Exploratory Project 2023

BATTERY MANAGEMENT SYSTEM

Overview:

- Introduction to BMS
- Functions of BMS
- What is SOC?
- Need for SOC estimation
- Methods to find SOC
- Conclusion

Introduction to BMS

- As the world is moving towards adopting sustainable energy solution, there is an increase in the use of electricity as a fuel.
- In order to use electricity for functioning of large machines, we need batteries to store it.
- A battery management system is required to ensure proper functioning of the battery by managing the various aspects of battery such as state of charge, state of health, temperature etc.

Functions of BMS

- Protection – Over-charge., Discharge, Over-current, short circuit, extreme temperature.
- Perfomance management – state of charge estimation, power limit computation, data recording and reporting,
- Diagnostics – abuse detection, state of health estimation, state of life estimation.
- Sensing and high-voltage control – measure voltage, current, temperature, control contractor, pre-charge, ground fault detection, thermal management.
- Balancing – balances the individual cells in a battery pack.

Why do we use lithium ion batteries over other types of batteries

- High Energy Density
- Long Cycle Life
- Low Self-Discharge Rate
- Fast Charging
- Wide Temperature Range

State of Charge

- The SOC of a battery is defined as the ratio of its current capacity Q(t) to the nominal capacity Q(n). The nominal capacity is given by the manufacturer and represents the maximum amount of charge that can be stored in the battery.
- SOC changes only due to passage of current, either charging or discharging the cell due to external circuitry, or due to self-discharge within the cell.

Why do we need to estimate SOC?

- Prevent overcharge or discharge.
- Improve the battery life
- Protect battery
- Improves the battery performance
- For cell balancing applications, it is only necessary to know the SOC of any cell relative to the other cells in the battery chain.

Methods to find SOC

- Coulomb counting method -

Also known as ampere hour counting and current integration method.

This method employs battery current readings mathematically integrated over the usage period to calculate SOC value given by :

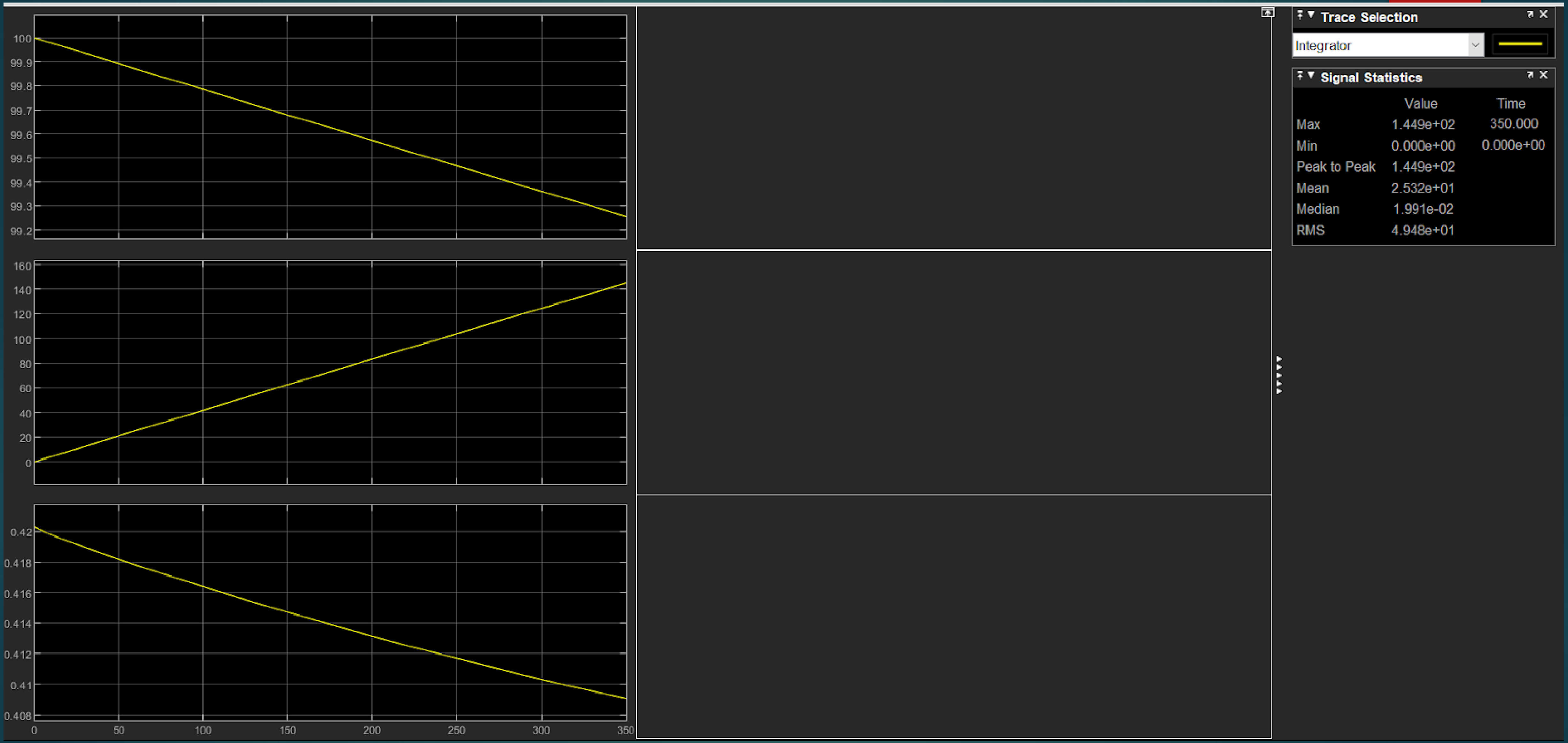
$$z(t) = z(t_0) - \frac{1}{Q}\int_{t_0}^{t} \eta(\tau) i(\tau)\, d\tau.$$

Q is total capacity in Ah.

n(t) (unitless quantity) is coulombic efficiency.

Limitation of coulomb counting :

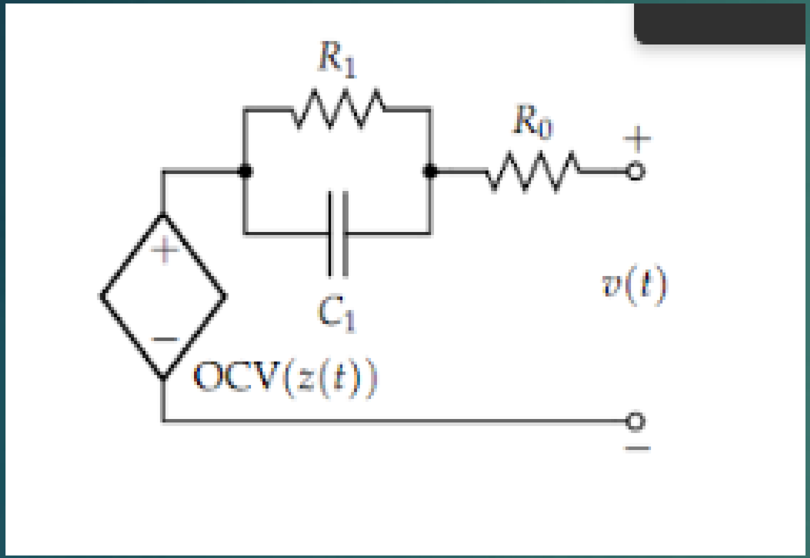
There is some drift in current sensing due to which error get add in integrating the current with time which results in low accuracy.



Trace Selection
Integrator
Signal Statistics
Value
Time
Max
1.449e+02
350.000
Min
0.000e+00
0.000e+00
Peak to Peak
1.449e+02
Mean
2.532e+01
Median
1.991e-02
RMS
4.948e+01

Equivalent circuit model and Parameter estimation

Equivalent circuit model represent dynamic performance of a battery cell and in order to fit the model with the experimental data we need to parameterize it.



$$v(t) = \mathrm{OCV}(z(t)) - R_1 i_{R_1}(t) - R_0 i(t)$$
$$v[k] = \mathrm{OCV}(z[k]) - R_1 i_{R_1}[k] - R_0 i[k].$$

$$i_{R_1}(t) + C_1 \dot{v}_{C_1}(t) = i(t).$$

since $v_{C_1}(t) = R_1 i_{R_1}(t)$,

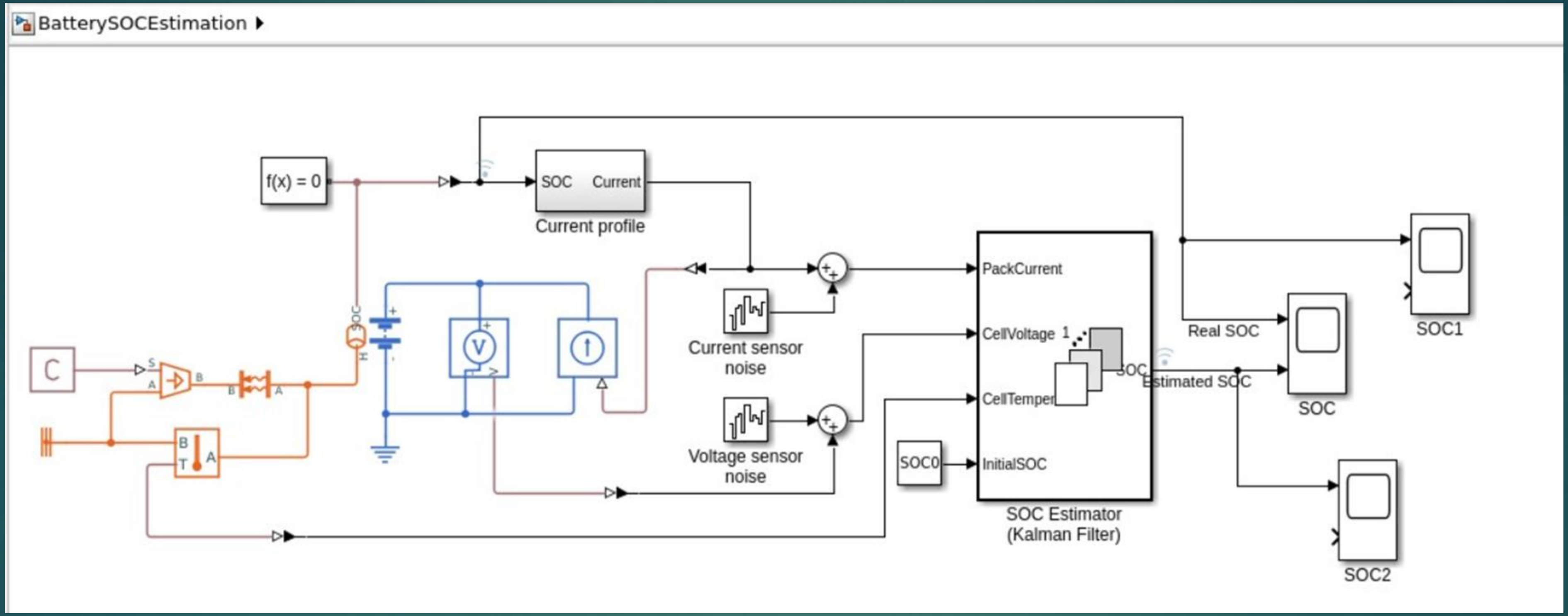
$$i_{R_1}(t) + R_1 C_1 \frac{d i_{R_1}(t)}{dt} = i(t)$$
$$\frac{d i_{R_1}(t)}{dt} = -\frac{1}{R_1 C_1} i_{R_1}(t) + \frac{1}{R_1 C_1} i(t).$$

$$i_{R_1}[k+1] = \exp\left(-\frac{\Delta t}{R_1 C_1}\right) i_{R_1}[k] + \left(1 - \exp\left(-\frac{\Delta t}{R_1 C_1}\right)\right) i[k]$$
$$v[k] = \mathrm{OCV}(z[k]) - R_1 i_{R_1}[k] - R_0 i[k].$$

SOC Estimation using Kalman filter

- As the behaviour of a battery is non linear, its soc depends on various factors such as cell temperature, current, voltage and initial SOC which are subject to measurement errors and noise.
- In this method, these parameters are used by the Kalman Filter to estimate SOC of the battery.
- The Kalman filter's ability to account for uncertainty in the measurement and the model makes it more robust and accurate.
- Unlike coulomb counting method,this method also rectifies the false initialisation .

Model used to estimate SOC using Kalman filter



Data based Estimation

- Data used is of 3Ah LG HG2. The training data contains five predictors: voltage, current, temperature, average voltage and average current and one target: the state of charge.
- Feed-Forward neural network is used. Activation function are embedded in the layers to introduce non linearity.
- The model has been trained on backpropagation algorithm to reduce loss after each epoch. The loss function used is Mean Squared Error.

Comparison between real and predicted SOC on test data

9612	0.466018
9613	0.465979
9614	0.465882
9615	0.46574
9616	0.46553
9617	0.465268
9618	0.464983
9619	0.464904
9620	0.464768
9621	0.464403
9622	0.464223
9623	0.464081
9624	0.46402
9625	0.464029
9626	0.464059
9627	0.464092

Real SOC

9612	0.481834
9613	0.481506
9614	0.480602
9615	0.479646
9616	0.478192
9617	0.476698
9618	0.472947
9619	0.477002
9620	0.47969
9621	0.471352
9622	0.474254
9623	0.474525
9624	0.473245
9625	0.476912
9626	0.477783
9627	0.478282

Predicted SOC

CONCLUSION:

- We observed that in coulomb counting there is a drift in current sensing due to which error get added in integrating current with respect to time which results in low accuracy.
- On the other hand, Kalman filter and neural network estimates the soc more accurately as it continuously keeps decreasing the error and keeps on updating the parameters .

THANK YOU!

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