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Estimation of SOC using EKF and UKF Filter for Controlling Overcharging, over Discharging of LI-ION Battery for Electric Vehicle

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Abstract: Mostly lithium ion batteries are more famous among the people because of its energy density, long life span and high power. Battery management system is necessary for safe operation as well as long life span of lithium ion battery. The wide spreading of EV is encouraging for research on electric energy storage systems as well as Battery Management Systems. To control charging as well as discharging of battery, state of charging estimation is necessary. For monitoring battery state, it is important to analyze the factors which are affecting the errors in evaluation of state of charging along with health parameters such as internal resistance and capacity. For accurate calculation of state of charging we can use Extended Kalman Filter or Unscented Kalman Filter.
Keywords: SOC, EKF, SPKF, SOC-OCV

I. INTRODUCTION

Now a days, demand of energy increasing. Because of excess use of fuel like petrol diesel there is decrease in fuel resources, environmental disorientation and increase in greenhouse gases. Rising crude oil prices, the awareness about environmental issues had resulted in increased development in energy storage systems. Because of its low pollution as well as more efficiency, battery is more charming system for storage of energy. Due to this, renewable energy has gained more attention and derives use of electric vehicles. Electric vehicles are more popular because of its wider acceptance among the customers, improved performance such as acceleration rate and large distance running from single charging.

It is no overemphasis to say that power batteries have been the heart of new energy vehicle, and play a significant role in the developing of new energy automobile industry. Lithium-ion battery has been mostly used in electric vehicles due to its large specific capacity, high energy density, pollution-free and long driving distance [11].With the rapid development of new energy industry, Li-ion batteries are widely used in electric vehicles and power grid as energy storage unit [2]. Battery management system is an essential module, which results in optimal power performance, reliable power management, secure as well as safe vehicle. This is lead back to boost power in electric vehicle.

The State Of Charging estimation is important feature in BMS [19]. Considering the complex dynamic driving conditions for electric vehicle, accurate State Of Charging estimation of the battery can greatly prolong its service life, improve its efficiency and ensure its safety and reliability. Because of their more energy density, more power and long life span, lithium-ion and lithium-polymer batteries are popular among the people.

Lithium –ion battery that is used in electric vehicle is consists of many cells. These cells may be connected either in parallel or series to each other.

The performance of the battery should be predicted for reduction in the energy use and increase battery life. Therefore use of a reliable simulation model for the BMS is important for designers to guide about the performance of the battery as well as to increase the power efficiency of a battery-based system. In electrical vehicle, a BMS with the function of state of charging estimation is required for user to know how long the electric vehicle can be used before the battery state approaches to empty.

Moreover, the Lithium-Ion battery should not be excess charged or excess-discharged, correct State Of Charging estimation is necessary to avoid the system from unintentional battery misuse and thus ensuring safety and longevity. A good simulation model for battery is necessary, so both battery behavior and the physical interaction of the battery with all the other components are properly reflected in the model. For effective as well as adequate design of battery for Electric Vehicle is important part.

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II. ADAPTIVE FILTERS

Based on current and voltage measurement the battery state is determined to be in either charge, discharge or open-circuit voltage and SOC relation are established for each .These relations are the used to estimate SOC over a cycle, resetting different parameters values for each start of estimation. For state estimation on nonlinear systems, or parameter estimation using Kalman Filter, one of the approaches is to lineralize the system under investigation around its current state and force the filter to use this linearized version of our system as a model. This is Extended Kalman Filter. EKF is not very stable and many times, when it does coverage to the right solution, it does it very slowly. In order to improve this filter, instead of using linearization to predict the behavior of the system under investigation some of researcher started using Unscented Kalman Filter. In EKF, it is difficult to calculate the Jacobians if they need to be found analytically. If Jacobians found numerically, then there is a high computational cost. Extended Kalman Filter only works on system that has a differential model. Extended Kalman Filter is not optimal if the system is highly nonlinear.

Unscented Kalman Filter has some advantages over Extended Kalman Filter. UKF transformation describes the nonlinear system better than the linearization. Hence these filter coverage to the right solution more rapidly. However, as the EKF, this filter may become unstable and results may be biased. In Sigma Point Kalman Filter (Unscented Kalman Filter) produces several sample points around the current state estimate based on its covariance. Then, propagating these points through the nonlinear map to get more accurate estimation of the mean and covariance of the mapping results. In this way, it avoids the need to calculate the Jacobian, hence incurs only the similar computation load as the Extended Kalman Filter.

III. METHDOLOGY

The Simscape language makes modeling physical systems easier and more intuitive. Thevenin Equivalent model is mostly used to model the Lithium ion battery (1-RC cell) as shown in Fig.1., but it is not accurate if all of its elements can change, depending on the state of the battery and its conditions. Here we have used lithium-ion cell (1RC circuit) from simscape sources for battery modeling purpose. A controlled pulsed current discharge gives the result in a form of voltage response that the model should be able to regenerate when correctly parameterized. 1-RC simscape MATLAB model is as shown below:

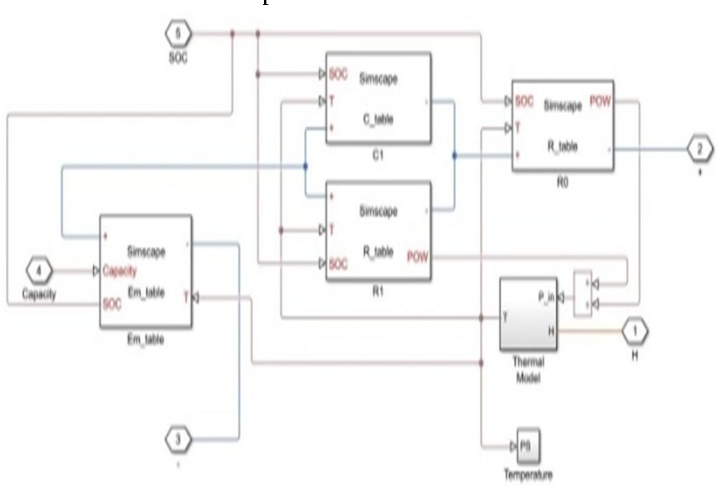


Fig.1. 1-RC cell Simscape Model

The state transition equations for 1-RC battery model,

$$\frac{d}{dt}\begin{pmatrix} SOC \\ U1 \end{pmatrix} = \begin{pmatrix} 0 \\ -\frac{1}{R1(SOC,Tb)*C1(SOC,Tb)}U1 \end{pmatrix} + \begin{pmatrix} -\frac{1}{3600+Cq} \\ \frac{1}{C1(SOC,Tb)} \end{pmatrix} I + W.$$

Where $R_1(SOC,T_b)$ and $C_1(SOC,T_b)$ are the thermal and SOC-dependent resistor and capacitor in the RC block, U_1 is the voltage across capacitor C_1, I is the input current, T_b is the battery temperature, C_q is the battery capacity (unit: Ah), and W is the process noise .

To improve the model reliability, unlike the general equivalent Thevenin model, one more RC branch is added as shown in Fig. 2. These blocks shown in the figure were created in Simulink Simscape Language to define the custom components as text files. The texts include complete parameterization, physical connections, and equations represented as a couple of causal implicit differential algebraic equations. The blocks utilize look up tables with variable values for each of battery circuit element employed. These values are obtained by a minimization problem to fit the actual voltage current relation of the battery. This relation is obtained as a result from experimental work as explained in [25].

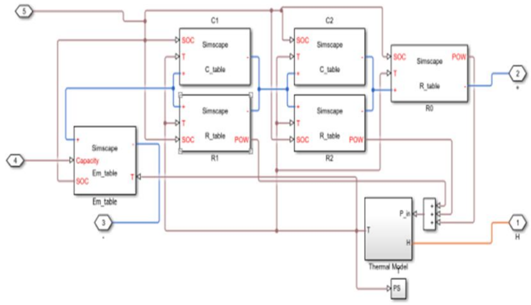


Fig.2. 2-RC cell Simscape Model

A. Battery Modelling

Battery modeling forms the basis of and stands as an effective tool for battery design, manufacturing, and control.

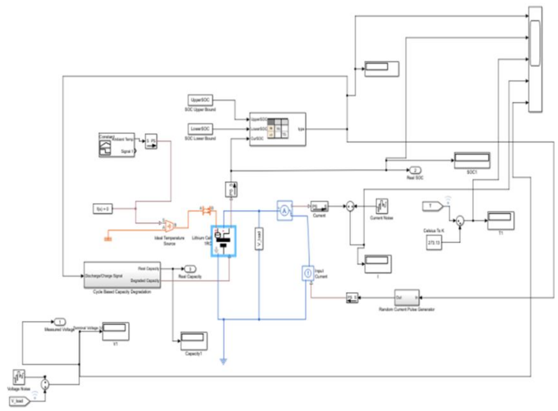
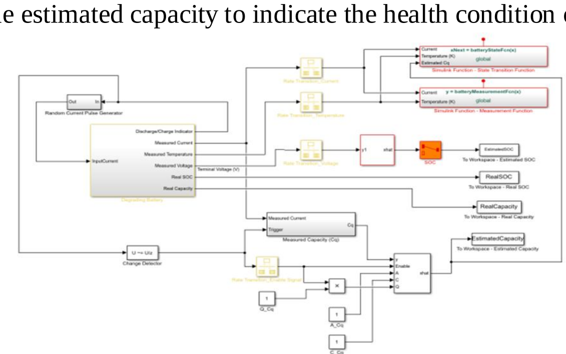


Fig.3.Battery Modeling

The simulink model that we have used is as shown above. It is available in simscape examples. Battery modeling is important task to get values of Real SOC, current, Voltage, temperature as well as battery capacity. It consists of two important blocks current measurement block, voltage measurement block. We connected current measurement block in series with lithium-ion cell. And voltage measurement block is connected across the lithium cell. Here we have connected 1 RC lithium cell. After that using same simulink model we analysis 2RC circuit.

B. SOC Estimation Using Simulink Model

The Simulink model contains three major components: a battery model, an EKF & UKF block and an event-based Kalman Filter block. This model is available in simscape examples. We assume the battery is a nonlinear system, and estimate the SOC using an EKF as well as UKF. The capacity of the battery decreases with every discharge-charge cycle and gives an inaccurate SOC estimation. We use an event-based linear Kalman filter to estimate the battery capacity when the battery transitions between charging and discharging. Then we use the estimated capacity to indicate the health condition of the battery.



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IV. RESULTS

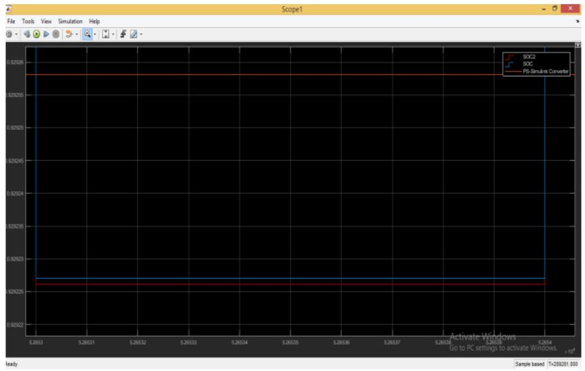

Fig. Zoomed View Of Simulink Output

As we can see in above screenshot orange color line indicates real soc of battery cell. Blue and Red color line shows estimated SOC using UKF and EKF filter respectively. From above output screenshot it is clear that UKF gives better results than that of EKF filter. In place of 1RC cell we replaced 2RC cell. After testing 2RC model for same simulink model, results shows less error in estimated SOC and real SOC as compared to 1RC cell model.

V. CONCLUSION

We reviewed number of papers on SOC estimation methods. There are different methods are used for soc estimation. Out of them the kalman filter method is more effective. In kalman filter two blocks are important i.e, time update block and measurement update block. The measurements will be updated after time update and time will be updated after measurements update, it is continuous process. We have estimated SOC using EKF and UKF. The difference between the real SOC and estimated SOC is very small. For estimation of state, EKF linearize nonlinear system. And UKF uses sigma point method for nonlinear system. From overall study and results obtained, it is clear that the Unscented Kalman Filter gives better results than Extended Kalman Filter with minimum drawback. Second order RC-Cell gives better results than First-order RC-Cell.

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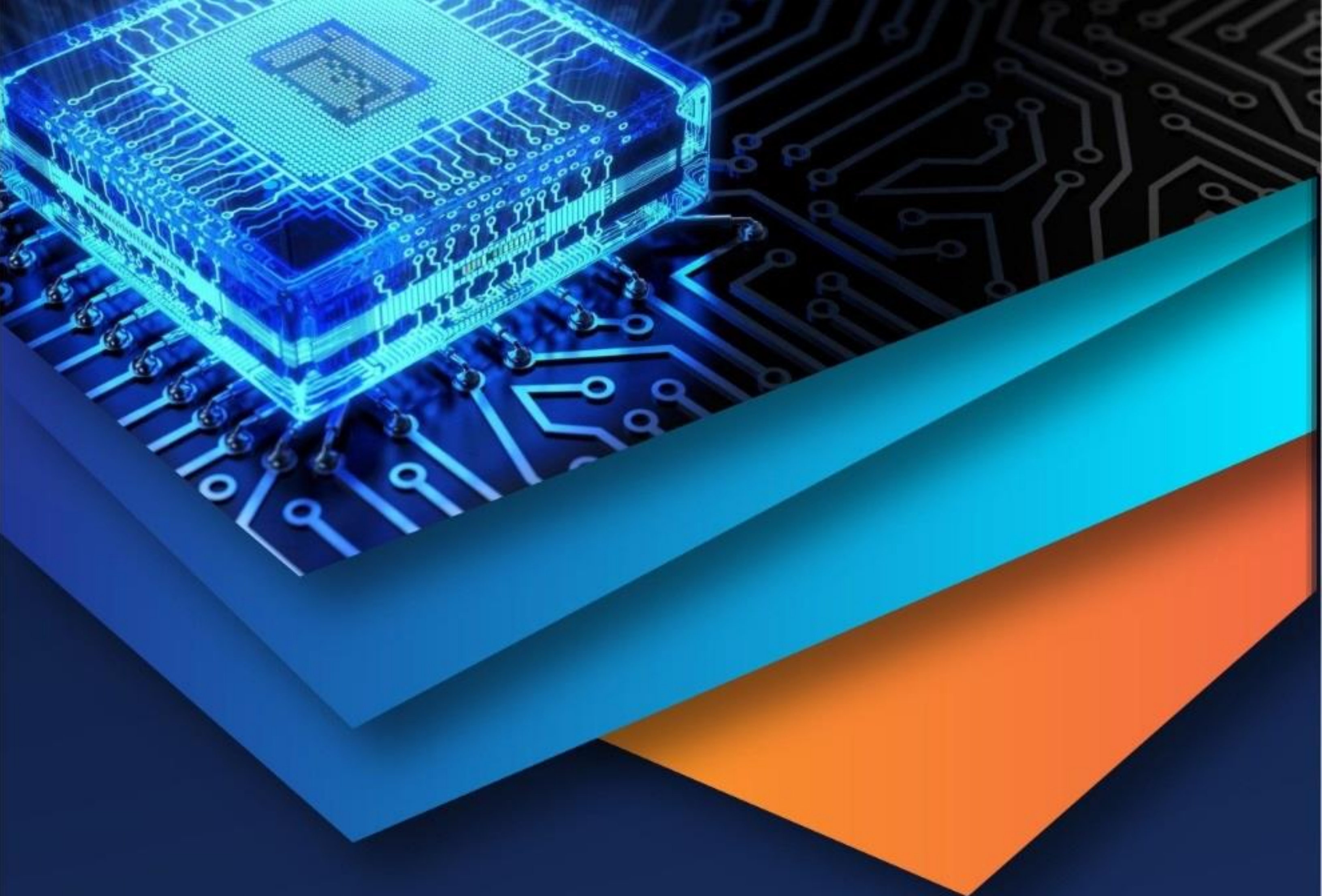

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