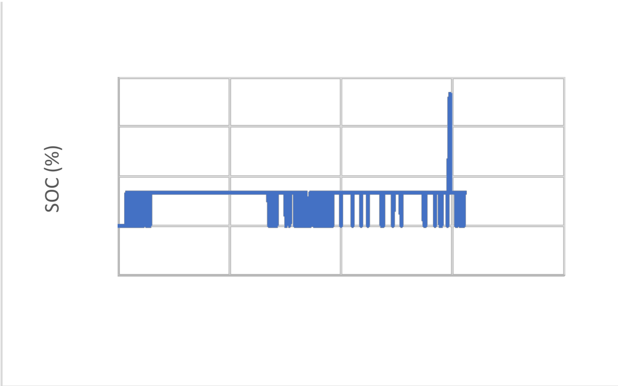

Fig. 10. State of Charge (SOC)

4. Conclusions

Smart Charging is able to predict the current to be used according to the SOC, which is 73% of the 12 V 30Ah Lead Acid Battery after usage that will be recharged. With a Charging Current of 1.4 Amperes during charging. The Ant Colony Optimisation algorithm produces a stable current that results in efficient and safe charging for the battery, so this algorithm can be a sustainable solution for charging methods for electric vehicles.

5. Acknowledgments

We express our deep appreciation to all those who have contributed to the success of this research. Special thanks to Sriwijaya State Polytechnic for their continuous support, both in terms of providing facilities and in providing the opportunity to carry out this research. We also greatly appreciate all the individuals involved in the development of Smart Charging ACO as a solution for safe and efficient battery charging. The expertise, dedication and co-operation of each contributor were instrumental in achieving the resultsof thisresearch. This research would not have been realised without the commitment and collective effortsof all parties involved. Thank you for your tremendoussupport and contribution.

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