State of battery charge estimation techniques and management systems for electric vehicle using sodiumion batteries

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ABSTRACT

By keeping tabs on and regulating the charging and discharging of the batteries in an electric vehicle, battery management systems (BMS) help keep costs down. A battery's safety, dependability, and longevity can all be improved by a management system that prevents the battery from entering a destructive, older-battery state. Battery, voltage, current, and environmental temperature are all monitored in various ways to keep them in optimal condition. Numerous analogue and digital sensors coupled with microcontrollers are employed for keeping tabs. The BMS is there to make sure your batteries always work properly and safely. In a system, it is utilised to boost battery performance while keeping everything secure. Battery maximum capacity, charge level, and health are discussed, along with their respective characteristics. The challenges of the future, as well as potential answers, can be gleaned through a comprehensive examination of various approaches.

Keywords: State of charge, battery health and battery longevity are all aspects of a battery management system.

INTRODUCTION:

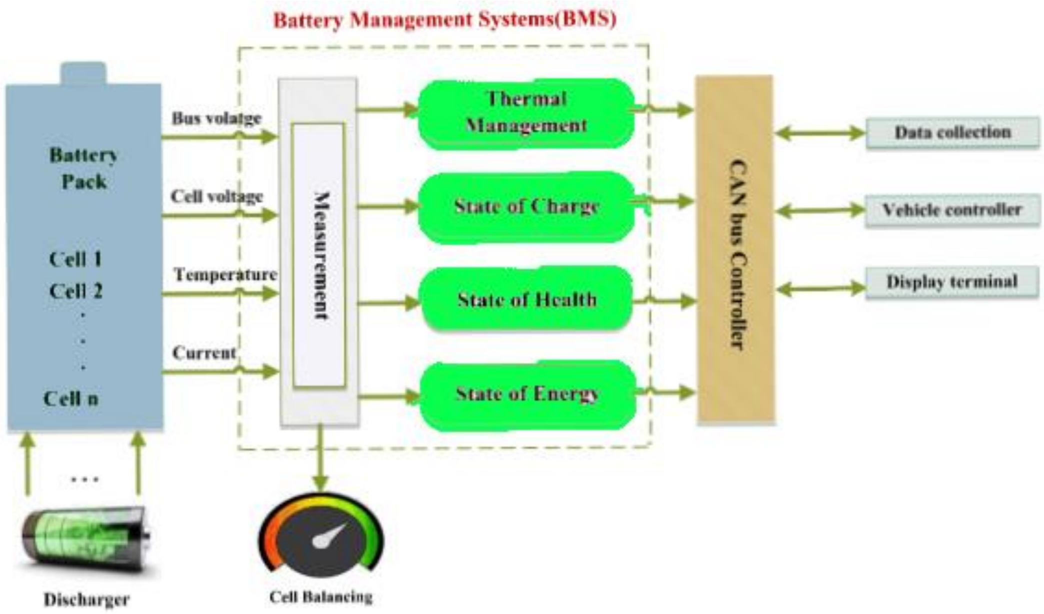
Due to their ability to produce no greenhouse gases and to make optimal use of energy, electric vehicles (EV) are playing an important role. When powering an electric car, the numerous battery cells it contains must be managed by a reliable battery management system (BMS). A long-lasting, high-power battery is essential for an electric car. Although lead-acid and lithium-ion batteries, as well as nickel-metal hydride batteries, are widely utilised in traction applications, lithium-ion batteries have recently taken the lead due to their many practical and efficient benefits. Lithium ion batteries may not be able to keep up with the burgeoning demand for both small and medium to large-scale energy storage applications. New studies have focused on developing alternate energy storage devices as a means of addressing these concerns. Sodium-ion batteries are considered the top contenders for future power sources due to their similarities in chemistry to Lithium ion Batteries and their abundance. New cathode materials have been introduced for use in Sodium ion Batteries; these include sodiated layer transition metal oxides, phosphates, as well as organic compounds. Particular carbonaceous materials, transition metal oxides (or sulphides), & intermetallic and organic compounds have been used to create cutting-edge anodes for Sodium ion Batteries. A typical electric vehicle's battery pack may store anywhere from 30 to 100 KWH of energy. The battery management system takes into account the battery's charging and discharging rates as well as the battery's estimated state of charge, estimated state of health, cell voltage, temperature, current, etc.

BATTERY MANAGEMENT SYSTEM (BMS):

The battery management system (BMS) is essential in EVs since the batteries must be carefully managed to prevent overcharging and over discharging. This can be dangerous for the people using the battery, the battery itself, and the environment if it causes the temperature to rise. It also helps drivers get the most mileage out of their vehicles by making the most of their batteries.

Reasons why a battery management system is necessary:

- ❖ Preserve the battery's trustworthiness and security
- ❖ Keeping tabs on and assessing the health of your batteries
- ❖ Regulate the level of electric charge
- ❖ Cellular temperature regulation and equilibrium
- ❖ Renewable energy management
- ❖ Modeling the charge state
- ❖ Defending cells from both over- and under-voltage conditions
- ❖ Using battery intelligence to strike a balance (passive)
- ❖ Modulating the Battery Charger
- ❖ Temperature sensing in packs
- ❖ Checks the battery's condition



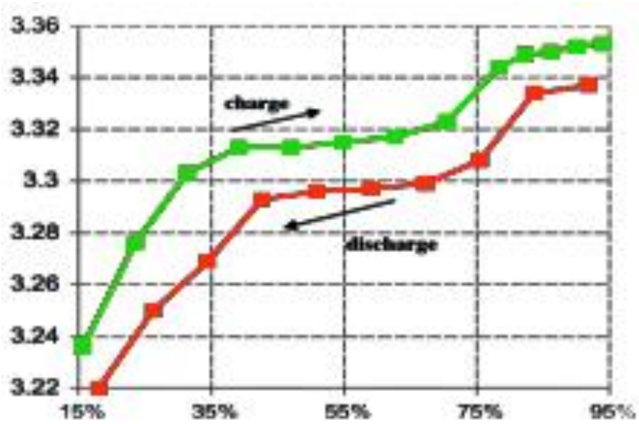
STATE OF CHARGE ESTIMATION:

Data and estimations of battery reliability are obtained by state of charge estimation. A plethora of techniques for SOC estimation have been developed since the 1980s. When referring to batteries, "state of charge" refers to the percentage of the battery's maximum capacity that is currently usable. The status of charge is a vital piece of information used by the battery management system, which regulates the battery's charging and discharging to keep it within its safe operating range. A battery's lifespan is also lengthened by this. The assessment of SOC has been a major concern for all energy-storing systems. SOC estimate is a significant obstacle for EV batteries because it is not directly measurable. The battery's characteristics can only be described with the help of a tailored algorithm. It is not possible to directly estimate the state of charge. A mathematical formula is used to determine this:

$$SOC = 1 - \int i \frac{dt}{cm} \qquad (1)$$

Where i symbolises the current of the battery and cm indicates the total capacity

Integration of current is the most common method used for SOC estimate. Equation (1) illustrates the proportion of usable battery capacity to total battery capacity.



The level of charge can be estimated in a number of ways. The many techniques for estimating the charge state are as follows:

1. Method for calculating the SOC based on the number of coulombs
2. SOC estimation with fuzzy logic
3. Technique for determining SOC through Impedance Spectroscopy
4. Method for SOC estimate using Kalman filters
5. Procedure for SOC Estimation Utilizing Open Circuit Voltage

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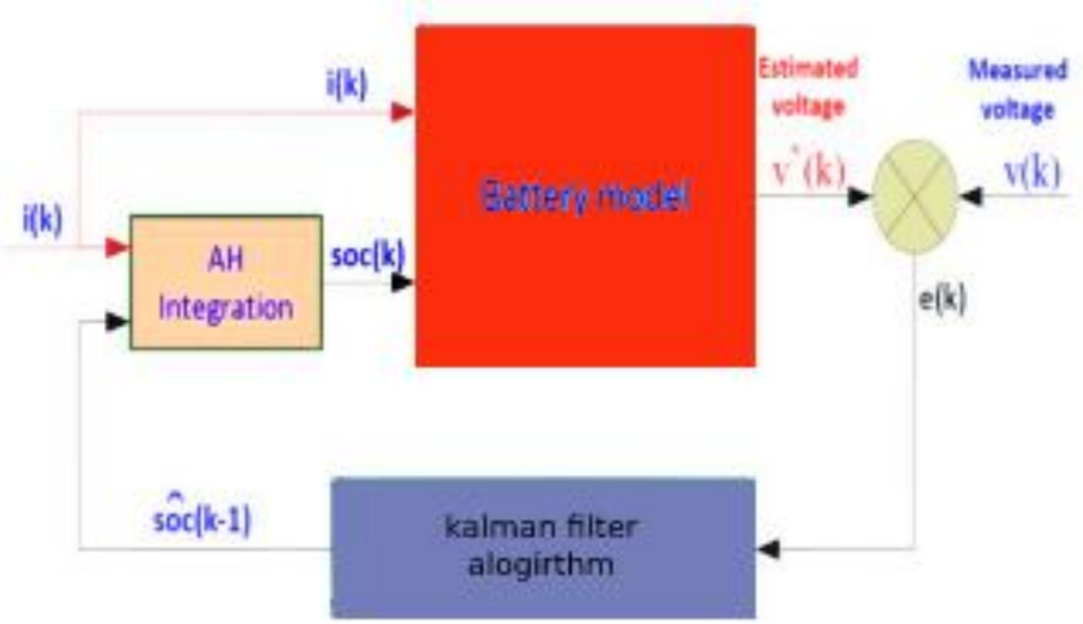
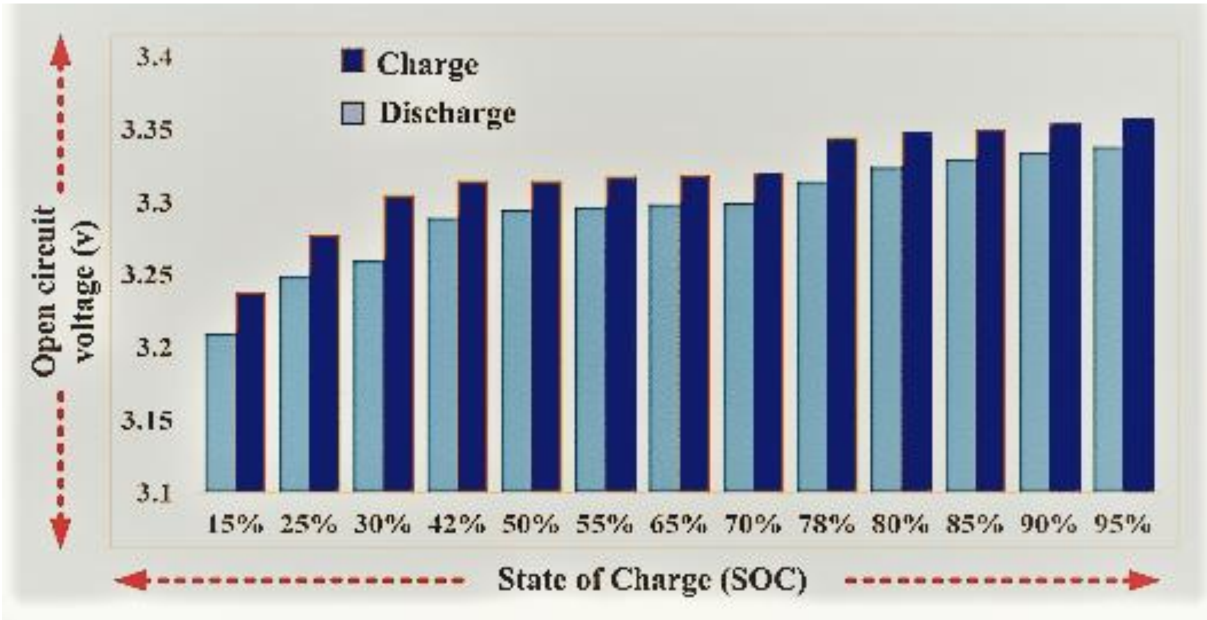


The Kalman filtering method has proven to be the most accurate for estimating EVs' SOC. The Kalman fliter is a sophisticated and well-designed instrument utilised in many fields, including transportation, navigational tracking, and aerospace. The Kalman filter's self-correcting nature is one of its most distinctive features. The state equation, which is used to make predictions about the present state, and the measurement equation are both components of a Kalman filter linear model. At 0.1C, the highest possible discharge capacity 150 mAhg -1 was achieved when the sodium ion battery was manufactured and tested. Compared to its lithium equivalent, the discharge profile of a transition metal oxide Sodium ion Battery (SIB) features numerous voltage plateaus, making it necessary to determine SIBs' estimated current state.



The manufactured SIB was subjected to discharging currents of 0.5C and 1C, at temperatures of 30, 45, and 55 degrees Celsius. Cascade Forward Backpropagation (CFB) was trained with experimental data from discharge cycles to estimate Sodium ion Battery State of Charge (SOC). The calculated SOC for the Sodium ion batteries was found to be quite accurate. The algorithm appears to have learned the pattern more well after being exposed to it for a longer period of time—that is, more training cycles—for the battery discharged at 0.5C at 55^0C. We found that the battery's discharge capacity and its behaviour changed with both temperature and discharge current. As a result, the SOC estimation technique must be flexible enough to account for these shifts. When compared to a CFB network with the same number of neurons and layers, performance using feedforward backpropagation techniques was found to be slower and have a greater MSE. It is not recommended to discharge a battery to zero, as doing so can cause permanent harm to the battery's crystal structure and shorten its cycle life. With capacity retention and cycle life in mind, we limited the depth of discharge to well within the allowable voltage range.

SODIUM-ION BATTERY MODEL

Figure 2 depicts an analogous circuit model of a sodium battery pack. Battery storage capacity (Ccb) is represented by the bulk capacitance, and battery diffusion effects (Ccs) are represented by the surface capacitance. The internal resistance (Ri) and the polarisation resistance (Rt) both have numerical values. Voltages (Vcb) and (Vcs) represent the potential difference between the bulk capacitor and the surface capacitor. Terminal current (I) and terminal voltage (V0) represent the state of charge at the battery pack's output. In order to get the necessary parameters for the battery model, it is possible to conduct OCV tests by repeatedly discharging the battery and injecting small amounts of current.

The characteristics of the model in Figure 2 are governed by the following equations

$V_{cb} = I/C_{CB}$

$Vcs = i/R_tC_{cs}\, V_{cs} + 1/C_s\, i$

V0 = Vcb + Vcs + IRi

Since there is only a piecewise link between battery OCV & SOC,

If we assume a linear setting, VCB can be written as

Vcb = kSoc + d

where k and d are not fixed values but rather shift depending on the state of charge of the battery and the surrounding temperature. So

Soc = . IkCcb

Vcs = – Vcs + I . 1RtCcs1Ccs

V0 = kSoc + Vcs + IRi + d

Then the final system equations can be rewritten as

V0 = kSoc + Vcs + IRi + d

State of Health Estimation

The battery's "state of health" is described in comparison to a brand new battery. As such, it provides data on the total amount of discharge capacity that can be used over its service life. The range of an EV is typically described in terms of its "state of health," or SOH. Deterioration in both capacity and power are considered indicators of poor health, under Patriate's theory. With a fully charged battery, the term "capacity fade" refers to the diminished driving range, while the term "power fade" describes the diminished speeding up. As a cell's impedance rises with age, its power output gradually decreases. In this paper, an LSTM neural network-based SOH estimate approach for EVs' battery packs is provided. Using large amounts of cleaned, historical charging data, ampere-hour integral method can be used directly to determine capacity. Preliminary results are refined by removing the effect of charging environment temperature, using data from temperature tests. The locally weighted linear regression (LWLR) method is employed to fit the nonlinear capacity versus mileage curve, and the resulting estimate of SOH is then utilised to qualitatively show how SOH degrades with time. Environmental factors that hasten battery deterioration were also analysed, and relevant health metrics were collected. To improve the precision of SOH offline estimate and the speed of calculations, First, the MIC method is used to verify the association of health features as well as capacity, then the health features also with highest correlation are selected to construct the training data. While increasing the model's accuracy, Bayesian optimization (BO) drastically shortens the time it takes to train the model. SOH prediction for the battery pack is then made using an LSTM neural network.

BATTERY CAPACITY ESTIMATION AND ENVIRONMENTAL TEMPERATURES:

A battery's lifespan is affected by its charge/discharge cycles, its location, and the materials it's made of. If you discharge a battery at a steady current and temperature, you can estimate its health. Here are some factors discovered via experimenting with a sodium ion battery at varying rates of discharge and temperatures.

Discharge Rate Temperature	Celius
0.5C (350 mA)	25 °C
0.5C (350 mA)	25 °C
1C (700 mA)	25 °C
1C (700 mA)	25 °C

CHARGING AND DISCHARGING OF SODIUM-ION CELL USING BMS:

Na-ion batteries are the most powerful, smallest in size, and most reactive. Sodium-ion batteries have incredibly rapid charging and discharging times compared to other types of batteries. To avoid a chain reaction of chemical reactions, heat, with eventual cell venting and fire, lithium-ion batteries should not be worked at voltages above their safe working range. To prevent the battery from being overworked or underutilised, a Battery management system (BMS) is used.

CONCLUSION:

We are developing a model for battery management in electric vehicles by keeping an eye on and changing important metrics like voltage, current, state of charge, health, lifespan, and temperature. The safety and dependability of the battery is dependent on the BMS being serviced on a regular basis. When it comes to electric vehicles, the battery management system is crucial because it ensures the safe, efficient, and dependable use of the battery. They also provide answers to issues with electric vehicles' heating, power, and inclination. Since short circuits are widely recognised as a significant threat to the security of Evs, the diagnosis and forecasting of shorts serve a crucial role in advancing battery safety. This article provides a comprehensive summary of the current diagnostic and prognostic knowledge around short circuit. Mechanical testing have poor repeatability and controllability in experiments for ISC. This research investigates battery management systems (BMS) with an eye toward bettering the efficiency of electric car power systems. Because of its similarities to lithium-ion battery systems, sodium-ion battery technologies have benefited from a great deal of recent research activity, leading to significant advancements in the field. Na-ion battery commercialisation is moving forward thanks to new findings such hard carbon as a superior anode material and rising demand for large-scale electrical energy storage. The rapid development of sodium-ion battery technology suggests that it will soon provide a formidable challenge to lithium-ion in the field of rechargeable batteries. However, this can only be accomplished by increasing funding for sodium-ion battery R&D so that this technology for low-cost, highly scalable, and widespread electrical energy storage can be brought to market. Moreover, the usage of a battery management system can help go very close to the goal of decreasing greenhouse gases.

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