핫 스왑 촉진을 위한 확장 가능한 배터리 아키텍처에 관한 연구

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A study on scalable battery architectures for hot-swap facilitation

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ABSTRACT

High power and energy applications of battery require a large number of batteries to be connected in series, parallel or mixed configurations. The reliability of these batteries is improved by making them tolerant to faults i.e. by bypassing the fault cells and adding new cells to compensate the voltage and current requirement. The addition or removal of cells may cause the current stress on other healthy cells. The estimation and control of this current stress is one of the technique proposed by other researchers. This study intends to identify a suitable scalable configuration which can either avoid or reduce the efforts on the estimation and control of stress current. In addition, this paper will explore the issues associated with hot-swap.

1. Introduction

An efficient battery architecture comes with following characteristics: robustness to failures caused by open circuit or short circuit, flexible output terminals to supply variety of voltages, reconfigurable to support different power levels, require least time and power for switching, full utilization of the battery, minimum number of reserved cells and tolerant as well as optimal for hotswap. The design of a battery pack just in terms of energy and power requirements is not a recommended approach due to high risk, low reliability and sub-optimal performance. Different architectures of battery packs have been proposed by the researchers to overcome these constraints. This study intends to evaluate those different designs to identify a suitable design having low risk, high reliability and optimized performance while executing the hot-swap.

Conventional battery management techniques used scheduling techniques to explore the characteristics of battery for better performance [1]. These scheduling techiques become complex for large batteries and the non-linear behavior of battery can not be addressed properly. These static algorithms have been replaced with re-configurable battery management systems, which could overcome the limitations of conventional configurations and ensures extended lifetime, full utilization of a battery pack, and offers flexibility and robustness to the battery. Researchers have introduced different schemes of reconfigurable battery packs to solve the issues faced by static configurations. A topology presented in [2] is expected to maximize the battery utilization. A self X topolgy introduced by [3] intends to achieve self-configuration, self-balance, self healing and self-optimization of cells. There are some technical difficulties which have been overlooked in these existing topologies. This study focuses to identify those constraints, and provide suggestions to address them.

1.1 Motivation

Like wise there are many topologies, however, all scalable designs are not equally significant. This study uses three performance assessment indicators; risk, reliability and optimization to evaluate different flexible designs currently existing. For risk analysis, the key words are short-circuit, open circuit and failure. The footprints for reliability are recovery from faults, and support to a load which has changing power levels.

2. Evaluation of architectures

The development of reconfigurable designs has necessarily brought many advantages. Fig.1 shows a static series connected topology which has module D as the reserve module, and the path of the current is shown by green dotted line. The same module was subjected to fault at module B, and to avoid disruption of power supply module B was bypassed, and reserve module D was added to compensate for voltage as shown in Fig.2. The bypass was done at 100 seconds and the new module was added at 150 seconds to discern the impact of each separately. The SOC of the newly added module was set same to the existing modules to avoid voltage imbalance and current shoot up. Fig.3 shows the SOCs of each module at the time of bypass and new addition. Fig.4 shows the seamless transfer of current to the newly added module.

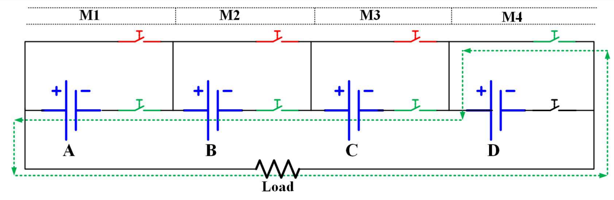

Figure 1. Series connected topology with reserve module D

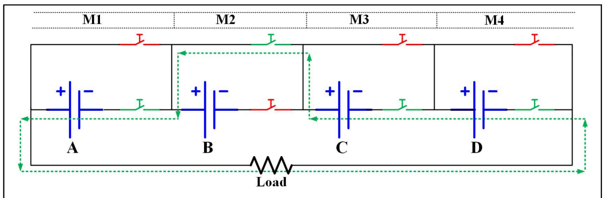

Figure 2. Bypass of the faulty module and addition of new module.

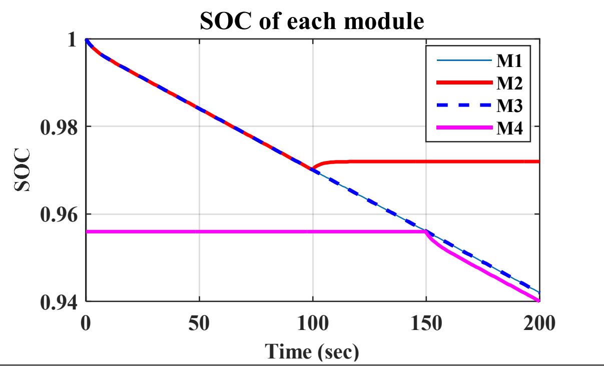

Figure 3. SOCs of each modules at the time of connection and removal

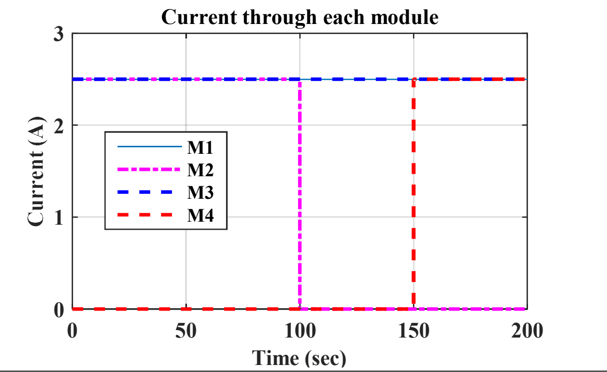

Figure 4. Current transition due to removal and addition of modules

2.1 Hot -swap facilitation

As discussed above, the hot swap is not a self-balancing issue for all the configuration, rather it is required to bring the incoming battery to SOC level same to that of existing batteries. As shown in series-connected case above that if the battery is connected at high SOC and Low SOC than the existing cells, the current will rush into the newly added battery and out of it respectively. The higher the SOC difference, the higher will be the magnitude of current. In addition, the difference in resistance among the cells also cause an imbalance. There are some battery configurations, which are comparatively more facilitating.

3. Future work

This study will be extended to analyze different scalable designs while keeping the hot-swap facilitation as the main keyword. In addition, it will be discussed how to control the inrush and outrush current.

4. Conclusion

The motivation behind the transit from static battery configurations to reconfigurable designs have been discussed. Different scalable architectures have been evaluated to identify unnoticed limitations in terms of risk, reliability and optimization for hot-swap. In conclusion, self-balancing is the key solution for hot-swap faciliatation.

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