Designing Battery Systems

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Battery cell technology is evolving rapidly, and the cost/KWh is falling, however one of the obstacles to the wide-spread adoption of battery storage systems, across a broad range of industries and applications, is simple, elegant power management. Motiv's unique approach to designing and building battery packs and battery management systems is discussed below

Battery Management Systems – Background

Electric vehicle companies, telecom companies and electric utilities are all concerned about battery management, and rightly so. Without proper charge management, small imbalances in cell capacity, impedance, or thermal properties can be significantly magnified over many pack cycles. Weaker cells can limit pack capacity and lifetime. With some chemistries, poor or absent management can cause catastrophic failure. The management of many battery cells can be a very involved and difficult problem, requiring careful design with input from multiple engineering domains of expertise. Charge management scales super-linearly with the number of cells; 200 cells are more than twice as difficult to manage as 100 cells because additional management hierarchy is required as cell numbers increase. This scaling is one reason that very large packs are not currently available.

Beyond a typical battery charge management system, thermal management is also critical to successful pack design. If a thermal gradient exists across a pack, hotter cells will age faster and limit pack lifetime. Even small thermal gradients will cause major imbalances since cycle lifetime is related exponentially to temperature. With some cell chemistries, an increase of 10 degrees Celsius can halve the cycle lifetime! As with charge management, increasing cell count makes thermal management much more difficult, since more heat must be moved greater distances and thermal gradients must be even more tightly controlled.

Motiv's Battery System Architecture

Motiv's battery pack design typically consists of multiple battery modules. Each module is defined as having its own unique Battery Management System (BMS), and is typically in the range of 1 to 20KWh, depending on application. Modules are combined together to build battery systems, with a system-level controller managing module interaction. This design allows for the independent management of each module and for coordination of modules across the whole battery system. Since each module is decoupled, problems or failures in one module will not affect other modules. This design also allows for the combining of a virtually unlimited number of battery modules to provide battery pack designs that are useful over a large range of applications.

Battery Pack Design

Motiv's battery system design is simulation-driven. Our focus is on both charge and thermal management. Off-the-shelf hardware components are utilized and integrated into the pack with minimal use of free wires - which are major failure points. We use standard IC's to measure voltages of every cell. Our proprietary software combines the present voltage measurement with past voltage measurements and coulomb-counting circuitry and sophisticated battery cell models to arrive at an accurate measure of cell state of charge. Using cell state of charge, we actively balance the cells to ensure weaker cells do not bring a module down. The hardware design is universal over all cells that have the same form factor, and the software configuration changes depending on the chemistry and manufacturing statistics of the cells. We custom-design a heat exchanger based on cell, module and system simulation to reduce the thermal gradient across a module, and across the complete system – which is critical to cell, and therefore, pack longevity. Figure 1 illustrates the interconnected nature of a battery system model, which is necessary for accurate prediction of overall pack health. Proper packaging, thermal, and charge management systems, derived from simulation-based design, extend the pack's lifetime, reduce failures, and increase preventative diagnostic ability

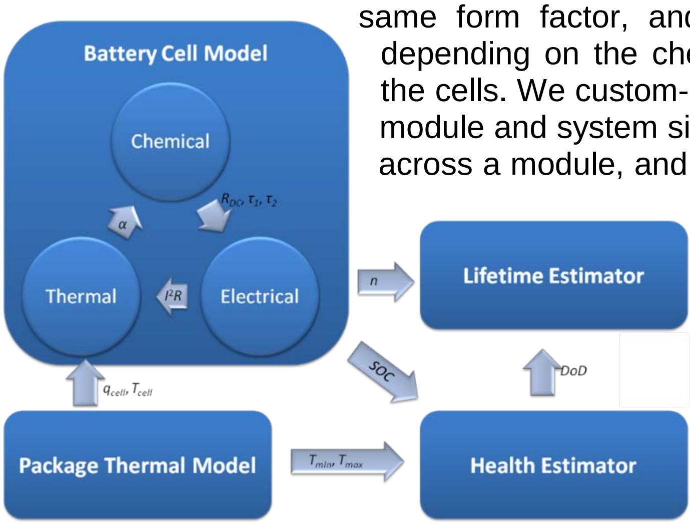

Figure 1: Diagram of a Pack Model

System Benefits

This battery system design approach has many compelling competitive advantages for battery manufacturers and battery system customers.

1. Optimal cell performance and longevity due to cell-level power management.
2. Fault tolerance. A failed battery module will not bring down the system.
3. Safety. Modules can be shut down when their health deteriorates, preventing catastrophic failure while maintaining some level of system operation.
4. Ease of packaging. Applications over a broad range of energy storage, physical dimension, and environmental requirements can be addressed by combining multiple battery modules into different mechanical system designs.
5. Large energy storage is possible, without significant complication of the BMS. Battery management can be isolated, and no new design is required for even the largest energy storage requirements. Very high electric range is possible. Since pack failures are isolated from each other, battery management can also be isolated and no new design is required for even the highest electric range requests.

The Future of Power Management

Batteries are being examined and tested as the solution for ever increasingly sophisticated and demanding applications. Whether it is for use in a commercial EV such as a bus or truck, community-level or home-level power back up systems, or load shaving applications for electric utilities, battery systems must meet high power and energy requirements. While doing so, they must also meet the stringent safety, reliability and longevity goals that these applications demand. Intelligent battery management systems, such as those designed by Motiv are the only way to successfully attain these goals.

For more information about Motiv Power Systems, please contact
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