Performance Improved Battery Modeling for EV Simulation

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***Abstract*— An electric vehicle (EV) is one that is powered by an electric motor rather than an internal-combustion engine that burns a mixture of fuel and gases. State of charge (SOC) is the level of charge of an electric battery relative to its capacity. The state of charge is defined as the ratio of Q(t) (available capacity) and the maximum possible charge that can be stored in a battery, i.e., the nominal capacity Q_n. A fully discharged battery has an SOC of 0 or 0% while a fully charged battery has SOC 1 or 100%.**

With the development of modern society, the automobile has become an essential and necessary part of the world. The battery management system (BMS) relies on the remaining useful life (RUL) to ensure the safety and reliability of electric vehicle (EV) operation. State-of-Charge (SOC) and remaining useful life (RUL) both are crucial for electric vehicles. But very few articles are accessible to remaining useful life (RUL) and State-of-Charge (SOC). So, the key objective of this research is the estimation of SOC Model performance with the help of EV model.

Within the framework of this study, a method for obtaining the value of SOC model's parameters i.e., SOC, current and power from the predicted values of EV model's parameters i.e., input range, input time, input speed, input charge, and input voltage is used. The method is solely based on the values of two models i.e., SOC model and EV model.

So, this research aims to obtain the values of SOC model's parameters for EV. In this research the values of EV model's parameters have been predicted by which, values of the parameters of SOC model i.e., SOC, current and power have been obtained. A total of 9 readings of EV model's parameters have been predicted for obtaining the values of SOC model parameters and the values of SOC model parameters from all the readings have been calculated appropriately by the proposed method.

I. INTRODUCTION

The vehicle has become a significant and essential part of the environment through the growth of modern society [1]. The popularity of automobiles adds great comfort to the everyday lives of people. However, the resulting problems of electricity consumption and environmental pollution do have a huge effect on economic development of society [2]. The advent of EVs offers a potential solution to the issue of energy and the atmosphere, and many countries and policymakers have laid down significant policies in recent years to facilitate the implementation of EVs [3][4]. One of the bottleneck elements in EVs is the battery pack, and the battery pack's operating state is immediately affected by the battery management system's (BMS) performance [5] [6]and reliability of the BMS has a huge effect on the economy and complex EV performance.

Therefore, to promote the promotion of EVs [7], it is important to establish an appropriate method of battery management. The advent of EVs offers a potential alternative to the issue of energy and the climate, and several governments or countries have developed serious policies to encourage the adoption of EVs, in recent years. The Electric Vehicle (EV) is a dynamic multi-domain physical structure of mechanical, electronic and hydraulic components whose architecture requires organized modeling and simulation through multiple disciplines.

Electric cars are becoming increasingly common and more accessible. Highlights of the EVs include: no greenhouse gas pollution, lower operating and servicing costs, capacity to start and stop regularly, smooth and quiet driving, regenerative braking, quick and steady acceleration (full torque even at the lowest speed), enhanced safety features, potential usage of clean renewable energy for driving, less moving parts, etc.

Based on the design of the drive train, electric cars can be categorized as Battery Electric Car, Fuel Cell Electric Vehicle (FCEV), Plug-in Hybrid Electric Vehicle, and Hybrid Electric Vehicle (HEV). To conserve energy both EVs are fitted with regenerative braking systems otherwise due to friction during braking lost as heat. The electrical vehicle is an application of the vehicle body, electrical drive, energy storage and energy control. It is not only a transport vehicle, but also a modern form of electrical equipment. The road vehicle such as electric vehicle focused on current electrical propulsion, consisting of a power generator, an energy supply, electric engine, which has its own distinct characteristics. The electrical vehicle's machine design is totally different from that of the internal combustion engine vehicle. The design of the electrical vehicle system comprises of mechanical, electrical and computer subsystems.

Electric vehicles (EVs) have become highly common due to zero carbon pollution, limited fossil fuel supplies, comfortable and light travel. However, EVs utilizing a lithium-ion battery face difficulty in estimating reliable health and remaining usable life spans due to numerous internal and external influences. Actually, so few articles are accessible to remaining useful life (RUL) figures and to outline health condition (SOH). In this regard, the purpose of this study is to conduct the various estimation models through analysis for forecasting SOH and RUL in a comparative manner. The findings describe classifications, attributes and measurement methods with advantages and drawbacks for EV applications. The analysis often discusses problems and concerns with alternative remedies. In addition, the study points out several selective recommendations for the calculation SOH. It is anticipated that all the highlights of this analysis would contribute to a growing attempt to improve innovative SOH and RUL approaches for potential EV uses.

II. EV CHARGING SCHEMES AND BATTERY CHARGING METHODS

The batteries efficiency, safety, and durability rely strongly on how they are discharged or charged. Damage to the battery will shorten its durability significantly, which can be harmful. Both are discharging, and charging control is part of the new battery protection scheme. It will be built into the system of grid distribution in the future. Therefore, the attention here is on the charging and charging technology debate for EVs.

A. EV Charging Schemes

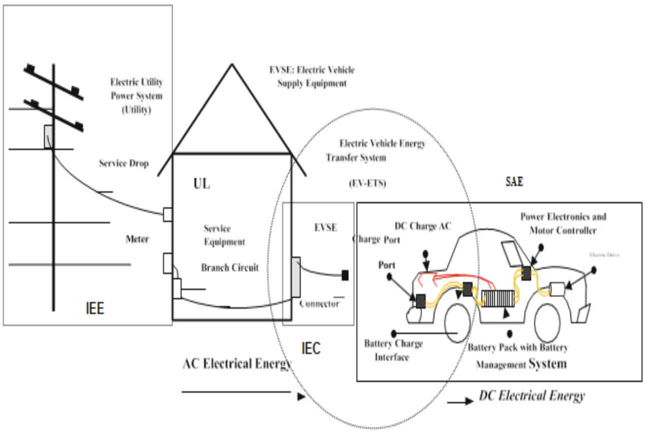

Figure 1 For Electric Vehicle Energy Transfer System's Applicable Standards

For fast accessibility, effective electric vehicles would be more reliant on which charging stations can be installed. That is also important for the potential grid support that electric vehicles will offer. Homes and offices can be the first location to be considered for charging stations. Other possible sites with large concentrations include gas stations, shopping malls, hotels, entertainment venues, public buildings, colleges, and highway rest areas. There are several principles for EV charging regarding communication, energy transfer, connection interface [10][11].

B. Battery Management Systems (BMS)

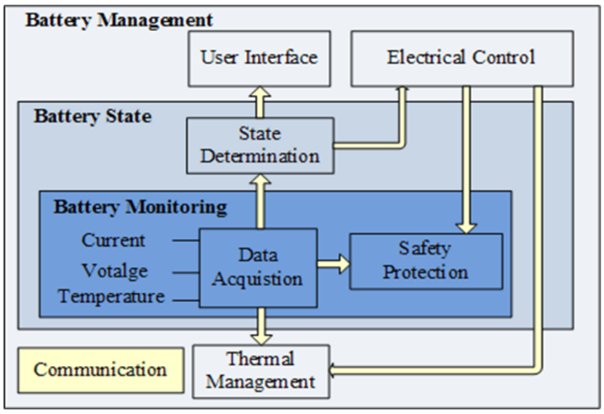

Figure 2 Illustration of a Battery Management System

For the prevention of battery loss, various types of BMS are used. A tracking system of the battery monitors main operating factors like internal battery temperature, ambient temperature, voltage, and current while discharging and charging is the most common type. The system provides protection systems with inputs. When some of the factors reach the protection region's values, the control circuits will activate warnings and remove the battery from the charger.

The single source of energy in pure electric vehicles is the battery. The BMS should also have battery management and protection systems in this mode of use, as needed, the battery that is maintained by a system prepared to provide the power as full, and a system that can extend the battery life. The battery management system should have systems by which the method of charging and those that deal with thermal problems are controlled. The BMS is part of a power control system in a vehicle that is fast-acting and complex. In addition, other on-board systems, like the car controller, the engine controller, the temperature controller, the protection device, and the communication bus, may be able to communicate.

C. BMS Objectives

- It means that the battery is forever available for use.
- It prevents the cells of the battery from damage and abuse.
- It retains, as long as possible, the battery life.

D. BMS Function

1. Discharging control

Holding the battery out of its safety zone is the primary objective of the battery control system. From any unloading danger, the cell is must be protected by the battery management system. The cell may otherwise work outside its limits.

2. Charging control

More often than any other source, the source which affects the batteries is excessive charging. Hence, a crucial component of the BMS is the charging mechanism. The 2-stage charging mechanism use by Lithium-ion batteries are called the CC-CV (constant current- constant voltage) charging cycle. The charger produces a steady current, increasing the battery voltage during the first charging cycle (constant current stage). It reaches the constant voltage (CV) stage when the battery is almost complete, and the battery voltage hits a constant value. As the battery current decays exponentially, at this stage, the charger manages a constant voltage before batteries charging.

E. State of Charge Determination

For battery control, one of the device's capabilities is to maintain track of the battery's SOC. The SOC could signal and monitor the process of charging and unloading to the customer. There are 3 forms of charge state determination: direct calculation, coulomb counting, and the synthesis of the two methods. One can use a voltmeter as the battery voltage reduces linearly over the battery's discharge phase to measure the state of charge directly. The current that reaches or leaves the battery to produce its charge's relative value is combined in the Coulomb-counting phase. Evaluating the relative balance in the savings account are the same as bank accounts in or out counting of funds. In contrast, both methods can be combined. As the end of the actual charge is hit, the voltmeter can control the battery voltage and calibrate the SOC and, to determine the relative charge in and out of the battery, the battery current may be combined.

F. Determination of State-of-Health

The state of health (SOH) is a metric that reflects the overall efficiency and ability of the battery to have the specified benefit compared to the new battery. To view the state of health of the cell, any factor that changes significantly with age such as behavior and cell impedance may be used. In fact, the state of health can be determined from a single measurement of either cell conductivity or cell impedance.

G. Cell Balancing

In the chain to maximize the overall life of battery by equalizing the voltage on all cells, cell balance compensates for weaker cells. In multi-cell battery chains, for each charging- discharge cycle, due to operating condition and output tolerances, minor dissimilarity between cells appear to be magnified. Weak cells until they eventually die, can become much weaker and overstressed during charging, this causes the battery to fail early. For this problem to present a complex approach to this problem, for the cells balancing one of the three cell balancing mechanisms utilize by the battery control system and from being over-stressed, the individual cells are avoided while taking into account the working state and the age of the cells: the load shunting system, the active balancing system, and the passive balancing system.

From the stronger cells, the charge is withdrawn and transfer to the weaker cells in active cell equilibrium. To find cells with the highest load in the pack, as seen by higher cell voltages, dissipative strategies are used in passive balance. Before the voltage or charge corresponds to the weaker cells' voltage, by the bypass resistor the extra energy is then withdrawn. To the rated voltage of an effective cell both cells' voltage would be levelled upward, in charge switching. The current will bypass the fully charged cells once the cell's rated voltage has been reached, until they hit maximum voltage to charge the weaker cells.

H. Logbook Function

The system of measurement must retain, for comparison, a set of standard conditions or a record of the original conditions as the state of health is equal to the new battery's state. Another way to estimating the state of health based on the battery's experience of usage rather than the measured metrics, is to estimate the state of health value, for example, the amount of battery charging periods performed. The battery management system's logbook function would then report to the memory system that important information.

I. Communications

A data link can monitor set device parameters or to diagnose, performance, log data, and provide the BMS communication mechanism. With system control signals, communication channel can also provide the function. Instead of the battery, application of the battery decides the preference of a communication protocol. To ensure the car's safe function, the battery management system used in electric vehicles must interact with the upper vehicle controller and engine controller. In order to communicate with the car, the BMS uses two main protocols: the data bus and controller area network (CAN) bus. The CAN bus, which is most widely used for automotive purposes, is the industry standard for on-board vehicle communications. Data buses include EIA-485 (also referred to as the RS485 connection) and RS232 connections.

III. PROBLEM FORMULATION

To assess its output through using mathematical symbols, numerous researchers have performed comprehensive research on LIB system identification and have suggested several other innovative forms. Several parameters that affect LIB efficiency, which in turn impacts the overall efficiency of EVs. Parameters such as temperature, self-discharge, vibration, and shelf-life have been recognized by Omariba et al. [23].

The purpose of this study is to measure the tolerance of the OCV and the corresponding set of batteries, as they are intricately linked to the SOC and SOH battery cells. As a result, LIBs in EVs, combined with motion and temperature parameters, are calculated by parameter identification, SOC and SOH approximation. In the form of normal analysis, certain factors contributing to the assessment of the efficiency of the electrodes in the EVs need to be considered.

In the current work various real-time parameters like Drag coefficient c_d, Electric vehicles constant, velocity v is used to evaluate the acceleration (a), total tractive effort (FTe), The total effort for moving the vehicle is the result of algebraic addition of all the forces acting over the vehicle, energy required each second, motor angular speed (w) using driving cycle and torque(T) and motor efficiency are considered for the simulation of the battery performance.

IV. RESEARCH METHODOLOGY

- In this research, an EV device is planned and installed to measure all the efficiency of the batteries. The advanced production block diagram includes an EV system, along with battery SOC calculations, battery voltage measurement systems, vehicle wide variety and vehicle speed measurement systems.

- For estimating certain parameters like range & SOC, some more real-time parameters are counted like Drag coefficient c_d, Electric vehicles constant, velocity v is used to evaluate the acceleration (a), total tractive effort (FTe), The total effort for moving the vehicle is the result of algebraic addition of all the forces acting over the vehicle, energy required each second, motor angular speed (w) using driving cycle and torque(T) and motor efficiency. The defined parameters will help for the accurate simulation of the battery performance evaluation.
- In this research, a revised basic cost - effective form is used in the method. As with the basic dynamical system, this method seems to have the same electrical circuit. The input voltage of the battery, however, is a feature of the battery's SOC. Due to this aspect, the battery's input voltage changes inversely.

V. TERMS USED IN METHODOLOGY

➢ State-of-Charge (SOC)

The SOC is a very crucial parameter for batteries, but defining it poses several challenges [24]. A battery's SOC is specified as the ratio of its current capacity (Q(t)) to its nominal capacity (Qn) in general. The manufacturer specifies the nominal power, which is the charge's maximum amount that can be collected in the battery. The following is a description of SOC:

$$SOCt=Q(t)Qn$$

The numerous mathematical estimation methods are divided into groups based on methodology. In different literatures, these SOC estimation approaches are classified differently. However, some literatures [25] allow for categorization into 4 types mentioned below.

➢ Direct Measurement

This approach makes use of physical battery properties including voltage and impedance.

Book-Keeping Estimation

This approach takes the discharging current as an input and calculates SOC by integrating the discharging current over time.

➢ Adaptive Systems

Self-designing adaptive systems will automatically alter the SOC for several conditions of discharging. Adaptive systems for SOC estimation have been built in a variety of ways.

Hybrid Methods

The benefits of every SOC estimation approach are combined in hybrid models, resulting in a globally optimal estimation efficiency. In comparison to individual methods, hybrid methods yield strong SOC estimation. Considering the approach .

VI. RESULTS

This work is focused on two models, namely the electric vehicle model and the SOC measurement model. The methodology involved certain parameters and described that to estimate certain parameters like range & SOC, some more real-time parameters are counted like Drag coefficient c_d, Electric vehicles constant, velocity 'v' is used to evaluate the acceleration 'a', total tractive effort (FTe).

The total effort for moving the vehicle is the result of the algebraic addition of all the forces acting over the vehicle, the energy required each second, motor angular speed (w) using driving cycle and torque(T), and motor efficiency. The defined parameters will help for the accurate simulation of the battery performance evaluation.

In this research, a revised basic cost-effective form is used in the method. As with the basic dynamical system, this method seems to have the same electrical circuit. The input voltage of the battery, however, is a feature of the battery's SOC. Due to this aspect, the battery's input voltage changes inversely.

In the proposed methodology, firstly the performance parameters are measured and evaluated. After that, it will be split into two models: the EV model and the SOC measurement model. After this point, the parameters of both models, such as Time, Range, and Speed for the EV model, and Power, Speed, and other parameters for the SOC measurement model, are specified.

The methsodology mainly focused on determining the values of the SOC model. The nine input readings of the EV model will be estimated to derive the values of the SOC model's parameters i.e., SOC, current, and power.

VII. Implementation Results

Firstly, nine readings of the EV model i.e., range, time, speed, charge, and voltage have been put for determining the values of the SOC model i.e., SOC, current, and power. All the nine readings of the EV model are shown in Table.

Input Values of EV Model

EV Model				
Input Range	**Input Time**	**Input Speed**	**Input Charge**	**Voltage**
500	3	70	40	400
500	2	60	35	450
500	1	50	40	450
500	10	45	40	450
500	3.5	75	40	500
500	2	35	60	600
500	2.5	50	60	600
500	1	80	60	550
500	2	90	60	700

Table 1 Based on these values, the SOC model will be calculated.

Formulas for finding the values of the SOC model's parameters:

SOC is calculated by Equation

$$SOCt=Q(t)Qn$$

where SOC is the state of charge.

Current is calculated by Equation

$$I=q*t$$

where 'I' is the current which has to be calculated, q is input charge and t is the input time.

Power is calculated by Equation

$$P=V*I$$

where ‘P’ is the power that has to be calculated, V is the voltage, and I is the current which is calculated by equation
Distance is calculated by Equation

$$D=S*t$$

where D is the distance that has to be calculated, s is the input speed and t is the input time.

So, with the help of these all formulas, the values of SOC parameters have been obtained. The first input values of the EV model's parameters and the obtained values of SOC parameters for the same.

. First Predicted Reading of EV Model's Parameters

EV Model				
Input Range	**Input Time**	**Input Speed**	**Input Charge**	**Voltage**
500	3	70	40	400

Table 2 Predicte Reading of Ev Model’s Parameters

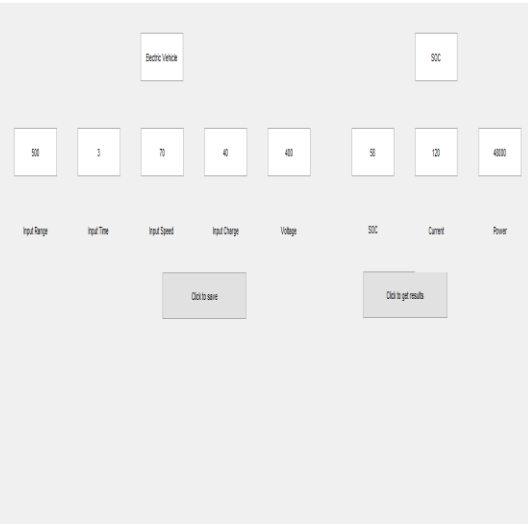

Figure 4 Obtained Values of SOC model’s parameters for First Predicted Reading

VIII. CONCLUSION & FUTURE DIRECTIONS

An EV device is planned and installed to measure all the efficiency of the batteries. The advanced production block diagram includes an EV system, along with battery SOC calculations, battery voltage measurement systems, vehicle wide variety and vehicle speed measurement systems. The main goal of the battery management system (BMS) is to keep the battery charged at all times. And to keep the battery charged at all times, the value of the available charge in the battery should be known. The value of SOC is measured in this study to determine the amount of available charge in the battery.

In the proposed methodology, firstly the performance parameters are measured and evaluated into two models i.e., EV model and the SOC measurement model. The parameters of both models, such as Time, Range, and Speed for the EV model, and Power, Speed, and other parameters for the SOC measurement model, are specified. The methodology mainly focused on determining the values of the SOC model. The nine input readings of the EV model will be estimated to derive the values of the SOC model’s parameters i.e., SOC, current, and power.

The proposed research methodology is implemented over MATLAB R2020a.

A total of 9 readings of EV model’s parameters i.e., input range, input time, input speed, input charge, and input voltage have been predicted. Through these predicted readings of EV model’s parameters, the values of SOC model’s parameters i.e., SOC, current and power have been obtained for all 9 readings by the method which has been utilized. For properly understand the variation in the values of SOC, current and power with respect to predicted readings, have been demonstrated by individual graphs.

It is concluded that the method which is utilized to obtain the values of the SOC model’s parameters with the help of the EV model’s parameters gives the calculated value of all parameters of the SOC model i.e., SOC, current, and power. To properly understand the variation in the values of SOC, current, and power with respect to predicted readings of EV model’s parameters, have been demonstrated by individual graphs. This method is truly relevant and desirable to calculate the value of SOC. As it is helpful to prevent the cells of the battery from damage and retains the battery life.

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