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Automating Estimation of Battery State of Charge Using Experimental Data in MatLab

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Abstract

This paper explains how to estimate the state of charge (SOC) of a battery using implementation of characteristics governing equations and and lookup table. Look up table containing experimental data like charging resistance, discharging resistance and battery voltage in a excel sheet. Estimation of state of charge as a function of voltage is simulated with the help of experimental data in the form of lookup table in Matlab simulink and mscript. A 4V battery was charged and discharged at a 2.3 ampere for an hour. Matlab simulunk model with m.scipt is developed to determine terminal voltage and state of charge is obtained at any given time.

Introduction

Many SOC Estimating Mathematical Methods Ab Halim, (2020) are available like Open Circuit Voltage Method, Terminal Voltage Method, Impedance Method which come under direct method.

We have Book-Keeping Estimation like Coulomb Counting Method, Modified Coulomb Counting Method. We also have Adaptive Systems like BP Neural Network, RBF Neural Network, Fuzzy Logic Method, Support Vector Machine (SVM), Fuzzy Neural Network, Kalman Filter, and also we have many hybrid like Coulomb Counting Ab Halim, (2020l) and EMF Combination, Coulomb Counting and Kalman Filter Combination etc., which are more accurate, sophisticated and adaptive algorithms.

Methodology

The method used in this paper is the coulomb counting method (Book Keeping) is used. The current integration is performed and is compared to the nominal battery capacity thus SOC can be calculated

$$z(t) = z(0) - \frac{1}{C_n}\int_0^t \eta_i i(\tau) d\tau$$

C_n is the battery nominal capacity

$z(t)$ is the cell state of charge

$i(\tau)$ is the instantaneous cell current

Sign convention: $(+)$ **for discharge,** $(-)$ **for charge**

t is the time.

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η_i: Coulomb efficiency

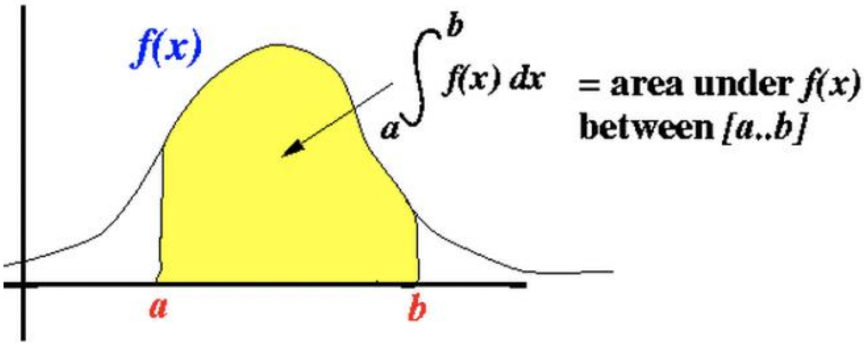

Figure 1. Integration of the function $f(x)$ represents the area under the curve

Courtesy http://www.mathcs.emory.edu

The coulomb counting is used here since implementing mathematical modelling is Simulink is simpler as the equation governing the SOC itself is simple (Dawed, 2017). This Coulomb counting is the method which measures the battery discharging current and over time integrates the discharging current in order to estimate SOC. Coulomb counting method is done to estimate the SOC_K, which is estimated from the discharging current I_K, and previously estimated SOC values SOC_{K-1}. SOC is calculated using.

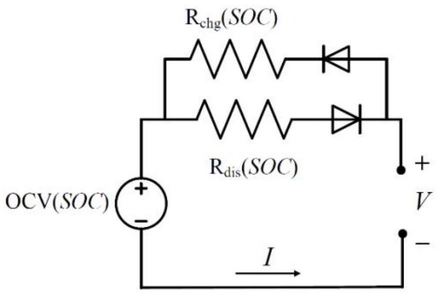

Figure 2. Electric Circuit of battery

$$\text{SOC} = SOC_0 \pm \frac{1}{C_n}\int_0^t I(t)\,\text{dt}\ldots\ldots\ldots(1)$$

$$V_t = OCV(SOC_k) \pm \text{I} * R(T, SOC)\ldots(2)$$

Results and Discussion

The above equation (1) represents the state of charge which is quite obvious that the sum of present charge and accumulation of charge over time t, sum for charging and subtraction for discharging. Equation 2 represents the terminal voltage which is the sum of open circuit voltage(OCV) Li & Yang, (2011) with the drop due to charging and discharging resistance. It is quite evident that open circuit voltage is a function of state of charge. The relationship between SOC and OCV is shown in Figure. 3, as the battery charges over time its SOC increases and whents its fully charges it reaches to 100% SOC . Figure 3 shows an important relationship because it can be used to infer the SOC from the OCV. This technique is called voltage based SOC Estimation.

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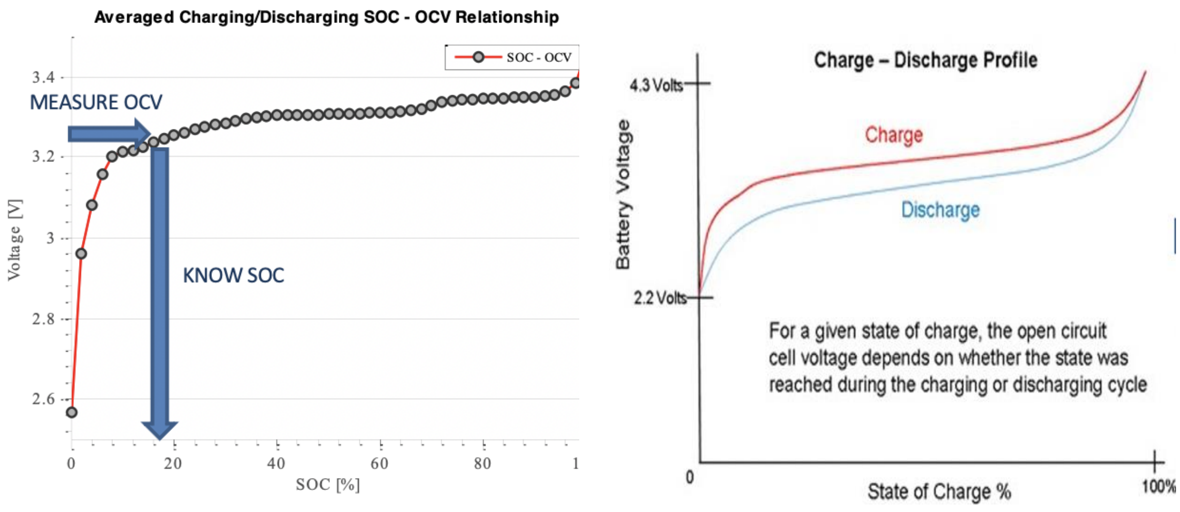
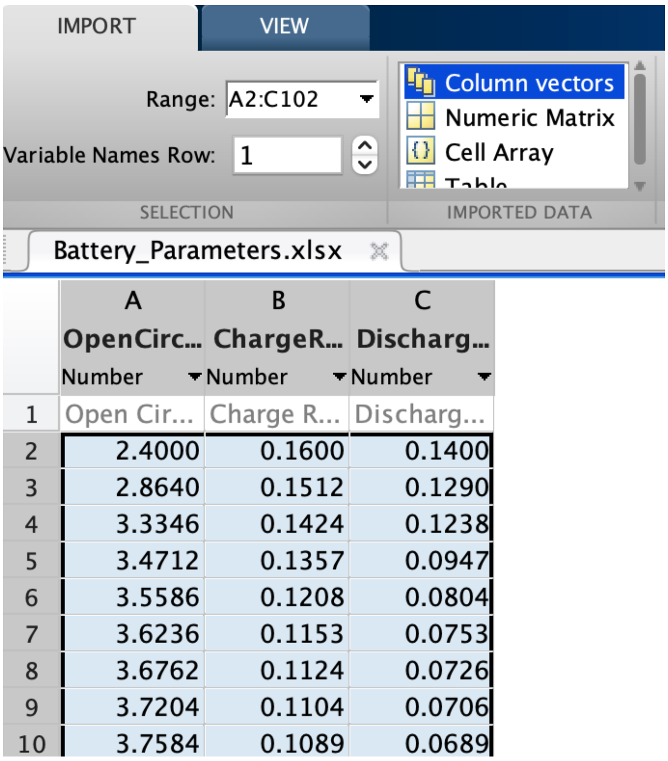


Figure 4. Charge and Discharge profile of a battery

$$SOC_{k+1} = SOC_k - \frac{\Delta t}{C_n} i_k \ldots\ldots\ldots\ldots(3)$$

$$V_k = OCV(SOC_k) - i_k * R \ldots\ldots\ldots\ldots(4)$$

The experimental measured open circuit voltage, charging resistance & discharge resistance are tabulated in Microsoft excel sheet and read through mscript which is shown in figure 5. The 1-Dimentional lookup table Menyhárt & Szabolcsi, (2019) is used to corelate the simulated SOC and OCV to obtain terminal voltage as shown in figure 7.



	A	B	C
	OpenCirc...	ChargeR...	Discharg...
	Number	Number	Number
1	Open Cir...	Charge R...	Discharg...
2	2.4000	0.1600	0.1400
3	2.8640	0.1512	0.1290
4	3.3346	0.1424	0.1238
5	3.4712	0.1357	0.0947
6	3.5586	0.1208	0.0804
7	3.6236	0.1153	0.0753
8	3.6762	0.1124	0.0726
9	3.7204	0.1104	0.0706
10	3.7584	0.1089	0.0689

Figure 5. Battery parameters Input to the mscript such as OCV, Charge_resistance & Dis_resistance

The battery parameters observed in experiment is tabulated in a table and made available to matlab m.script in the form of excel sheet (Wang, 2014). The OCV, charge_resistance & discharge resistance refers to first column, second column and third column respectively.

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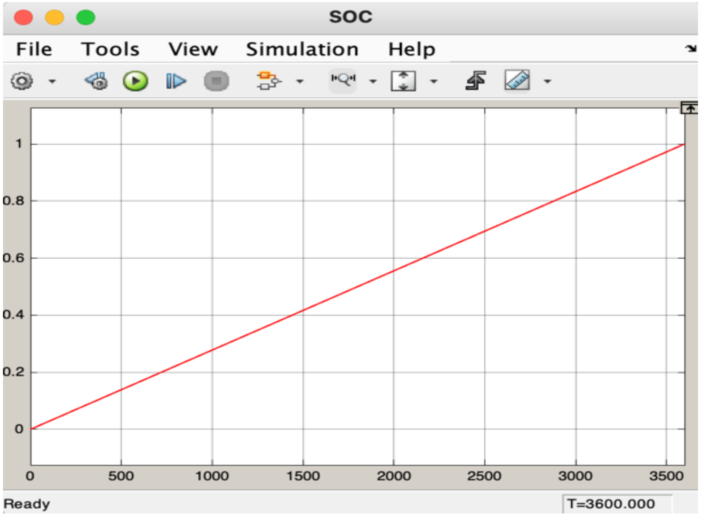

Figure 6. State of Charge v/s Time (3600 Sec)

State of charge of battery over time of one hour is shown in figureure 6. The plot is obtained at the scope SOC shown in figure 8 which is the realization of equation 1.

Equation 2 is realized to obtain terminal voltage Kumar & Majhi, (2014) of the battery which is the summation of open circuit voltage with the drop due to internal resistance. The expected results shown in figure 4 is obtained in figure 7.

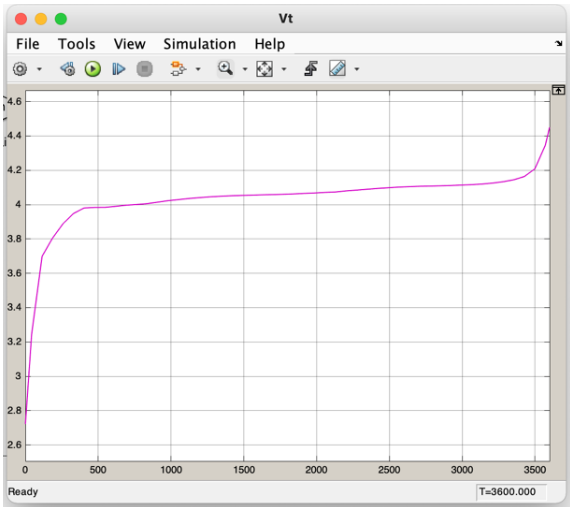

Figure 7. Terminal Voltage of 4V battery charged over 1hour (3600 Sec).

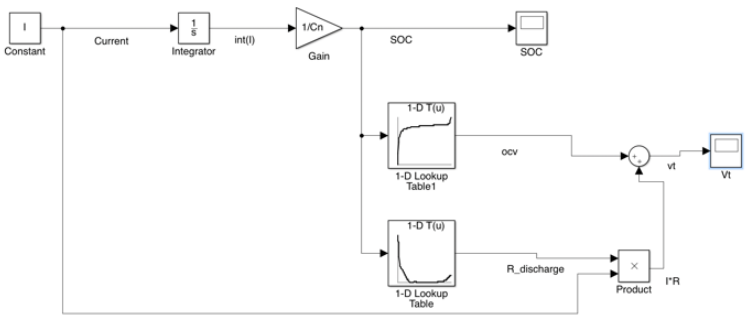

Figure 8. Simulink model representing equation 1 and equation 2.

Simulink Model shown in figure 8 is built upon equation 1 and equation 2. The 1-D lookup blocks in Simulink library reads the data Dell & Rand, (2001) from the excel sheets table to

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match the present SOC. The current value, value of Cn and simulation times are defined as per the rating of the battery and its charging and discharging durations (Ehsani et al., 2018). Figureure 9 shows the commands used to simulate the Simulink model.

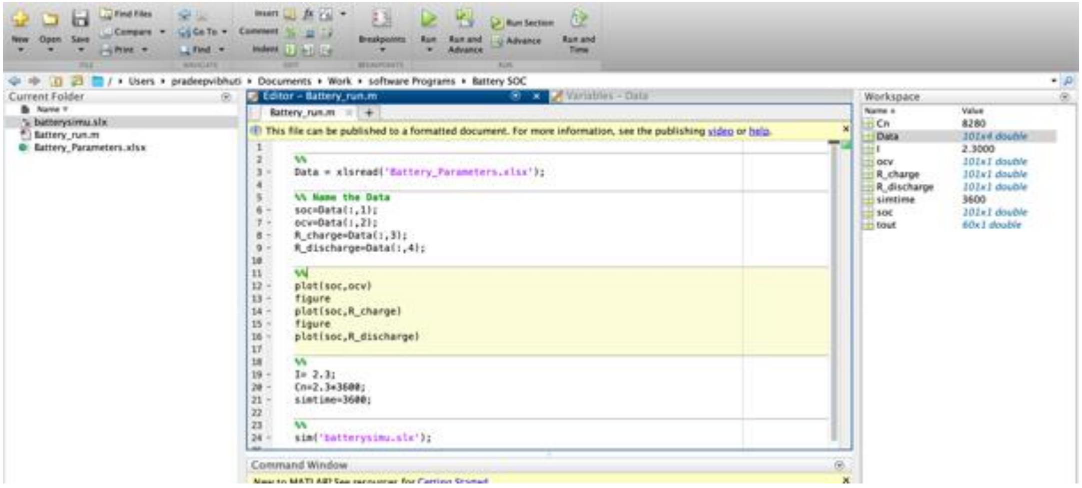

Figure 9. m.script of Simulink file of figure 8

Conclusion

The state of charge estimation and battery voltage is realized using the equation 1 & 2. These equations are mathematically modelled to obtain the desired nature of graphs shown in figure 4. Both MatLab programming and Simulink is used to implement the automated estimation process.

References

Ab Halim, M. M., Annuar, K. A. M., Harun, M. H., Anuar, N. F., Abid, M. A. A. M., & Zainuddin, M. A. (2020l). Evaluation of Charging Profile of Lead Acid Battery used in Electrical

Dawed, H. A. (2017). Lithium Ion Battery Cell Modelling.

Dell, R., & Rand, D. A. J. (2001). *Understanding batteries*. Royal society of chemistry.

Ehsani, M., Gao, Y., Longo, S., & Ebrahimi, K. (2018). *Modern electric, hybrid electric, and fuel cell vehicles*. CRC press.

Kumar, P., & Majhi, S. (2014). Introduction to Hybrid and Electric Vehicles.

Li, X., & Yang, Y. (2011). Research on the calculation method and dynamic modeling of traction-battery SOC for electric vehicle. In *2011 Second International Conference on Mechanic Automation and Control Engineering* (pp. 6778-6782). IEEE.

Menyhárt, J., & Szabolcsi, R. (2019). Battery Measurement Methods and Artificial Intelligence Applied in Energy Management Systems. *International Journal of Engineering and Management Sciences*, *4*(1), 428-436.

Scooter. In *Journal of Physics: Conference Series* (Vol. 1529, No. 3, p. 032096). IOP Publishing.

Wang, L. (2014). *Development of a Hardware-In-the-Loop Simulator for Battery Management Systems* (Doctoral dissertation, The Ohio State University).

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