Real Time Estimation and Monitoring of Battery Parameters

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Abstract- In this paper real time monitoring and state of charge(SOC) estimation of Li-ion battery parameters is done with the help of different techniques such as internal resistance method, open-circuit voltage method, coulombs counting method, modified coulombs counting method. With the advancement in technology and continuous surge in amount of Carbon-dioxide in the environment by the use of fossil fuel, many industrial applications like automobile are now relying on chemical Battery as their foremost energy sources. Our purpose is to interface voltage detecting sensor in circuit which is being operated by battery through voltage divider approach with the microprocessor Raspberry pi 3 and for sensing voltage part uno board is used which will transmit data serially to the Raspberry Pi which will control and monitor the ADC device.. As lithium-ion based batteries exhibit splendid electrical attribute like high energy density, steep voltage but they are highly prone to deeply discharging issues also. So to ensure reliable and efficient use of battery a ceaseless observation on its parameter is important because these parameters describe lasting capacity and performance of battery. Lithium- Ion cells work well when cells operate within limited voltage and temperature. Otherwise, damage will occur to the cells and will be irreversible. Methods adopted in this paper can be used for the application such as grid energy storage, Electrical vehicles, and renewable energy storage for later use. This paper specifically focuses on the comparison of different batteries and selecting one with better parameters.

Keywords: Li-ion Battery, State-of-Charge, Battery, Discharging Current.

1.INTRODUCTION

In today's growing automobile market, the battery management system has become a very essential part. As we all are moving towards more production of electronic vehicles and more digitalization, the selection of the right battery for the right application has also become an essential part. Sampling Voltage of the battery, sampling current of the battery, and cell balancing determine SoC [1]. The key methods available for SoC estimation are Current Counting Method, Internal Resistance Method, and Open Circuit Voltage [2]. The battery characteristics and the comparison of the batteries shown through equivalent circuit model and simulated it in MATLAB/Simulink. concluded that Lead-acid has the largest energy storage system[3].But charging and discharging data (discharge parameters) analyzed in the MATLAB/Simulink [4] shows that Li-ion batteries (3.7V,1400mAh) are better than Lead-acid batteries(12V,100Ah) except the internal resistance method .We can analyze the behavior of the Li-ion batteries through ECM [5]. Li-ion and Lead-acid are widely used in the EV/HEV industry. Their Frequent discharge operations can harm battery life, to overcome that Hybrid Energy Storage System (HESS) is used. This combines Super capacitors and batteries the identification of different parameters require different signal patterns to ensure high accuracy, rendering trade-offs in the multi-parameter identification of battery HESS for condition monitoring and maximum power estimation [6]. The charging and discharging cycles of all battery types [7], shows Li-ion battery is 500-3000, better than the rest also the risk of damaging of batteries when they are over-charged or deeply discharged. The algorithms are implemented on a hardware platform based PIC18F MCU. The overview of SOC estimation methods like the Coulomb counting method, Voltage method, and Kalman filter is given[8]. To overcome the demerits of the Coulomb counting method and Kalman filter enhanced Coulomb counting and extended Kalman filter algorithm and the selection of method choices and SOC algorithms for different battery types is also proposed . As per recent research on this topic, Li-ion Batteries exhibit complex non-linear behavior and to overcome that deep neural networks are built [9]. For the EV/HEV industry, for battery management system applications efficient hardware testbed is designed [10]. Co-estimation is discussed in this paper; it is (hardware testbed results) then compared with the results of Simulink. To estimate the battery SOC accurately, the Co-estimation algorithm is implemented. The technique used in SOC estimation is an observer based on the simplicity of implementation purposes

The SOC parameter enable us to rate the potential energy of the battery. Manifesto to be used for SOC measurement model for energy storage is a 7800mAh and 15v module comprising of 4 Li-ion cells with 80% Depth of discharge (DOD). Assessment platform includes hardware system comprising of MCU and needed interfaces and peripherals, embedded software for the implementation of SOC algorithm, and data displaying software. Assessment manifesto regularly measures the voltage and module current with the help of suitable ADCs and sensors and will execute the SOC estimation algorithm in real time. This algorithm will give output based on measured voltage and current values and sometimes also on the temperature sensor statistics. Algorithm output will be then sent to the user interface for dynamic display. [11]

For monitoring part of voltage and current we need microprocessor which supports ADC conversion (Analog to digital) and for this part we are using raspberry pi, although it does not have on chip ADC converter but it support serial communication and by using it, we can get data from Arduinonano or uno board which has on chip ADC conversion unit.

There are several methods for finding out SoC of battery including Coulomb's counting method, electric Circuit model, internal resistance method, Kalman's filter method [12].Need of clean fuel is increasing rather than thermal power or the power generated by petroleum product. Dependency on unconventional energy sources like wind, Solar; tidal and nuclear energy is rising day by day. But the unconventional energy sources cannot provide sufficient energy as it has time and weather boundaries in harnessing it. To eliminate these factors Battery storage system is needed. [13]. . this paper focuses only on the Photovoltaic system and not on any other applications.

2. DEFINITION OF SOC

2.1 State of Charge

SOC monitoring helps to determine performance of vehicle Battery like its efficiency, feasibility, accuracy under different ambience condition. These parameters estimation prevent battery from drainage, surpass lifespan of battery. SOC is the temporary capability of Battery. Generally, it is defined as ratio of current capacity Qt to the rated capacity Qr. Rated capacity is predefined by manufacturers.

$$SOC_t = Q_t/Q_r$$

Where Q_t = Battery Capacity at time 't'

Q_r = predefined rated capacity of Battery.

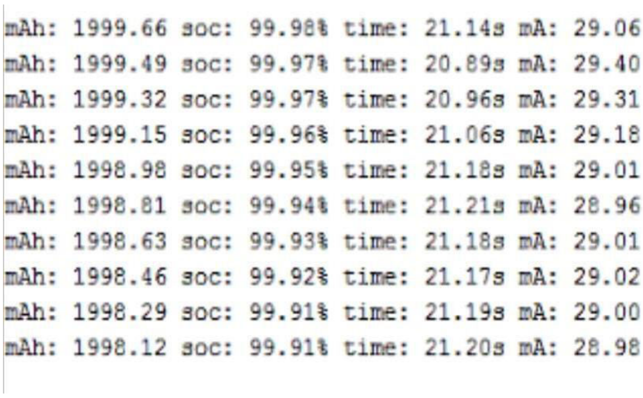
3.METHODOLOGY FOR SOC ESTIMATION

3.1 Coulomb counting method:

Determining state of charge of any battery involves complexities which includes what kind of load is connected to the battery, type of battery, environment in which battery is being used. Ampere hour counting method commonly called as coulomb counting method estimated the state of charge of battery by integrating the current with respect to time. This method requires current sensor (ACS712 5A in our case) which reads the value of current at continuous definite time interval and integrate over the time period of usage to calculate the State of Charge.

$SOC = SOC(t0) \pm (1/Crated) \int Ibdt$

Here SOC(*t*0) is the initial SOC which is 1 in case battery is fully charged, *C*rated is the rated capacity of the battery which is written on the battery by the manufacturer, *I*b is the current of the battery. Addition (+) operation is done in case of charging and subtraction(–) operation is done in case of discharging.



```
mAh: 1999.66 soc: 99.98% time: 21.14s mA: 29.06
mAh: 1999.49 soc: 99.97% time: 20.89s mA: 29.40
mAh: 1999.32 soc: 99.97% time: 20.96s mA: 29.31
mAh: 1999.15 soc: 99.96% time: 21.06s mA: 29.18
mAh: 1998.98 soc: 99.95% time: 21.18s mA: 29.01
mAh: 1998.81 soc: 99.94% time: 21.21s mA: 28.96
mAh: 1998.63 soc: 99.93% time: 21.18s mA: 29.01
mAh: 1998.46 soc: 99.92% time: 21.17s mA: 29.02
mAh: 1998.29 soc: 99.91% time: 21.19s mA: 29.00
mAh: 1998.12 soc: 99.91% time: 21.20s mA: 28.98
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Result Analysis.

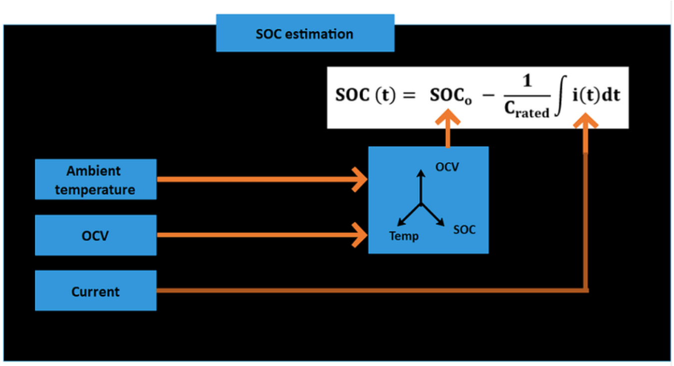


Fig.1.Block Diagram

This method calculates the capacity of battery left by simply adding or subtracting the charge transferred with respect to rated current capacity in or out from the battery with the initial State of charge. The greatest advantage of State of charge estimation with Coulomb counting method is that it can estimate SOC in real time at the same time it has disadvantage that it is not accurate due to unknown initial value in SOC ,error which accumulate during integration of current and due to the current consumed in lossreaction.

3.2 Open circuit voltage method:

In order to find State of charge of battery to predict the remaining energy stored in the battery and what duration it can function for particular load, open current voltage method is another technique, here a battery is discharged in controlled environment that is temperature, fixed load and voltage across battery is measured and graph of Voltage vs SOC is made.

$U_{ocv} = U + IR$

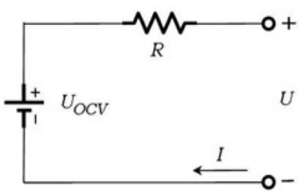
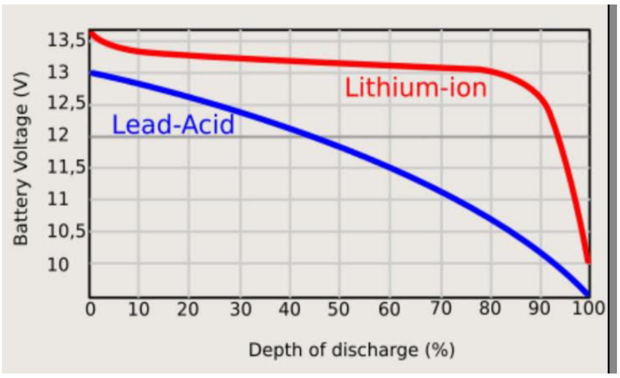
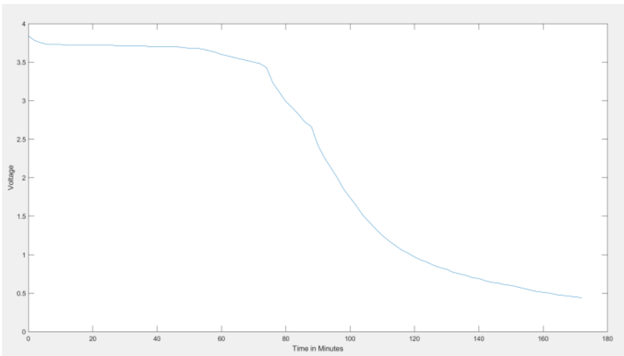


Fig.2

Where U_{ocv} is open circuit voltage of battery, U is the terminal voltage , I is the battery current and R is the resistance. Firstly in controlled environment OCV curve and relationship with SOC of the bettery is found. Once OCV-SOC curve is made in controlled environment, standard data is kept as reference and for battery with unknown SOC, by just finding out U_{ocv} of the battery the state of charge can be estimated by the standard graph which was made that is OCV vs SOC. This method of SOC estimation is very succesfull in estimating the SOC of Led acid battery but fails terribly in case of lithium ion battery and the lead acid battery the discharge curve of the battery is in linear fashion but in case of lithium ion battery the discharge curve is ot linear thus graph between U_{ocv} and SOC can not be plotted.



Due to non linearity in the dischrge curve of lithium ion battery it is not possibble to to estimate SOC using OCV method. Also this method of estimation is offline that is we can not estimate real time SOC of any battery being used.



Discharge curve for battery used

3.3 Impedance Measurement-Based Estimation

An Impedance measurement system is obtained from sinusoidal excitation at different excitation frequencies in which both voltage and current are recorded and their complex quotient is computed as the cell impedance.The impedance spectroscopy of a battery cell can be approximated with two circles on the Nyquist plane.In recent years, methods based on electrochemical impedance spectroscopy (EIS) have found application for accurate analysis of occurring electrochemical processes and diagnosis of LiBs, as the cell chemistry has a strong effect on the curve of the impedance spectrum. An experimental lifetime model that can predict the internal resistance increase at various temperature and SOC levels was developed.

Battery Model is established using a simple ECM whose parameters are determined by the impedance measured data,presented as Nyquist plot. The measured impedance(at frequencies between 100mHz and 100khz) is decomposed with the help of a phase angle in real part(x axis) and an imaginary part(y axis),which are plotted against each other. Once the parameters of the model are known, the SOC can be estimated.

This estimation method is suitable only for identical charging conditions. So, it is not suitable for EVs that could be charged inconsistently with different current. Due to high temperature influence, this method can only be made in high frequency range.

3.4 Electrical Circuit Model-Based Estimation (ECM)

There are three different ECMs of a LiB widely adopted because of their excellent dynamic performance. The first is known as the Thevenin model and is a first-order RC model that consists of a nonlinear voltage source VOCV as a function of SoC, a capacitor to model polarization capacitance and diffusion effects within the battery, a diffusion resistance, an internal resistance, a charge/discharge current , and a battery terminal voltage. The second model adds a capacitor in series with the voltage source VOCV to characterize the capacity of store charge of the battery and to describe the changes in the OCV over time. This review calls this second model the first-order ECM. Similarly, the third one is obtained by adding in series an RC network (a parallel Resistance/Capacitance) to simulate concentration and electrochemical polarizations.

The model parameters can only be parameterized accurately for new batteries. The model parameters can only be parameterized accurately for new batteries in the laboratory, but this approach is costly, time consuming, and commonly not practical to obtain all parameters. It does not fully describe the electrochemical processes of the battery and can´t consider the inaccuracies. The number of circuit elements considered implies a trade-off between accuracy and computational complexity.

4. RESULT ANALYSIS

```
13:18:06.792 -> Current is  =  12.72 mA
13:18:08.766 -> Voltage of Battery is  =  32.98
13:18:08.800 -> Current is  =  11.70 mA
13:18:10.766 -> Voltage of Battery is  =  33.11
13:18:10.800 -> Current is  =  11.74 mA
13:18:12.774 -> Voltage of Battery is  =  62.62
13:18:12.809 -> Current is  =  22.20 mA
13:18:14.776 -> Voltage of Battery is  =  30.60
13:18:14.811 -> Current is  =  10.85 mA
13:18:16.782 -> Voltage of Battery is  =  38.75
13:18:16.816 -> Current is  =  13.74 mA
13:18:18.793 -> Voltage of Battery is  =  38.81
13:18:18.828 -> Current is  =  13.76 mA
13:18:20.794 -> Voltage of Battery is  =  27.34
13:18:20.828 -> Current is  =  9.70 mA
13:18:22.796 -> Voltage of Battery is  =  30.41
13:18:22.831 -> Current is  =  10.79 mA
13:18:24.800 -> Voltage of Battery is  =  25.28
13:18:24.834 -> Current is  =  8.96 mA
13:18:26.807 -> Voltage of Battery is  =  25.09
13:18:26.842 -> Current is  =  8.90 mA
13:18:28.813 -> Voltage of Battery is  =  25.40
13:18:28.848 -> Current is  =  9.01 mA
13:18:30.814 -> Voltage of Battery is  =  25.03
13:18:30.848 -> Current is  =  8.87 mA
13:18:32.815 -> Voltage of Battery is  =  25.03
13:18:32.850 -> Current is  =  8.87 mA
13:18:34.820 -> Voltage of Battery is  =  25.59
13:18:34.854 -> Current is  =  9.07 mA
13:18:36.822 -> Voltage of Battery is  =  25.15
13:18:36.856 -> Current is  =  8.92 mA
13:18:38.827 -> Voltage of Battery is  =  24.71
13:18:38.827 -> Current is  =  8.76 mA
13:18:40.833 -> Voltage of Battery is  =  25.40
13:18:40.833 -> Current is  =  9.01 mA
13:18:42.833 -> Voltage of Battery is  =  24.78
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Voltage and Current Experimental Result

Vo estimation of Battery can be done using internal Resistance method and Coulombs Counting Method has abnormal deviation in its result. So modified Coulombs Counting Method will be adopted for the same.

5. CONCLUSION

In this paper we have successfully monitored voltage and current in the circuit in real time and also implemented coulomb counting method and Open Circuit voltage method for estimation of state of charge. We verified the inefficiency of open circuit voltage method in case of li ion batteries and also saw problem in estimation of SOC initial in coulomb counting method.

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