State of Charge Estimation of Electric Vehicle Battery

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Abstract— The state of charge (SOC) of the Lithium Ion Batteries (LIBs) is a core parameter in the implementation and development of batteries management systems which requires the accurate measurement of the battery capacity which is used in the development of EVs, and thus is becoming a very critical issue. Only with the accurate measurement of the SOC using various equations and parameters, it is possible to manage the battery energy effectively to prevent it from risks resulting from over-charging and over-discharging. It can also provide the necessary data and form a basis for other energy related system requirements as well. In the process of the SOC value estimation, we must consider the impact of various factors in the LIBs' working process like Cell Ageing, Cell Imbalance etc., using various reasonable equivalent circuit model of the LIBs. Appropriate estimation algorithms are used to measure and improve the accuracy of SOC estimation. The batteries and battery management systems (BMS) are the key components of EVs. The SOC value, which marks the remaining capacity or power in the batteries, is also the core parameter of the BMS. It is a reflection of the operational status of the main feature, providing basis for the vehicle control strategy judgment and management. And the accurate estimation and management of SOC can improve the battery state of life (SOL) and the vehicle or application performance. The indication of SOC is often referred to as an estimate rather than a measurement or determination as there is no single correct process to be employed. And also, it is not yet possible to determine the SOC one-hundred percent accurately. In this method, real time battery used for calibration of SOC estimation using Arduino UNO controller. Also we will analyze the performance of battery with simulation of Arduino controller with MATLAB simulink model. ANN model will be design in MATLAB simulink for identification of exact SOC of battery.

Keywords: SOC Calibration, Electric Vehicle, ANN

I. Introduction

The world is seeing a spike in usage of energy resources. The existing and conventional sources of Energy such as the Fossil fuels (Petroleum, Natural Gas and coal) are getting difficult to harness. Thus, deeper oil wells are being dug in offshore locations, Hydraulic fracturing techniques and horizontal drilling techniques are being used to obtain shale gas. All these processes are expensive and damaging to the environment. Further the use of these energy sources adds to the greenhouse gas effects and global warming which are now playing havoc with weather all around the globe.

In the last decade, electric vehicles (EVs) have been rapidly developed with the increasing air pollution and decreasing fossil energy. As a key part of the EVs, battery has important influence on performance of the EVs, such as driving range, accelerating ability and lifespan. Currently in India, lead-acid batteries are widely used in energy storage systems for EVs due to their merits of low cost, long lifespan, pollution-free and low self-discharge rate. Battery has to be managed carefully to guarantee its reliability and safety, and the state of charge (SOC) is one of the most important state variables needed to be monitored.

Lead-acid batteries have been recently deployed in a wide range of energy-storage applications, ranging from energy-type batteries of a few kilowatt-hours in residential systems to multi-megawatt batteries for the provision of grid ancillary services. This trend brought to the fore, a series of requirements in high-energy and high-power applications, which strongly depend on the accurate state of charge (SOC) estimation. Accurate SOC estimation contributes to better protected battery packs against over-charging/discharging. Failure to estimate SOC accurately may result in a reduction of the power-output capability and the whole energy management system might be lowered severely.

SOC is defined as the present battery capacity and usually is expressed as a percentage of a reference capacity. The preferred SOC reference can be either the rated capacity of a new battery or more often the current maximum capacity of the battery. Several approaches have been proposed regarding SOC estimation of Lead-acid batteries. SOC estimation is a fundamental challenge for battery use. The SOC of a battery, which is used to describe its remaining capacity is a very important parameter for a control strategy. As the SOC is an important parameter, which reflects the battery performance, so accurate estimation of the SOC cannot only protect battery, prevent over discharge and improve the battery life but also allow the application to make rational control strategies to save energy. However a battery is a chemical energy storage source, and this chemical energy cannot be directly accessed. This issue makes the estimation of the SOC of a battery difficult. Accurate estimation of the SOC remains very complex and is difficult to implement, because battery models are limited and there are parametric uncertainties. Many examples of poor accuracy and reliability of the estimation of the SOC are found in practice.

II. Proposed Methodology

A. Flow Diagram

In this section, the components of the hardware connection diagram shown in fig 1 are described in detail and trained the neural network for SOC estimation. In the proposed methodology, 'voltage', 'current' and 'temperature' sensors along with Arduino is used in the experiment to sense voltage, current and temperature of the provided battery model. The module is connected to the personal computer through USB cable. All these will then eventually be processed by the MATLAB Simulink. Fig 1 shows the flow diagram of proposed methodology.

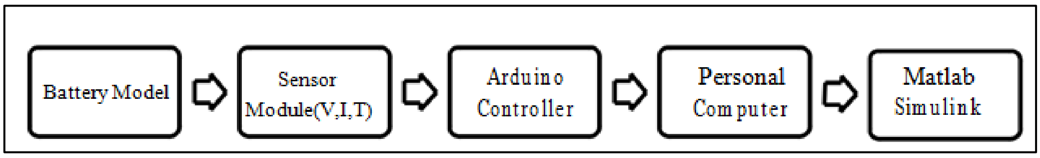

Fig.1: Flow diagram of proposed approach

B. Hardware Implementation

The hardware connection diagram is shown in the figure 3.2. Hardware components consists of Arduino UNO, voltage sensor, current sensor, temperature sensor, multimeter, battery, load and laptop with MATLAB simulation software. The hardware setup for measurement of V,I,T is shown in fig 2.

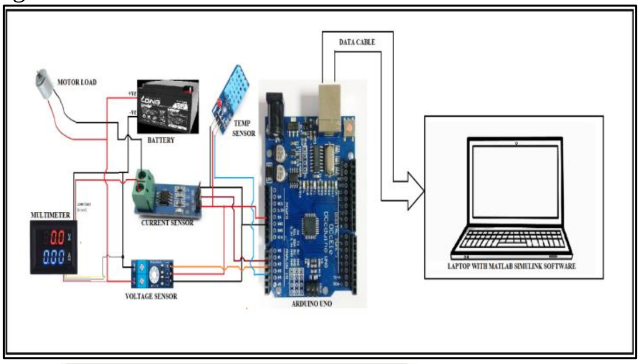

Fig. 2: Connection diagram of hardware components

The analog outputs of voltage sensor, current sensor and temperature sensor are connected to the analog pins of Arduino UNO i.e., A1, A2 and A3 respectively. The +ve terminals are connected to the Vcc and –ve terminals are commonly connected to the ground. The output port of Arduino is connected to the laptop having MATLAB simulink software by USB chord. The real time data of the battery can be seen on the screen on display and waveforms are also visualized on the MATLAB scope.

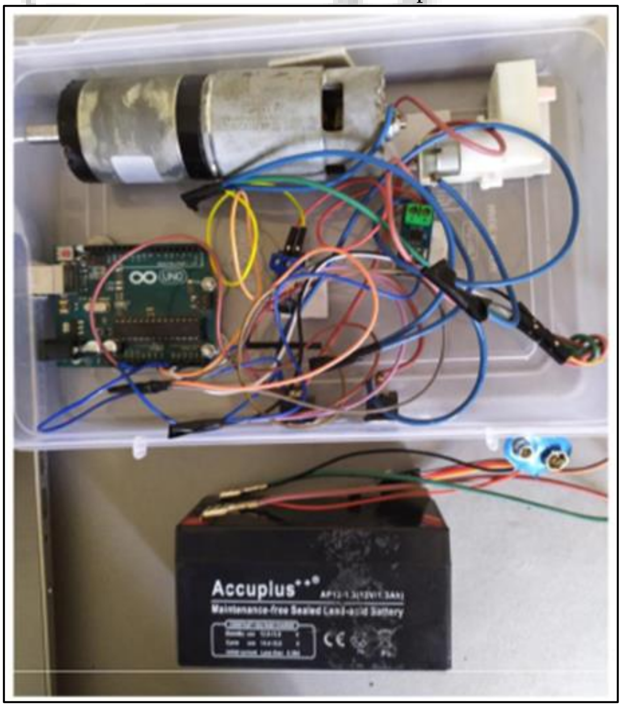

Fig. 3: Hardware implementation of proposed battery measurement system

C. MATLAB simulation model

The simulation model for the collection of battery data has been made on MATLAB simulation. This model is shown in fig 4. The description of the model blocks and its specifications is given below:

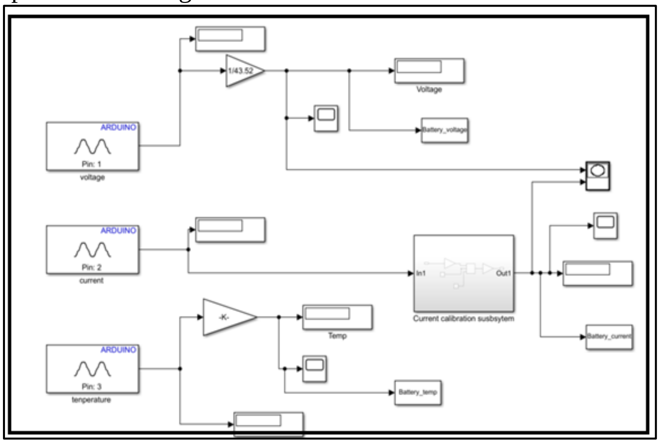

Fig. 4: MATLAB simulation model for battery parameter measurement

1) Battery Voltage:-

For measurement of battery voltage Pin no 1 of Arduino is allotted to analog block of simulation with the gain of 1/43.52.

2) Battery Current:-

For measurement of battery current Pin no 2 of Arduino is allotted to analog block of simulation. The current calibration subsystem is shown in the fig 5.

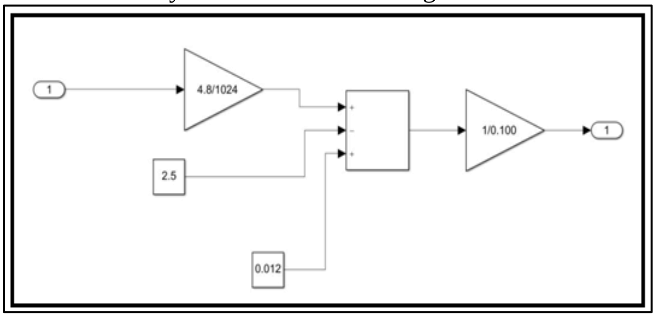

Fig. 5: MATLAB Simulink model of Current Calibration Subsystem

3) Battery Temperature:-

For measurement of temperature Pin no 3 of Arduino is allotted to analog block of simulation with the gain of 1/3.9583333.

4) Scope and Display:-

Scope is connected in the system to visualize the output waveforms of battery voltage and current. Display shows the numerical value for the hardware.

III. SIMULATION RESULTS

A. Battery parameter measurement

SOC	Voltage	Current	Temperature
100	12.7	0.4359	27
100	12.7	0.3566	27
100	12.7	0.3302	27
100	12.7	0.3038	27
100	12.7	0.2774	27
100	12.7	0.2246	27
95	12.6	0.3302	27
95	12.6	0.3038	27
95	12.6	0.2774	27
95	12.6	0.251	27
95	12.6	0.2246	27
95	12.6	0.1189	27
90	12.5	0.4887	27
90	12.5	0.3831	27
90	12.5	0.3566	27
90	12.5	0.3038	27
85	12.46	0.4359	27
85	12.46	0.3302	27
85	12.46	0.251	27
85	12.46	0.2246	27
80	12.42	0.3831	27
80	12.42	0.3566	27
80	12.42	0.3302	27
80	12.42	0.2246	27

Table 1: Battery Parameter Measurements from Hardware Model Usig MATALB Simulink

Table 1 shows the theoretical calculated SOC (state of charge) battery and there corresponding measured voltage, current and temperature of battery at corresponding SOC. This calibrated voltages and currents are real time values measured by currnet and voltage sensors which fed to arduino controller. Then arduino controller send that digital value to matlab simulink modeling. That matlab simulink modeling then convert those digital values into measured unit's values i.e. current in Ampere and Voltage in volts. Similarly temperature of battery measured in same way.

B. Battery Discharge curves

Figure 6 shows the real time battery load current versus time curve in which it is obsred that as load increases with respect to time then battery current also increases. In initial condition battery current is around 0.0865 Amp and it increases at maximum value 0.096 Amp at 6 th minutes time duration.

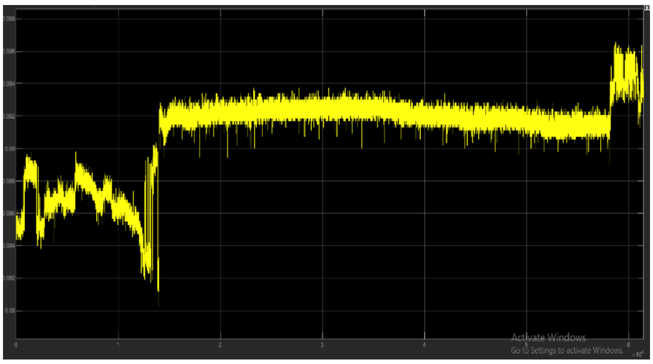

Fig. 6: Real time hardware battery current versus time curve

Figure 7 shows the real time battery body temperature versus time of operation of battery in which it observed that body temperature of battery directly depends upon battery load current. As load current increase then battery body temperature also increases. Initially battery temperature is around 29 Degree Celsius while at end battery temperature increases at maximum 29.9 Degree Celsius.

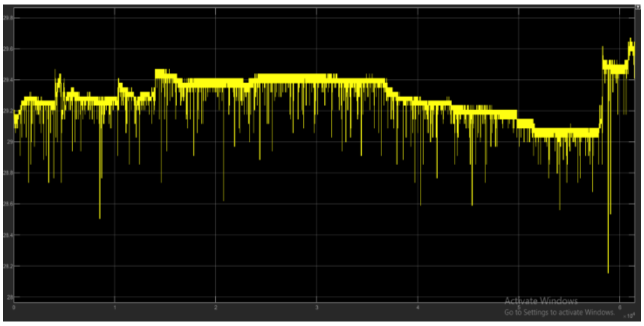

Fig. 7: Real time battery body temperature versus time curve

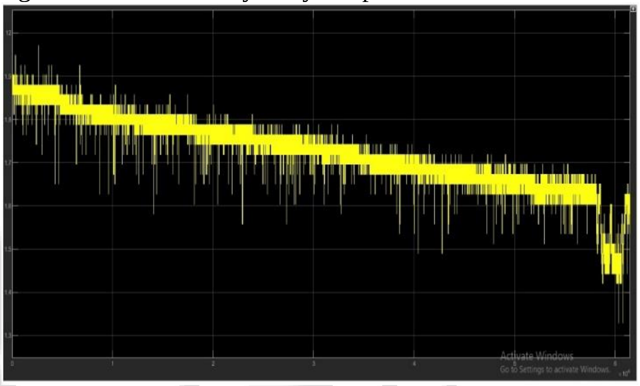

Fig. 8: Real time battery voltage versus time discharge curve

Figure 8 shows the real time battery voltage versus simulation time curve in which it is observed that voltage of the battery decreases as load current increase with respect to time. Initially battery voltage becomes 11.9 Volts and voltage becomes drop upto 11.6 Volts at 6 Minutes of time duration. This curve also called as battery discharge curve.

IV. CONCLUSION

In this paper, the real time hardware model of battery measurement system is design which measured the real time battery voltage, load current and battery body temperature. For measurement of real time data we used arduino controller with arduino voltage and current sensor as well as temperature sensor. With the help of Arduino hardware support package in MATLAB simulink, arduino is connected and simulated with MATLAB simulink model. In this paper, we were measured battery real time voltage, current and temperature with theoretical SOC calibration.

Also in this paper, we calibrates the real time battery discharge curve which is important curve for calibration of battery performance. Simultaneously, real time battery current versus time as well as battery temperature versus curves are calibrated for real time battery hardware model in software approach. This approach is alternate approach for calibration of battery parameters as well as battery performance curves. This method is very much easy and cost effective.

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