Towards an Advanced Battery Management System (BMS)

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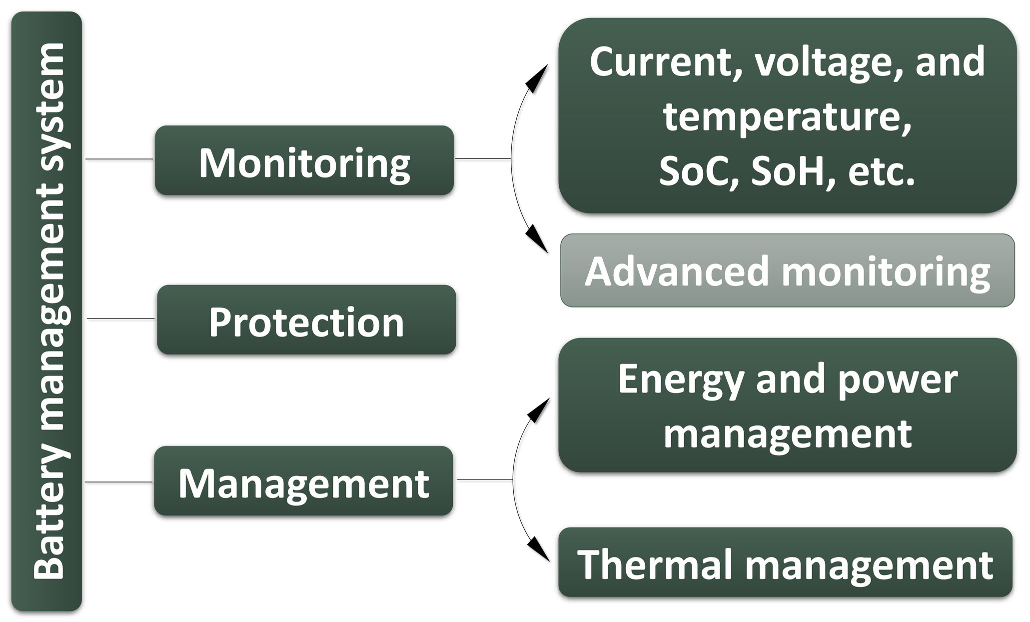
Battery Management System (BMS)



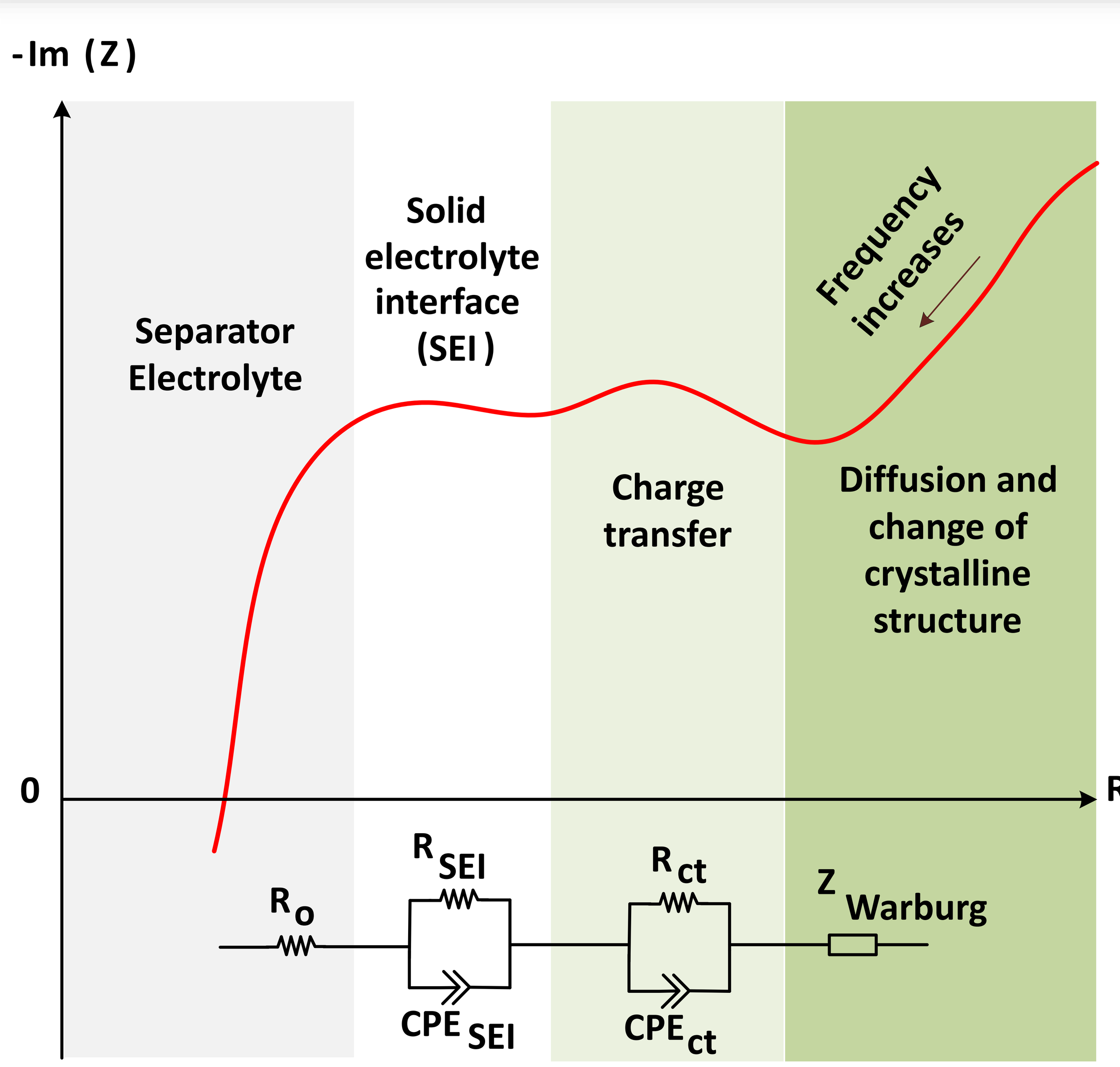
Energy management attempts to balance the amount of charge in the cells to maximize the total charge in a battery system and prevent overcharge and discharge of the cells.

Power management refers to a situation where cells of different types and power rating are used.

Thermal management attempts to maintain the temperature of the cells in a safe/optimal operating zone and to evenly distribute the thermal energy between the cells.

The monitoring layer aims to measure (current, voltage, and temperature) or estimate (SoC, SoH, remaining capacity, etc.) the required parameters for BMS at the cell level. Advanced monitoring tends to extract more information about the cells and monitor their internal characteristics. Electrochemical impedance spectroscopy **(EIS)** is a powerful tool to extract the necessary parameters for advanced BMS.

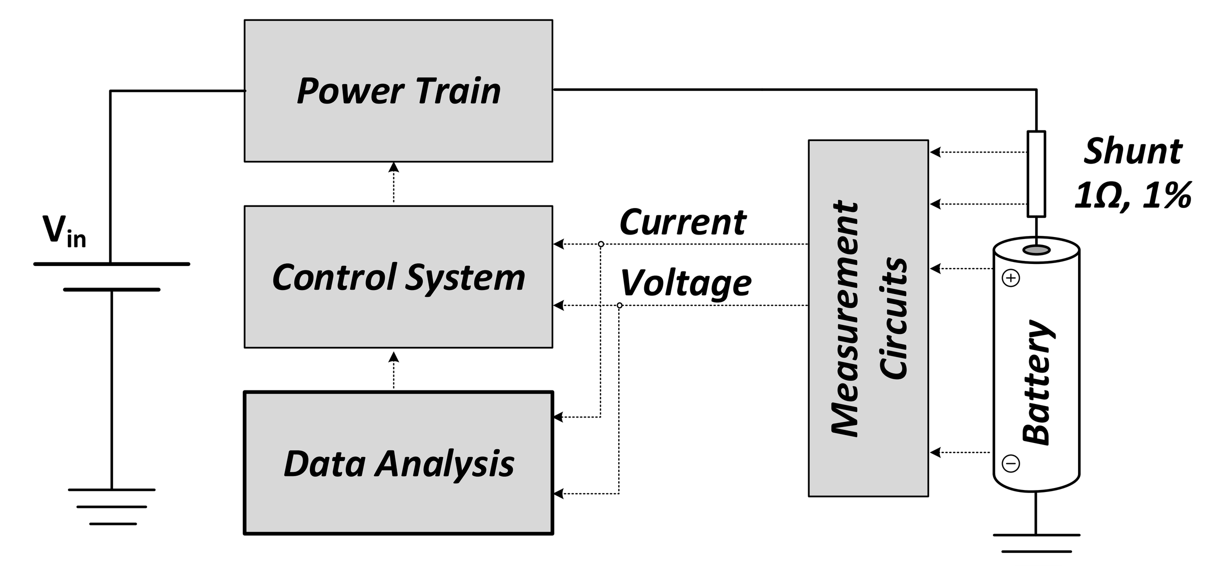
Electrochemical Impedance Spectroscopy (EIS)



EIS starts with obtaining the impedance spectrum of the battery from low frequency (mHz), passes through the mid frequencies, and ends up at high frequencies (kHz). Each of these frequency regions correspond to a certain electrical property inside the battery.

For a better understanding, EIS is also presented with equivalent circuit models (ECMs).

Power-Electronics-Based EIS



In recent years, instead of high cost and bulky EIS workstations, EIS is being implemented using power electronics (PE) interfaces, such as chargers, motor drives, cell balancing circuits, etc. An excitation signal is injected into the battery through the power train, and the response signal is measured. In most cases, the excitation signal is an ac current, e.g. sinusoidal, and the response signal is the ac voltage. The frequency range of the excitation signal defines the EIS bandwidth.

Technical Challenges of PE-based EIS

Power electronics design

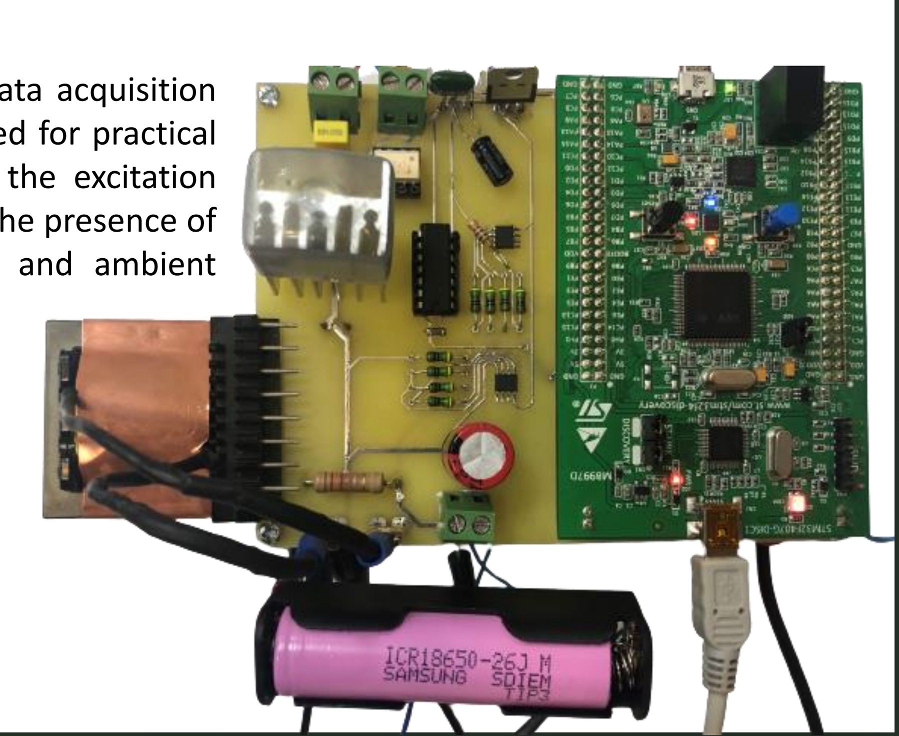
The most important factors in design of power electronics point for EIS is the converter's output resolution and bandwidths. These factors significantly effect the quality of EIS data.

Control system design

In case that a closed loop control system is used to control the injection of excitation signal, selection of the type of control system is a challenge, due to the advantage and disadvantage of each approach. PI, resonant, MPC, and their combinations are common control strategies.

Data acquisition system

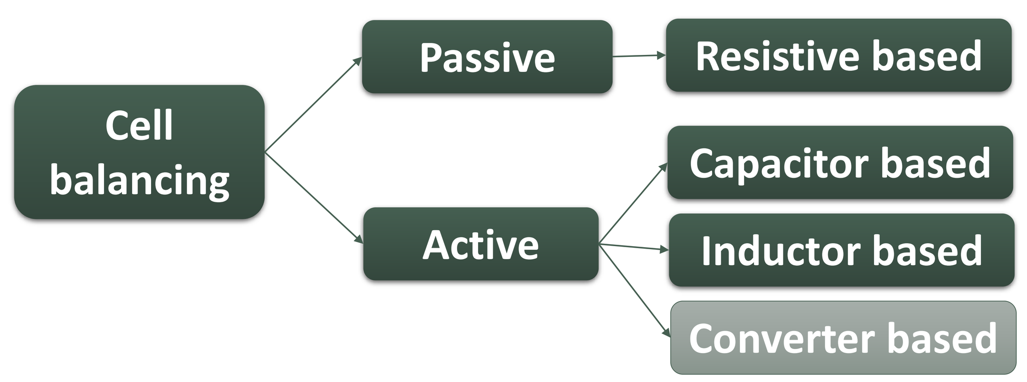
A dedicated, low cost data acquisition system is mainly designed for practical applications to capture the excitation and response signals in the presence of other operating signals and ambient noise.



Data analysis & Impedance presentation

Acquired data is fed to a computer to analyze and present the EIS in terms of spectra or ECM.

Integration of EIS with BMS



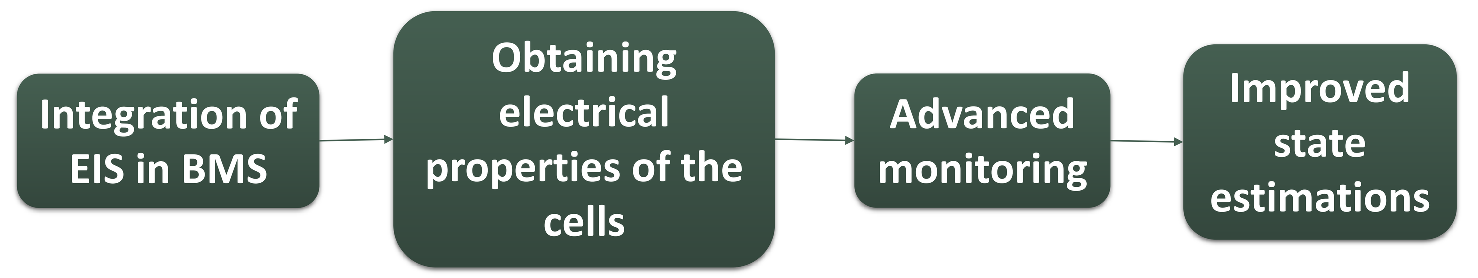
EIS is enabled using the converter-based cell balancing circuits which are a part of a BMS.

In distributed modular cell balancers each cell is connected to a converter and forms a module. The outputs of the modules form the battery pack's output. Distributed modular BMS is the best choice for integration with EIS, as there is access to each cell separately and the excitation signal is easily injected using the corresponding converter.

Various power electronics circuits are employed to perform energy management (cell balancing) for battery systems. This enables the integration with EIS without the need for a significant hardware change.

Some considerations have to be made for this integration. For online EIS where the battery cells are in use, the measurement time must be short enough to ensure the stability of the system. For offline EIS, a relaxation period is needed for the cells, then the circuit starts performing EIS and saving the data, preferably in the form of ECM parameters.

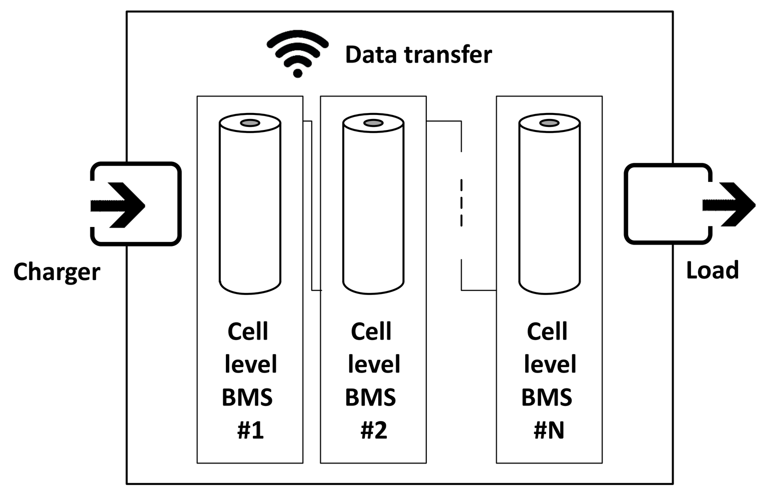
Benefits of The Integration of EIS with BMS



Having electrical properties of the cells in a BMS provides some benefits in the short as well as long term.

In the short term, those parameters can be used in accurate state estimations, as EIS is one of the powerful non-invasive tools for the estimation of SoH, SoC, and remaining capacity. Combination of the directly measured quantities such as the cell's surface temperature with EIS data can also lead to the estimation of the cell's internal temperature.

In the long term, by tracking the changes in the electrical properties, the remaining useful life of the battery can be estimated with high accuracy. It also provides a practical dataset for further research on the aging effect of battery cells.



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