Definition of BMS:

Battery management system (BMS) is technology dedicated to the oversight of a battery pack, which is an assembly of battery cells, electrically organized in a row x column matrix configuration to enable delivery of targeted range of voltage and current for a duration of time against expected load scenarios.

The oversight that a BMS provides usually includes:

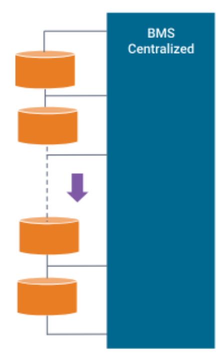
- Monitoring the battery
- Providing battery protection
- Estimating the battery's operational state
- Continually optimizing battery performance
- Reporting operational status to external devices

Types of battery management systems

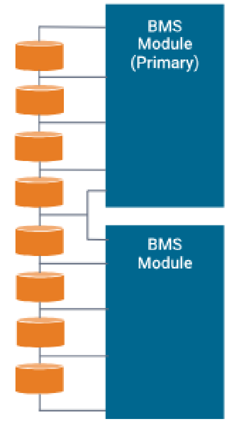
Battery management systems range from simple to complex and can embrace a wide range of different technologies to achieve their prime directive to "take care of the battery." However, these systems can be categorized based upon their topology, which relates to how they are installed and operate upon the cells or modules across the battery pack.

1- Centralized BMS Architecture

Has one central BMS in the battery pack assembly. All the battery packages are connected to the central BMS directly. The structure of a centralized BMS is shown. The centralized BMS has some advantages. It is more compact, and it tends to be the most economical since there is only one BMS. However, there are disadvantages of a centralized BMS. Since all the batteries are connected to the BMS directly, the BMS needs a lot of ports to connect with all the battery packages. This translates to lots of wires, cabling, connectors, etc. in large battery packs, which complicates both troubleshooting and maintenance.

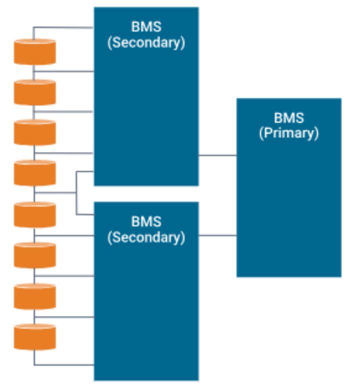


2- Modular BMS Topology



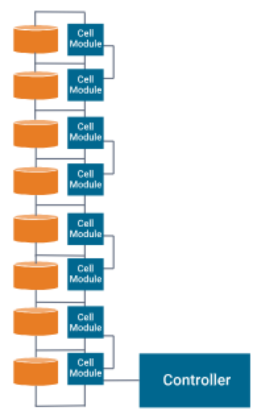
Similar to a centralized implementation, the BMS is divided into several duplicated modules, each with a dedicated bundle of wires and connections to an adjacent assigned portion of a battery stack. In some cases, these BMS submodules may reside under a primary BMS module oversight whose function is to monitor the status of the submodules and communicate with peripheral equipment. Thanks to the duplicated modularity, troubleshooting and maintenance is easier, and extension to larger battery packs is straightforward. The downside is overall costs are slightly higher, and there may be duplicated unused functionality depending on the application.

3- Primary/Subordinate BMS



Conceptually similar to the modular topology, however, in this case, the slaves are more restricted to just relaying measurement information, and the master is dedicated to computation and control, as well as external communication. So, while like the modular types, the costs may be lower since the functionality of the slaves tends to be simpler, with likely less overhead and fewer unused features.

Distributed BMS Architecture



Considerably different from the other topologies, where the electronic hardware and software are encapsulated in modules that interface to the cells via bundles of attached wiring. A distributed BMS incorporates all the electronic hardware on a control board placed directly on the cell or module that is being monitored. This alleviates the bulk of the cabling to a few sensor wires and communication wires between adjacent BMS modules. Consequently, each BMS is more self-contained, and handles computations and communications as required. However, despite this apparent simplicity, this integrated form does make troubleshooting and maintenance potentially problematic, as it resides deep inside a shield module assembly. Costs also tend to be higher as there are more BMSs in the overall battery pack structure.

Definition: cell balancing is the process of equalizing the voltages among individual cells

cell balancing is needed as:

discharging must stop - any cell first runs out of charge though other cells still hold charge

charging must stop - any cell reaches its maximum charging voltage

there are 2 techniques for cell balancing:

1. **Passive cell balancing:** if we have 3 cells have SOC of 100%, 50% and 75% respectively. So, cell 2 has the least SOC. The other two cells connect with resistor and their excess energy will drain in the form of heat to be equalized with cell 2.
   Pros: cost effective and simple architecture
   Cons: the capacity of pack is limited by weakest cell least soc, pack's energy spent as heat inherently wasteful and due to heat, additional coolant technique required

2. **Active cell balancing:** if we have 3 cells have SOC of 100%, 50% and 75% respectively. So, cell 1 has the highest SOC. The energy transfers from cell 1 to cell 2 by capacitor, inductor or DC-DC converter. So. The 3 cells become have SOC equal to the average of SOC of the 3 cells.
   Pros: energy is transferred from one cell to another less energy waste and SOC of pack is equal to the average of all individual cell SOC
   Cons: complex architecture and additional cost of electronics