International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Estimation of Soc and Soh Using Mixed Neural Network and Coulomb Counting Algorithm

Abhash Ganeshan, R.Shanmughasundaram

Abstract: ***The Lithium ion battery is widely used in most of the battery powered electronics and automotive products like mobile phones, laptop, wall watch, calculator and other. The Battery provides power to devices with the facility of movability. On the other hand, it also provides power backup to devices. The Battery State of charge (SOC) and state of health (SOH) are the key terms by which the available charge and its life span can be estimated. In this paper, SOC is estimated using a back-propagation neural network with 3 inputs namely, voltage, current, and temperature of the battery. Coulomb counting method is used to find the new or remaining capacity of the battery which will notify about its SOH. The whole setup is implemented in PIC16F877A with the voltage, current and temperature sensors.***

Keywords: Back-propagation, SOC, SOH, PIC16f877A, Coulomb counting.

I. INTRODUCTION

The lithium-ion battery is one of the most used batteries for electronic gadgets like laptop, iPod, mobile phone, watch, and calculator. As compared to other batteries they do not have a memory effect, lighter weight and loss percentage is very less of around 5% of charge per month. It can be used for a long time span and handles 100-times recharge and discharge cycle without losing much of its capacity [8].

Lithium-ion battery's electrode is made up of light weight lithium and carbon. They can store lot of energy in atomic bonds as lithium is a highly reactive element [2]. For better performance and stability of battery life, different parameters like temperature, charging/discharging current and voltage should be taken into consideration. There are different methods by which SOC of battery can be estimated such as terminal voltage method which is based on the potential difference and electromotive force of battery (EMF). The SOC of the battery is approximately proportional to the EMF of battery [5]. In this method, error is accumulated at the end of discharging cycle. The SOC is also affected by the temperature which is not considered in the terminal voltage method [7].

Manuscript published on 30 August 2019.
***Correspondence Author(s)**
Abhash Ganeshan, Department of Electrical and Electronics Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, India.
R.Shanmughasundaram, Assistant prof.(Sr.Gr) ,Department of Electrical and Electronics Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, India

This method works fine in ideal condition with a proper battery management system, as its accuracy is influenced from different external and internal parameters [6]. The SOC is also estimated using Kalman filter.However it requires a precise battery model with high computational and complexity to achieve high accuracy [4]. The coulomb counting method is an open-loop method, having a demerit that SOC cannot be determined without an initial value. It measures the discharging current of the battery and integrates over the discharging time period and calculates the SOC. The Capacity of the battery is also needed in this method. There are several factors by which this method is affected like initial SOC, temperature, battery history, discharging/charging current and life cycle [5].

The Neural network is also used to estimate the SOC of battery for high accuracy and precision. However, the system is complex and the learning of the network depends on architecture and learning rate. When the learning rate is low, the network learns slowly and accuracy is increased.

This paper proposes a technique for estimating the SOC and SOH of the battery using a mixed configuration of a neural network with coulomb counting method. The Neural network estimates the SOC while coulomb counting calculates the SOH of the battery.

II. BACK PROPAGATION NETWORK

A three-layer feed forward back propagation neural network (BPNN) is used for the estimation of SOC. The first layer or the input layer consists of 3 inputs namely voltage, current and temperature of battery which are taken from the respective sensors.

The second layer is a hidden layer. The weights are updated as per cost function. Third layer is output layer where activation function is implemented to obtain the desired signals.

Here, the learning of data is done on supervised learning where 80% of data is used to train and remaining 20% to test the accuracy of the network. The overall flow of BPNN is shown in figure 1 and explained as follows:

Step1. **Initialization of the network:-** The different parameters of BPNN like random weights, network size, and functions of hidden and output layers are initialized.

Step2. **Forward propagation**:- The network flows in forward manner in which Input layer's output will be the input of hidden layer. Similarly, the output of the hidden layer will be the input of the output layer.

Step 3. **Error calculation**:- The error between the desired and the actual value is calculated and it is propagated in the reverse direction. The calculation of error starts from the output layer, then goes to hidden layer and finally reaches the input layer.

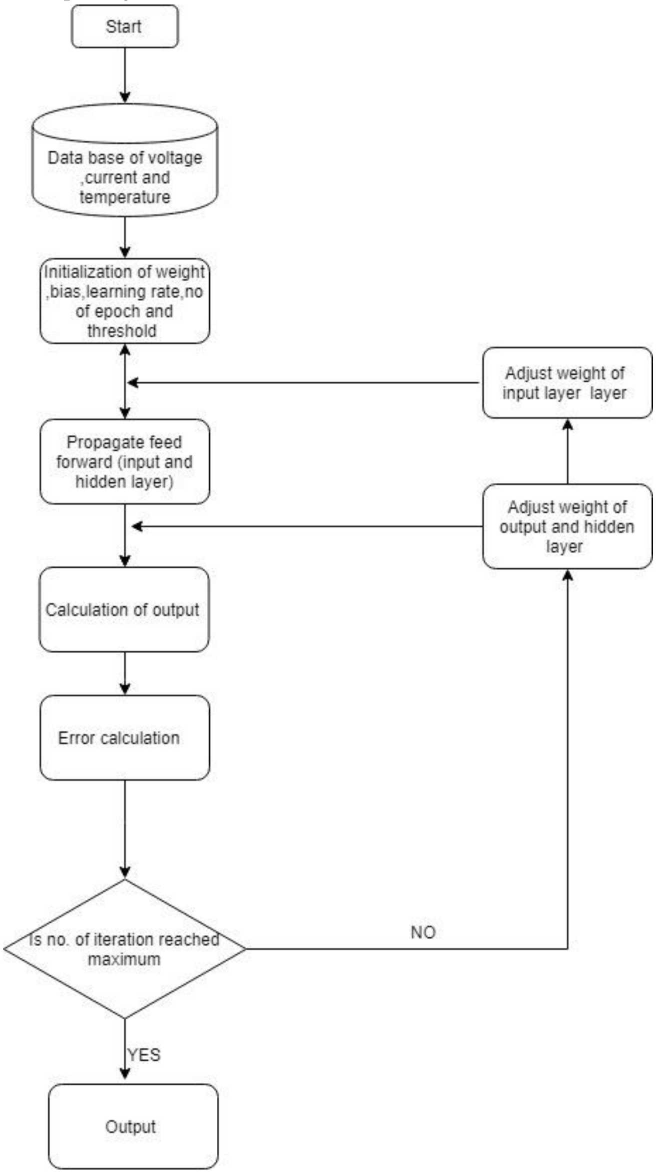

Figure 1. Flow Of Back–Propagation Network

Step 4. **Training of network**:- Learning of BPNN is done in supervised learning method where 80% of data from the experiment is used to train the network.

Step 5. **Prediction**:- The output of the BPNN is tested by the remaining 20% of data from the experiment.

To calculate the error of BPNN, cost function is designed as shown in equation 1. Cost function will check the difference between true and obtained output.

$$Cost\ Function = \sum (Obtained\ output - True\ output)^2 \quad (1)$$

III. COULOMB COUNTING ALGORITHM

Coulomb counting is a widely known method to estimate the SOC of battery. It works by the integration of active flow of current over a time to drive the total sum of energy entering or leaving the battery packet. In this paper, Coulomb counting is used to determine the capacity of battery.

$$soc(t) = soc(t_0) \pm \frac{1}{C}\int_{t_0}^{t} I\,dt \quad (2)$$

In equation no. 2, SOC (t) is the state of charge of the battery at time t, SOC (t_0) is the state of charge at time t_0 or initial state of charge of the battery, I is the charging or discharging current integrated over time. C is the rated capacity of battery measured in ampere-hours.

IV. EXPERIMENT

Experiment 4.1

A battery with a capacity of 4400 mAh is connected to a resistive load which draws a constant current of 1A until it is completely discharged. Then, it is charged with the same load. The voltage, current and temperature are sensed from the battery, sampled at a rate of 90.9 kHz and stored in the database as shown in table 1.

Experiment 4.2

In this setup, the battery is connected to different loads until it gets fully discharged. The voltage, current and temperature are sensed from the battery, sampled at a rate of 90.9 kHz and stored in the database.

Table 1. *Data base*

Current(A)	Voltage(V)	Time(s)	Temperature(°C)
1	3.866319	13182	25.1
1	3.865024	13193	24.9
1	3.864215	13204	24.9
1	3.863082	13215	25.8
1	3.861949	13286	25.8
1	3.860977	13287	25.8
1	3.860006	13288	25.8
1	3.859035	13289	25.8
1	3.858064	13290	25.8
1	3.856931	13291	25.8
1	3.85596	13292	25.6
1	3.854988	13293	25.6
1	3.854017	13294	25.4
1	3.852884	13295	24.9
1	3.852075	13296	24.9
1	3.85078	13297	24.8
1	3.849971	13298	24.8

V. METHODOLOGY FOR ESTIMATION OF SOC AND SOH

The data set obtained from the experiments are used to train the BPNN. The network is trained using Spyder integrated development environment (IDE) in Python 2.7. The SOC is estimated by the BPNN which has the input layer as voltage, current, and temperature.

Retrieval Number: J13080881019/19©BEIESP
DOI: 10.35940/ijitee.J1308.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

In the hidden layer, modified hyperbolic tangent function, linear proportional function and inverse linear proportional function are used for the input parameters respectively. In the output layer a modified sigmoidal function is used. The architecture of BPNN is shown in figure 2. After successful training of the network, it is implemented in PIC Microcontroller.

BPNN predicts SOC (t) and SOC (t0) and charging/discharging current is measured by the sensor. The new capacity of the battery is calculated using equation 2.The reduced SOH value is calculated by the equation no.3.

$$\frac{Rated\ capacity - New\ capacity}{Rated\ capacity} \times 100\ \% \ = SOH\ reduced \quad (3)$$

Here, the rated capacity is the actual capacity of the battery as specified by the manufacturer. The new capacity is determined by the Coulomb Counting method. At the time of calculation of reduced SOH, the battery conditions have to be ideal. These conditions are maintained using microcontroller and sensors.

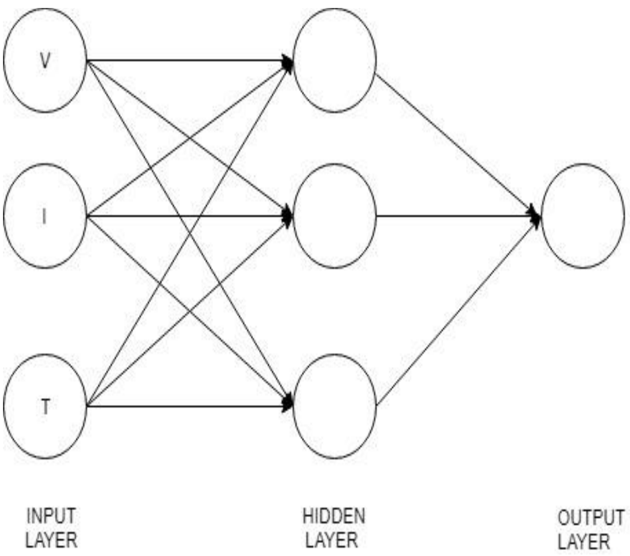

Figure 2. *Architecture of BPNN*

VI. IMPLEMENTATION OF THE BPNN AND COULOMB COUNTING ALGORITHM

The BPNN and coulomb counting algorithms are implemented in PIC16F877A microcontroller with sensors and LCD to display SOC and SOH as shown in figure 3. Three analog sensors and one digital sensor are used with PIC16F877A.The Analog sensors used are voltage sensor, current sensor, and temperature sensor. These sensors will provide input to the neural network and the digital sensor which is a push button results in hardware interruption for the calculation of SOH. The PIC16F877A has 10 bit analog to digital convertor (ADC) which will convert voltage, current and temperature signals to digital output.

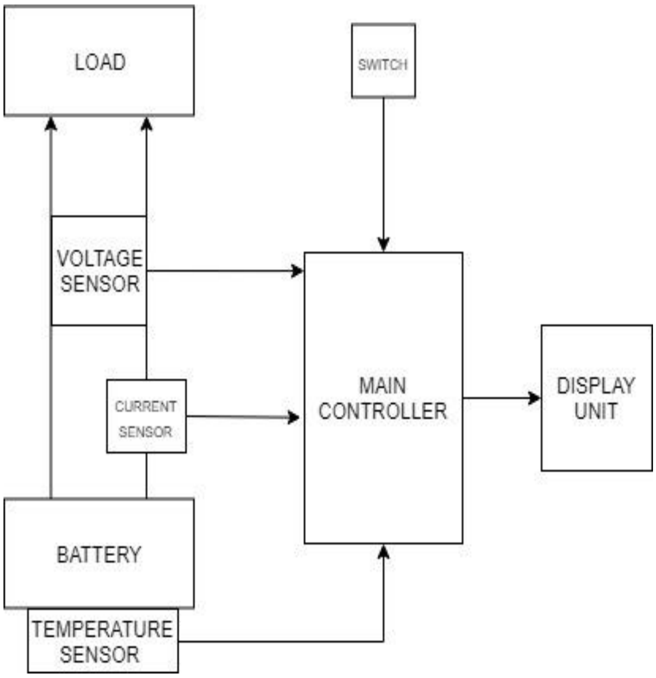

Figure 3. Block Diagram Of System

The reference voltage for ADC is set as 2 V. The voltage sensor is connected across load and the current sensor is in series with the load. The temperature sensor is directly connected to the body of the battery. Timer 0 is used with the Capture Compare and PWM module for the time calculations.The program starts with the calculation of SOC from the BPNN. The input to the neural network are voltage, current and temperature. The network estimates the SOC using these parameters. The whole program flow is shown in figure 4 and figure 5.

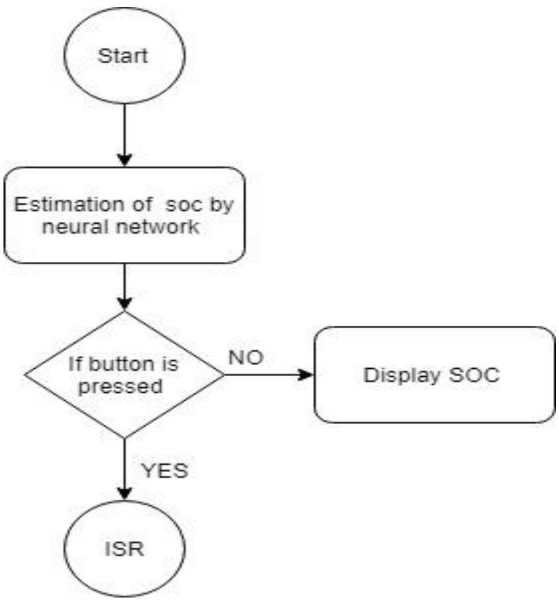

Figure 4. Flow of program for SOC calculation

Retrieval Number: J13080881019/19©BEIESP
DOI: 10.35940/ijitee.J1308.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

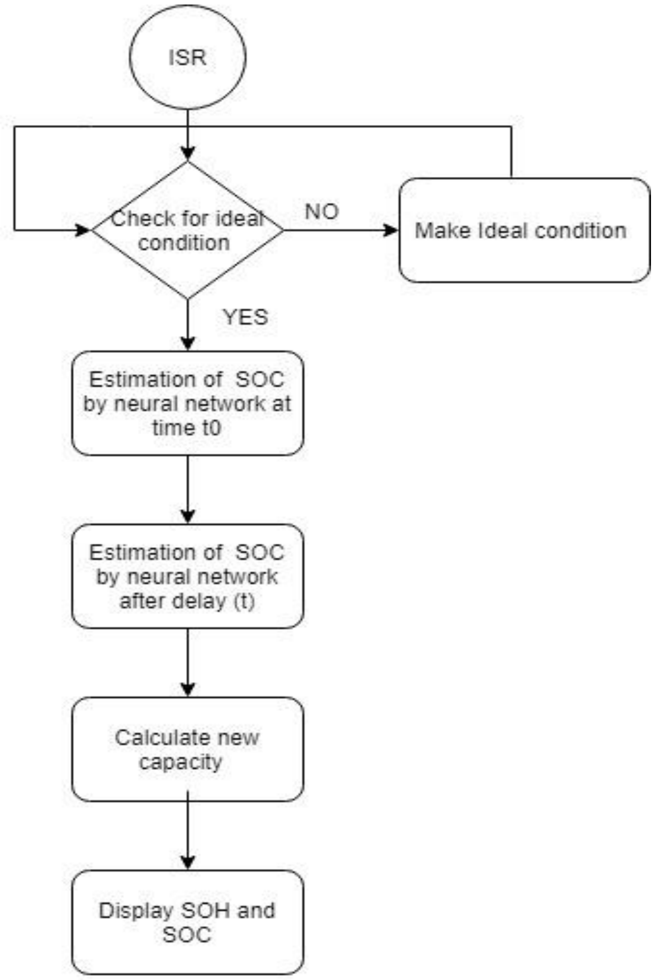

Figure 5. **Flow Of Program For SOH Calculation**

When the push button is pressed, program will go to the external interrupt mode. In the Interrupt Service Routine (ISR), the ideal condition of the battery is checked. If it is ideal, the SOC is calculated. Then, the program waits for pre-defined time and again it calculates the SOC. These two values of SOC at different instances of time is used by the Coulomb Counting method to calculate the new capacity which gives the SOH of the battery in equation no. 4. The SOH indicates about the change in the capacity of the battery.

$$SOH\ of\ battery = (100 - SOH\ reduced)\% \quad (4)$$

VII. RESULT

The SOC is computed from the neural network for 4.2 V battery of capacity 4400mAh. The data obtained from the experiments are used in python IDE to plot the graph of SOC. The voltage is shown in Y–axis and the SOC in the X-axis. The graph shows discharging cycle of battery where it is full charged with 100% of SOC at 4.2 V and 0% SOC from 2.8V to 3.1 V. When it crosses 3.2 V, there is a slight change in SOC. The change in SOC is observed during 3.4 V to 4.2 V, as shown in figure 6.

The new capacity of the battery measured from 100% to 84% of SOC shows that there is no significant reduction in SOH. As Li-ion battery can handle hundreds of charging/discharging cycles with very less loss, no loss in capacity was observed and hence the SOH of the battery is 100%.

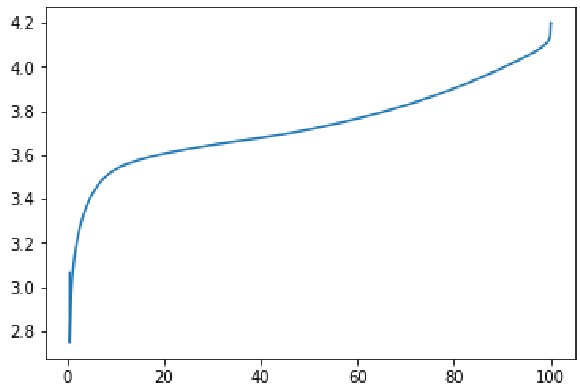

Figure 6. SOC vs Voltage of the battery

VIII. CONCLUSION

The SOC and SOH are the parameters useful for the analysis of any battery. The development of such a model will help users to estimate and understand battery performance and battery life. The Coulomb counting and neural network mixed algorithm is useful to calculate the SOC and SOH of battery. The demerits of Coulomb Counting method are eliminated by the neural network method. For future scope, the battery life span can also be predicted by using neural networks. The monitoring of battery SOH and usage cycle helps in predicting the life span of battery.

REFERENCES

1. T.R.Crompton, Batteries refrence book, newnews Book Company, third edition 2000.
2. A. Rahmoun and H. Biechl, “Modeling of Li-Ion Batteries using Equivalent Circuit Diagrams”, Przeglad Elektrotechniczny (Electrical Review) 2012”,pp 152-156.
3. Petzl M, Danzer MA. Advancements in OCV measurement and analysis for lithium-ion batteries. IEEE Trans Energy Convers 2013;28:675–81.M. Young, *The Techincal Writers Handbook.* Mill Valley, CA: University Science, 1989.
4. He HW, Xiong R, Peng JK. Real-time estimation of battery state-of-charge with unscented Kalman filter and RTOS mu COS-II platform. Appl Energy 2016;162:1410–8.
5. H.J. Bergveld, Dmitry Danilov, Paul P. L. Regtien, Peter H. L. Notten, Valer Pop"Battery Management Systems: Accurate State-of-Charge Indication for Battery-Powered Applications" published in 2018 springer.
6. G.Pistoia, Lithium-Ion Batteries Advances and Applications, Elsevier 1st edition 2014.
7. Harishankar,K.P.Sudharsan,U.Vignesh,T.Viveknath,P.Sivraj,K.Vijith, ”Efficient charging of battery and production of power from solar energy”, published in 2014 International Conference on Embedded Systems.
8. Ramprasath.R and Shanmughasundaram.R,“STCKF Algorithm Based SOC Estimation of Li-Ion Battery by Dynamic Parameter Modeling”:4th International Symposium SIRS 2018, Bangalore, India, September 19–22, 2018.

Retrieval Number: J13080881019/19©BEIESP
DOI: 10.35940/ijitee.J1308.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

AUTHORS PROFILE

Abhash Ganeshan is pursuing M.Tech., Embedded systems in the Department of Electrical and Electronics Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, India.

R.Shanmughasundaram is an Assistant Professor in the Department of Electrical and Electronics Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, India.

Retrieval Number: J13080881019/19©BEIESP
DOI: 10.35940/ijitee.J1308.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)