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Charge and Health Status Estimation of a Lithium Ion Battery in an Electric Vehicle using Cell Balancing IOT Modeling Techniques

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Abstract— In Present scenario Internal Combustion Engines [ICE] is overcome by Electric Vehicles [EV] due to advantages like reduction in carbon-di-oxide [CO_2] emission cost. Advancement in electric vehicles is extensively happening and one such concept is Battery management system [BMS] in Battery Electric vehicle. In electric vehicle battery, there are many types of batteries and from the literature survey Lithium Ion Battery are more suitable because it is advantageous in weight, cost, energy density and lots of aspects. Battery might be overcharged or going to undergo faults. Hence a reliable management system is required to control the Electric vehicle [EV]. In this paper two battery charge estimation models namely, open circuit voltage and Kalman filter has been considered. From the simulation results obtained it is found that data retrieval is difficult in open circuit voltage method can be achieved using Kalman filter and found out to be satisfactory.

Keywords* — *Battery Management System; Open Circuit Voltage; Kalman Filter; State of Charge.

1. Introduction

1.1 Battery Electric Vehicle

Battery Electric Vehicles, also called BEVs, are fully-electric vehicles with rechargeable batteries and no internal-combustion engine. In this paper Nissan leaf electric car has been considered since it has DC charging feature and monitors the charge status of the battery consistently and detailed analysis is as follows.

1.2 DC Fast Charging for Nissan Leaf

Battery Management System: In Battery electric vehicle Battery plays a crucial role. Battery could also be overcharged or it's going to undergo faults. Hence a correct management system is required to regulate the electrical vehicle [EV] and it's called Battery Management System [BMS]. To style Battery Management System several concepts, need to be taken care the most function of the Battery Management System is to stay any single cell of the battery.

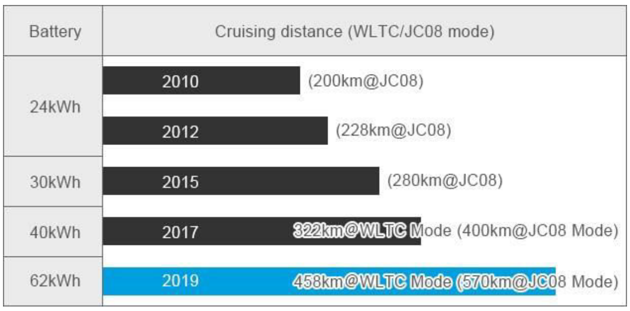

Fig. 1: Lithium ion battery importance in Nissan Leaf Electric car

Charge status has got to be determined properly. If it's not determined and if the battery is overcharged then lifetime of battery may reduce. Hence to work out state of charge algorithms are developed. Among the algorithms, a Comparative charge status analysis during a Battery Electric Vehicle using Model based Method Technique and Book keeping Method is administered with suitable circuit model and simulation results are tabulated for an equivalent.

From fig 1 importance of lithium ion battery in electric car is shown. In May 2020 recent development says 62kwh battery with 80% charge can be achieved in 45 min and it can reach up to 680km [1][6].

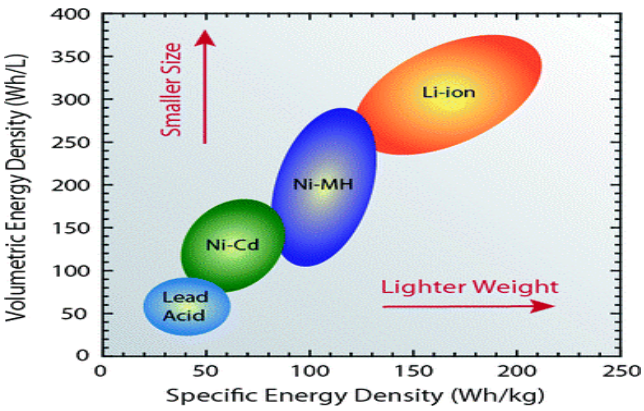

Fig.2: Characteristics of a Li-ion Battery

Section I gives detailed Introduction. Section II describes the description of state of charge. Section III describes the Methodology and Results. Section IV describes Conclusion and future Scope and Section V gives the References.

Open Circuit Voltage: In this method RC model has been built and simulated in Scilab. Simulation Results are compared with experimental results [7] and it is found that it is same and it is mapped with experimental results.

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2. Description of State of Charge

State of Charge: The units of SoC are 0% = empty; 100% = full. An alternative sort of an equivalent measure is the at the depth of discharge (DoD), the inverse of SoC (100%=empty;0%=full).Fig2.1indicates the block diagram representation of various algorithms used to calculate State of charge.

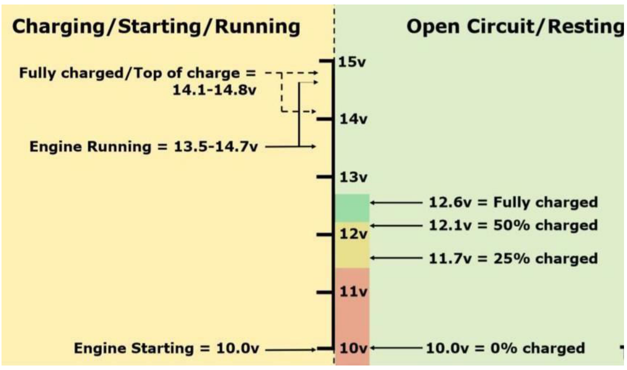

Fig. 2: State of charge calculation in an electric car

3. Methodology and Results

Comparative charge status analysis in a Battery Electric Vehicle using Model based Method has been carried out with suitable algorithms and simulation results. Among various algorithms used to calculate state of charge, detail analysis of Kalman filter and Open Circuit Voltage is explained below.

Table 1: Simulation result for a Nissan leaf electric car lithium ion battery identified RC model

State of Charge	12V Battery	Voltage per Cell
100%	12.7V	2.12V
95%	12.6 V	2.10V
90%	12.5 V	2.08V
80%	12.4V	2.06V
70%	12.3V	2.05V
60%	12.2V	2.03V
50%	12.05V	2.00V
40%	11.90V	1.98V
30%	11.75V	1.95V
20%	11.55V	1.92V
10%	11.30V	1.88V
Below 10% Dead	10.5V	1.75V

3.1 Open Circuit Voltage Method

Open Circuit Voltage (OCV) influence on the accuracy of Battery State of Charge (SOC) estimation. From the simulation model, consider RC network in addition with voltage source. State of charge is measured at output [5]. Voltage is measured at terminal 2 and total resistance is measured at terminal 1. Voltage and Resistance of the RC Circuit model has been developed using Scilab and has been indicated in fig 3.1. Open circuit voltage, Voc, internal resistances during discharging, Rdis, and charging, Rcha, are involved. The dependent variables considered for state of charge estimation includes, Open circuit voltage (Voc), Internal Resistance during discharge -Rdis

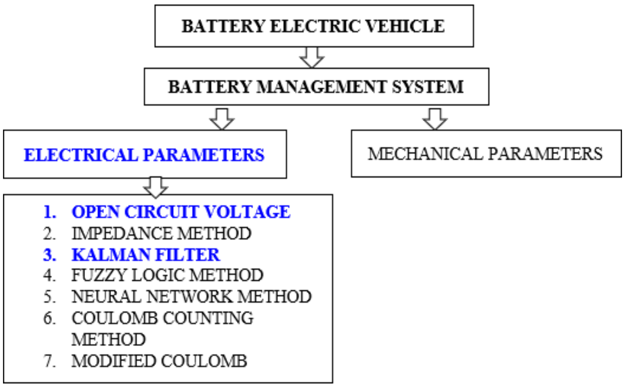

Fig. 3: Block diagram of State of charge calculation in an electric car

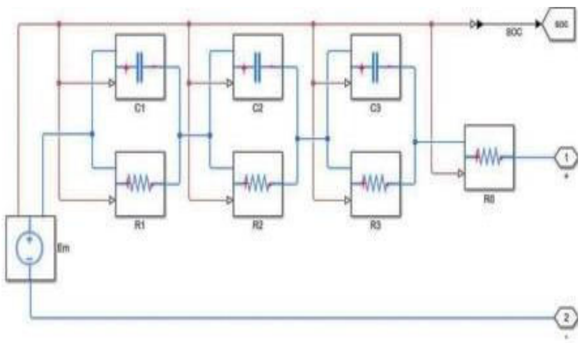

Fig.4: RC Circuit model of Open Circuit Voltage

The battery current and output voltage can be calculated by,

$$V \quad - V.$$

$$SOC = SOC_{ini} - \int_0^t \frac{I}{Q_b} d\tau$$

$$V_b = \frac{I_{ele,m}}{I}$$

Here, SOCini is the initial value of SOC, and Qb considered as the storage capacity of the battery. From the developed RC circuit model and simulation has been carried out and results have been compared with existing paper [6] and mapped all parameters and it is shown in figure.

3.2 Li-Ion Battery Modeling using Kalman Filter

To improve the model reliability, unlike the general equivalent the venin model, extra RC branch is added as shown in figure 5. These blocks shown in the figure were created in Simulink Simscape language to identify the

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components as text files. The texts include complete parameterization, physical connections, and equations represented as a couple of causal implicit differential algebraic equations. However the initial value cannot be stored and hence data retrieval is found out to be difficult when state of charge has to be calculated.

From Table 1 Simulation result for a Nissan leaf electric car lithiumion battery identified RC model is compared for a 12V battery. It is found that Nissan leaf electric car has used Level 2 charging and experimental and simulation results are same and it is validated.

3.3 Kalman Filter Method

This method is complex but data can be stored and data retrieval is also possible but has few errors like Battery model and parameter identification of Kalman filter. Consequently, the renewable energy technologies have gained more attention and derived the utilization of more electric vehicles. Lithium- ion batteries are becoming popular in both renewable energy systems and electric vehicles because of their high power and energy density. Therefore, accurate battery models are vital to the planning and simulation of hybrid/electric vehicle propulsion systems. Modelling and batteries are a toilsome task due to their complex electrochemical structure and nonlinear characteristics [3]. Accurate real- time SOC estimation reporting to drivers is additionally difficult. This paper tackles these challenges using extended Kalman filter algorithm and a two-RC block equivalent circuit (figure 5). This battery equivalent circuit model **is** meant in Matlab Simulink using the Simscape Language. Then, an algorithm with the EKF approach is developed to reinforce the SOC estimation has been obtained as a result from experimental work as explained in [1].

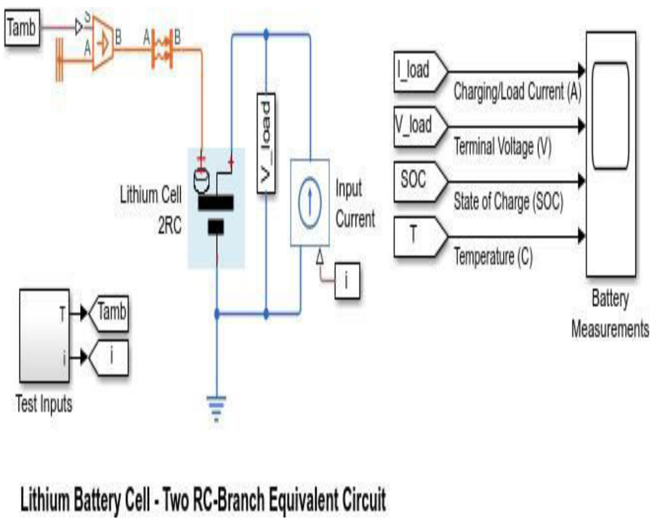

Fig. 5: Two RC Branch Equivalent circuit model

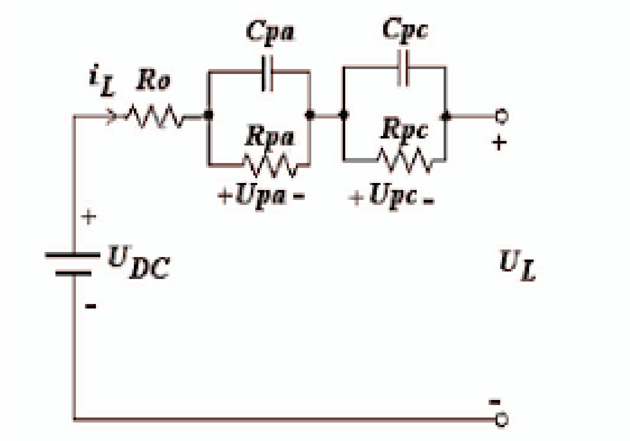

Fig. 6: RC TheveninModel

The soc output voltage is explained in figure 6.

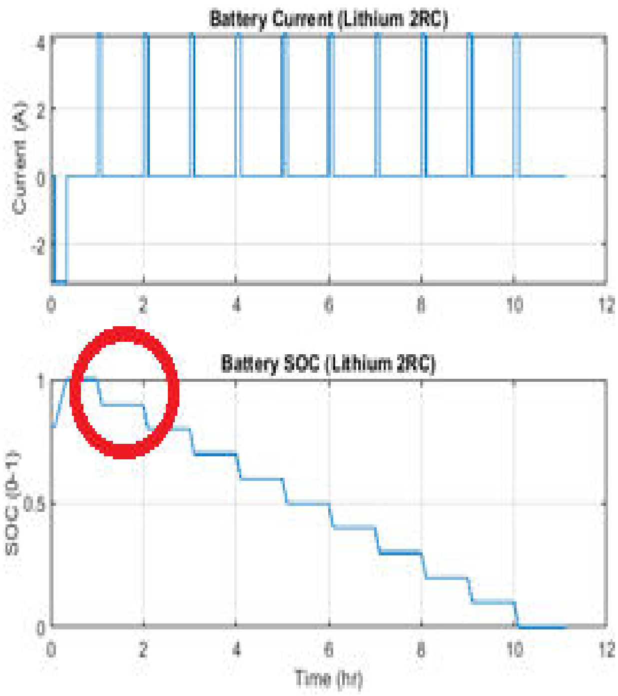

Fig.6: RC TheveninModel

The state of charge estimation using Kalman filter method and its equivalent battery model has been shown fig 3.6. The extended Kalman filter is for predicting the future state of a system based on the previous ones. It consists of two equations. The expressions of matrices and vectors are the same as [1]. Xk is the system state matrix and one of the matrix values represents SoC. Therefore, xk captures the system dynamics. Input of the system is uk which is a control variable matrix and known or can be measured.

$$xk+1 = A \times xk + B \times uk + wk$$
$$yk = C \times xk + D \times uk + vk$$

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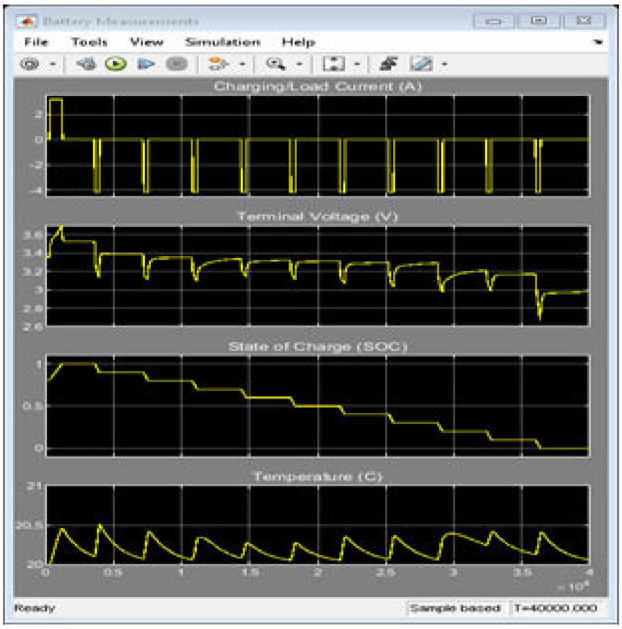

Fig. 7: Theoretical results of Kalman filter

Figure 3.7 indicate the Compare the simulation results with research paper results and found out to be same [7]. Maximum SOC error is found out to be 1% from the simulation results as per fig 3.7.1 and it proved to be successful implementation of Kalman filter technique.

4. Importance of IoT in Electric Vehicle

A system with IoT can used to streamline the working of Electronic Vehicle charging and looks the impacts. IoT will improve the city planning and makes the city life easy. It is a self organizing wireless linkage of devices for the interconnection of objects. Deployment of energy storage devices in the distribution grid will expedite this process and increase system performance [4]. Bulk energy storage has been used for decades in the utility grid and now the integration of renewable is creating a need for more distributed storage.

Fig. 8: Importance of IOT

Delivery operations in traffic and pollution: Urban logistics and delivery services are one of the main issues troubling every big and small city in the country. Hence, online delivery services can reduce the capacity of the roads by 30 percent in future due to the increase in online delivery companies and the rise in demand by the consumers. The movements of these vehicles in rush hours, which are already congested by private transport, have a high impact on congestion and urban environmental quality.

Methodology: Case a) Node-Red - The algorithm is implemented in the Node-Red environment. Node-Red is a graphical means for connecting various hardware appliances, Application Programming Interfaces and real-time facilities to equip the Internet of Things. The lightweight runtime is built on Node.js, taking maximum benefit of its event-driven, nonblocking model [15].

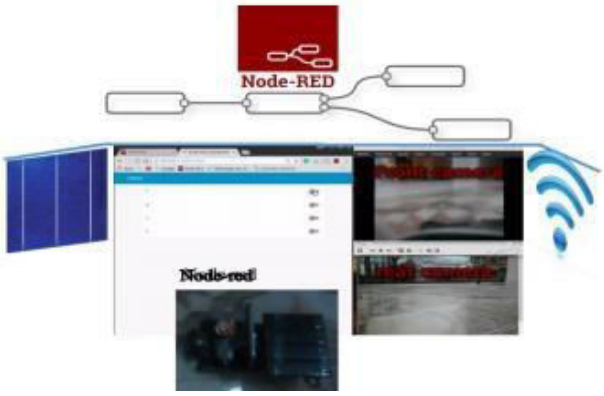

Fig. 9: Importance of Node-Red in Electric Vehicle

Case b) MQTT (Message Queuing Telemetry Transport) **-** is a messaging-based communication protocol that affords the lightweight network with an easy means to deliver data. The protocol is used for machine-to-machine.

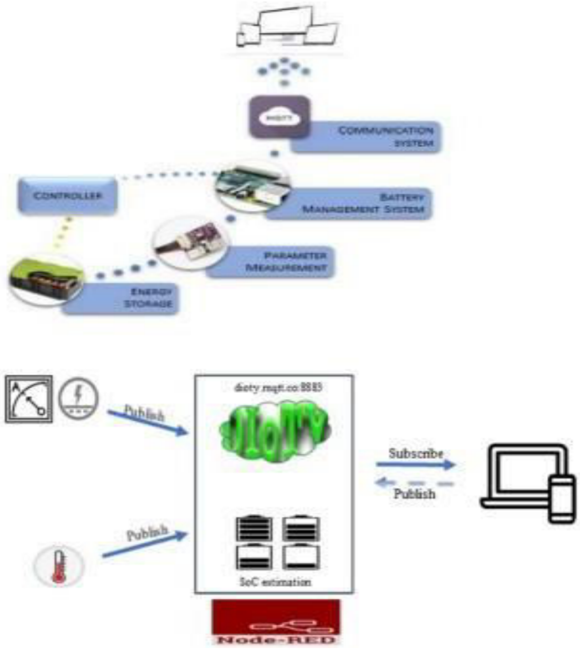

Fig. 10: BMS hardware prototype at the block level

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The battery packs electrical parameters are measured using Hall Effect voltage sensors and after amplification, In [6] the paper explains the problem of charging a set of electric vehicles from photovoltaic power and identified by "Maximum Variable Resource Allocation Problem" (MVRAP). In [7] & [8] an energy management algorithm that organize the optimal charging and discharging times of an electric vehicle battery has been introduced. In[10],they introduced charging rate compression (CRC) algorithm which decreases the problem-solving complexity in EVs. Implementation Electric vehicles are going to be the future transport.

Methodology: Data collection State of Charge (SoC) of a battery shows the remaining battery capacity and this value is expressed in percentage value (rangingfrom0to100)[9] [10.SoC = Initial SoC − (current flowing (1) through battery/Nominal capacity of battery) The magnitude of current is constantly positive for the discharging process and it will be negative for charging process. 2) SOC calculation: Coulomb counting method which means counting the charge flowing into (or) out of the battery.

5. Conclusion

For monitoring the charge status suitable algorithms has to be implemented. In this paper, optimization models for maximizing the trade revenue for aggregator of EVs is presented aimed at facilitating smart charging to reduce the impact of increased penetration of EVs on grid. Internet of Things (IoT) based smartgrid is introduced to monitor status of batteries in smartgrid systems. The car user can easily check the health of his car battery and he can easily decide whether to take power from grid or to sell power to grid.

6. Future Scope

Kalman filter is applicable only for nonlinear systems and it is hard to implement in linear system as there is no feedback compensation mechanism. Hence to overcome this issue of Kalman filter, other suitable algorithm like coulomb counting, fuzzy logic, modified coulomb counting method may be considered for reliable operation of a battery in a battery electric vehicle. In this paper we have proposed a model of electric vehicle charging station with the help of IOT. In addition to the vehicles charged, it has to be updated automatically using IOT. Optimal solution will be attained when a charging station decides which arriving EVs to admit and schedule according to its charge capacity. For this, the uncertainty factor i.e., the effect of solar energy prediction has to be determined. In order to avoid the charging time, the parking area itself can be utilized as charging station. Without making any contact with the vehicle, the charging can be done using mutual inductance of the coil which is the major advantage of this proposed system.

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