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Li-ion Battery for E-Bicycle

[1]Kartikeya Manoj Choudhari, [2]Aditi Premanand Lute, [3]Shruti Rajesh Zade, [4]Dipali Vilas Pawar, [5]Himanshu Sudhakar Bhoyar, [6]Pratik Pramod Nimje, [7]Prof. Pravin Pisal, [8]Dr. Mohammad Athar Hayat

Dept.of Electrical Engineering St. Vincent Pallotti College of Engg. and Technology, Nagpur, India
[1]kartikeyac.ee18@stvincentngp.edu.in, [2]aditil.ee18@stvincentngp.edu.in, [3]shrutiz.ee18@stvincentngp.edu.in, [4]dipalip.ee18@stvincentngp.edu.in, [5]himanshub.ee18@stvincentngp.edu.in, [6]pratikn.ee18@stvincentngp.edu.in, [7]ppisal@stvincentngp.edu.in, [8]ahayat@stvincentngp.edu.in

ABSTRACT

One of the greatest and most urgent needs of this world is to develop technology in the transport industry that can help reduce the consumption of fossil fuel exponentially. Our world is facing the danger of over- exploitation of fossil fuels which in turn is contributing to pollution and global warming. Thus, working on a solution for electric bikes that increase performance is the need. Therefore, lithium-ion battery-based electric bikes can be a breakthrough in the transport industry. The project presents a dedicated battery for an electric bicycle. This paper proposes a lithium- ion battery capacity estimation method for electric bicycles. Lithium-ion batteries consist of largely four main components: Cathode, Anode, Electrolyte, & Separator. It is a type of rechargeable battery in which lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge and back when charging. Battery capacity information informs the electric vehicle driver of the residual battery working time, facilitates the estimation of the mileage of electric bicycles and timing of battery charging to avoid over-charging or over-discharging. Factors such as different discharge rates, environmental temperature, battery charge, discharge efficiency, and battery aging affect the released capacity of the battery, which is an electrochemical reaction of the battery. This paper also proposes the prevention of degrading conditions using a tool to manage the battery usage both during the charging and discharging process. The proposed electronic Battery Management System (BMS) regulates, monitors, and maintains the condition of batteries to prevent any possible damage.

Key words: Lithium-ion battery, Electric bike, Performance, Battery capacity

INTRODUCTION

Despite their modern convenience, automobiles run on fuel oil, emitting carbon dioxide that endangers human health, exacerbates the greenhouse effect, and contributes to global warming. In recent years, there has been a greater emphasis on environmental protection, which explains the concentrated efforts to develop electric vehicles with lower exhaust emissions and higher energy efficiency than conventional automotive vehicles.

Battery capacity information alerts electric vehicle drivers to the current state of charge (SOC), allowing them to keep track of the battery's remaining operational duration and estimate miles to determine when to charge it. Drivers may reliably forecast the mileage of electric vehicles based on the current battery capacity by multiplying the battery residual capacity (Wh) with the energy consumption factor of an electric vehicle (km/Wh) [1-3].

Estimating the battery capacity also assists electric vehicle drivers to prevent overcharging and discharging the battery in order to extend its service life. Direct a discharge test [4], internal resistance measurement [5], loaded voltage measurement [6], electrolyte concentration measurement [6], Peuler equation estimation [7], fuzzy control [8,], open circuit voltage measurement [9-10], coulometric measurement [11-12], coup de fount effect [13], and artificial neural network [14] are some of the methods for estimating battery residual capacity.

E-bikes typically have a battery that can be charged from a standard household outlet and is connected to an electric motor in the bicycle transmission system. Using a handlebar-mounted computer display panel and controller, the rider can adjust the output power from the motor, i.e., speed. In our country, the use of electric motorcycles is far from insignificant. To overcome this issue, we must consider the following factors: 1. Environmental 2. The price. A lithium ion battery is used to improve the performance of an e-bike. A brushless DC motor, throttle, and controller are among the other components of an electric bike. Using lighter frames and motors and dynamos with acceptable ratings can help save money. The purpose of this paper is to review the design of the electric bicycle.

Lithium-ion 18650 batteries are commonly used to make up the battery pack in an electric bike (E-Bike). The battery has a nominal voltage of 3.7 V and a capacity of 2000 Mah to 3000 Mah. The great energy density of lithium-ion batteries is the primary rationale for their adoption [15]. Battery packs for electric vehicles, such as the E-Bike, are made up of many Li-ion batteries connected in series and parallel to achieve high voltage and capacity [16-21]. Each cell in a battery pack must be in the same energy condition for safety reasons and to achieve a long-life span [22,23].

The charging and discharging process must be stopped promptly if a cell has a banned condition (overvoltage, undervoltage, overcurrent, or overheat). Furthermore, all cells in the battery series must maintain the same voltage level, known as 'balancing.' The safeguard system will interrupt the charging or discharging operation if they are out of balance. When only one cell of a battery pack is in an overvoltage or undervoltage condition while the other cells are safe, the battery pack's overall performance suffers. The balancing procedure is carried out on the battery pack to solve this problem, and two fundamental ways are used: passive or active balance [2].

The passive approach, which is inexpensive and simple to install while being inefficient, involves releasing energy from each cell into a resistor until the voltage equals the voltage of the smallest cell. The active approach involves transferring the energy from the cell with the highest voltage to the cell with the lowest voltage until each cell has the same voltage. This technology is more expensive due to the need for complex components and mechanisms, but it is also more energy efficient.

Lead-acid batteries, lithium-ion batteries, Ni-MH batteries, and Ni-Cd batteries are all common secondary battery types. Lithium-ion batteries have a high energy density and other advantages in these secondary battery categories, including light weight, thin thickness, downsized size, extended service life, high-current discharge, minor memory effect, high output potential, and a variety of sizes. As a result, demand for lithium batteries, which are present in portable items such as digital cameras, mobile phones, and laptop computers, is expanding year after year. Because of its minimal weight, lithium-ion batteries are used in the creation of electric bicycles.

METHODOLOGY

Electric bicycle lithium-ion batteries differ greatly from those found in other devices such as cell phones, laptop computers, and uninterruptible power supply systems. Due to the fact that a bicycle battery functions constantly for a short length of time, battery capacity is often set to allow drivers to operate for 1-2 hours. As well as the battery's capacity.

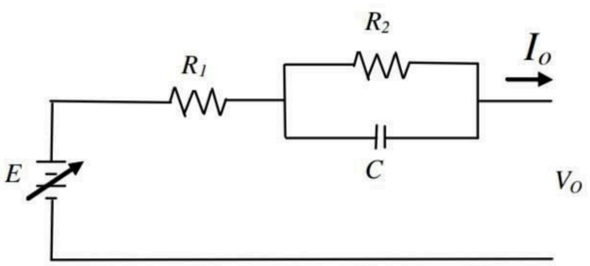

Fig. 1 Battery Equivalent Circuit

Coulometric measurement is now thought to be a very precise method. Although coulometric measurement allows us to precisely estimate battery capacity, it does so at the expense of a substantial accumulative inaccuracy when utilised over time. As a result, the open circuit voltage method and the coulometric measurement method are used in tandem in this article. In addition, the current effect, battery temperature, battery age, and charging efficiency must all be taken into account when correctly measuring lithium-ion battery capacity.

The battery equivalent circuit is shown in Fig.1 [16]. Internal resistance and capacitance of batteries vary depending on charge and discharge currents, temperature, ageing, and residual battery power variations. In Fig.1, R1 represents the equivalent resistance of electrode resistance and electrolyte resistance; R2 represents the electrode and electrolyte interface resistance; C represents the electrode and electrolyte interface polarisation capacitance; E represents the battery internal potential; and Vo represents the battery terminal voltage.

The battery terminal voltage Vo may be calculated using the equivalent circuit of a battery as Equation (1), where Io is the discharge current and VCo is the capacitor C's starting voltage.

A. BMS Design

BMS (Battery Management System) is a device that monitors the voltage and current of a battery and balances the battery pack to prevent it from harm. The BMS in this study employs an active balancing method with a cell-to-cell balancing mechanism and a series capacitor inductor circuit (resonant LC) as the energy transfer medium.

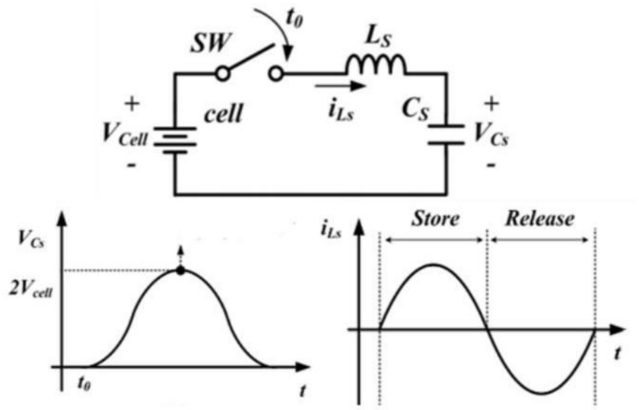

Fig. 2 Resonant LC series circuit

Inductors and capacitors are connected in series in the resonant LC circuit, which uses the charging and discharging process of the capacitors as temporary energy storage and the inductors as balancing current suppressors. Because the impedance values of the inductor and capacitor are the same but at different phases (ZL = ZC), the resonant frequency of the LC circuit is the frequency that generates the circuit's highest current and voltage amplitudes.

Fig.2 depicts the active balancing technique with a cell-to-cell balancing mechanism and a series capacitor inductor circuit (resonant LC) as the energy transfer media to be used in the BMS design, whereas Fig.3 depicts the associated schema consisting of many sub-modules.

A battery pack containing 52 Li-Ion batteries in a 13- series, 4-parallel configuration with a nominal voltage of 48.1 volts, a maximum voltage of 54.6 volts, and a total capacity of 10 Ah will be used to test the BMS design.

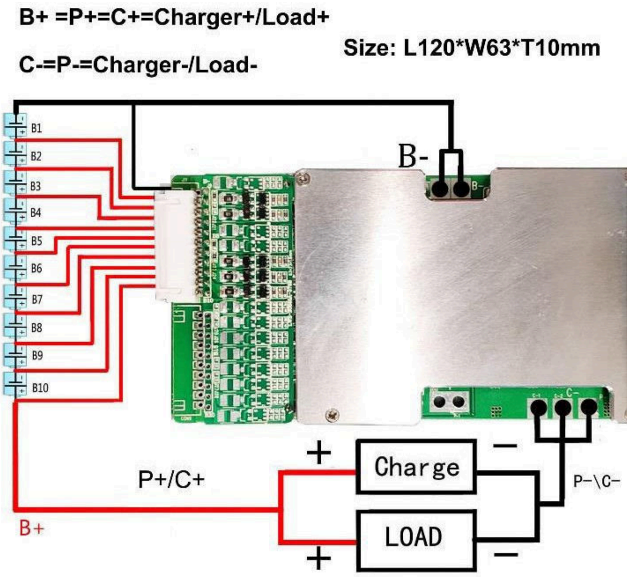

Fig. 3 Device block diagram

B. Lithium-ion Cell

In most lithium-ion cells, the negative electrode is carbon, the positive electrode is metal oxide, and the electrolyte is a lithium salt in an organic solvent. Depending on the direction of current flow through the cell, the electrodes' electrochemical responsibilities switch between anode and cathode. The most common negative electrode is graphite, which has a maximum capacity of 372 Mah/g in its completely litigated state of LiC6. A layered oxide, a polyanion, or a spinel are the most common materials for the positive electrode.

Fig. 4 Cylindrical Panasonic 18650 lithium-ion battery cell before closing.

Vendors and academics have been focusing on improving the energy density, operating temperature, safety, durability, charging time, output power, elimination of cobalt requirements, and affordability of lithium-ion battery technology as a result of rising demand.

C. Kapton Tape

DuPont created Kapton tape as a form of polyimide tape in the 1960s. The polar solvents used to make Kapton tape form strong hydrogen bonds with it. These bonds are formed at temperatures of up to 300°C, allowing the finished product to withstand high temperatures when used. Kapton tape is used for insulation, heat management, and chemical resistance, same like other polyimide tapes. Because batteries produce a lot of heat, Kapton tape is utilised to help with heat dissipation. Because of its low outgassing rate, Kapton is frequently employed as an insulator in ultra-high-vacuum conditions.

D. Heat Sink

PVC heat sinks are excellent for battery use, but they can become brittle over time and crack at the edges or at sharp corners. Using multiple layers is one way to get around this. This reinforces the heat sink and provides a second line of defense if one layer begins to crack. It also enables you to use multiple pieces of heat shrink perpendicular to each other to cover all six sides of a battery rather than just four, completely sealing your battery. A thin layer of foam around your battery can also help prevent heat sink cracking over time.

OBSERVATIONS

A. Battery Aging Effect

The battery capacity is affected by the number of battery cycles, discharge depth, discharge current size, and temperature. The link between the number of cycles and the battery capacity of a lithium-ion battery is depicted in Fig.
9. The battery capacity remained at 80-85 percent of the rate capacity after 200 cycles.

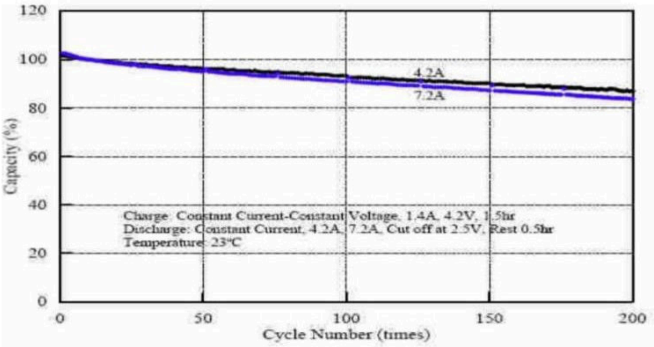

Fig. 5 Device block diagram

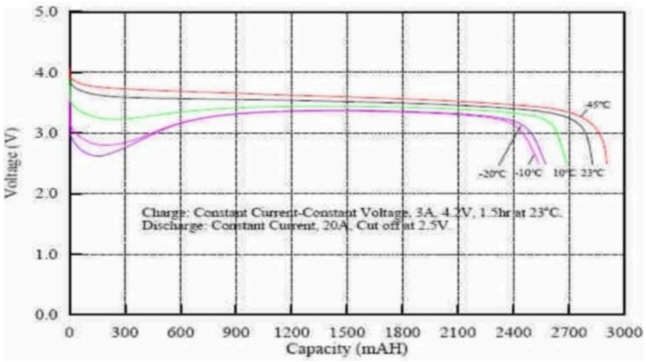

Fig. 6 Relationship between capacity and temperature

When the ambient temperature rises, the electrochemical process of a battery is completed. As a result, the battery's internal resistance is reduced, resulting in a higher capacity released. On the other side, the battery capacity drops. The capacity and temperature of a lithium-ion battery are depicted in Fig.6. Depending on the temperature difference between 100°C and 450°C, its capacity fluctuates by up to 10%.

BATTERY TEST

The battery has been thoroughly tested in a scientific setting. The battery was charged to 100% before being connected to the unloading device for the test. The initial voltage used to start the test was 42 V. A current of 2 A was used to charge the test battery. About 25 V is the cut-off voltage (BMS activation). 7.8 Ah was the capacity that was measured.

CONCLUSION

The paper presents a lithium-ion battery with a nominal voltage of 36 V and a capacity of 7.5 Ah, which was designed for an electric bicycle equipped with a 250W motor. The battery was tested in laboratory conditions that confirmed the assumed capacity and in road conditions on the basis of which the actual range of the bicycle was determined. Both studies confirmed the usefulness of the developed solution.

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