Series-Connected Reconfigurable Multicell Battery: A Novel Design toward Smart Batteries

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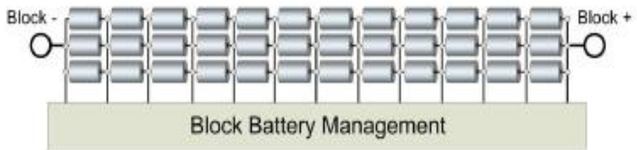
Background

It becomes more and more pervasive to use battery as the primary / secondary power supply for various industrial, commercial, residential systems and device. These battery systems typically consist of multiple cells rather than a monolithic high-capacity cell

The traditional multicell battery design usually employs a fixed configuration to connect multiple cells in series. This design has a low reliability and can only utilize a part of the total battery capacity if the cells have different usable capacities.

Recently, several reconfigurable multicell battery topology have been proposed. These topologies use many switches (e.g., five or six) to control each cell, resulting in high complexity and high cost of the cell switching circuits.



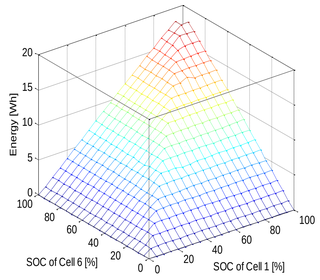
Objective

Design a novel series-connected reconfigurable multicell battery to

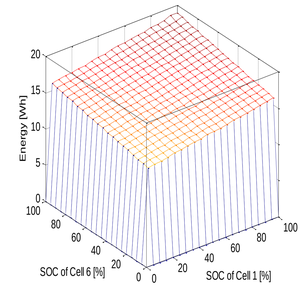
- Maximally utilize the capacity of battery
- Tolerant to failures of single or multicells
- Prolong the operating time and lifespan
- Enhance reliability of the battery system
- Can be used for variable input source voltage to improve power conversion efficiency
- Provide functionalities toward smart batteries
- Applicable to any type and size of battery cells

Simulation experimental results have shown a remarkably improved energy usage of multicell batteries using the proposed design

Simulation Results



(a) The fixed-configuration SOC: State OF charge



(b) The reconfigurable prototype Simulation in MATLAB/Simulink

Fig. 10. Total energy in Wh that can be supplied by a series-connected six-cell battery

Experimental Results

Table 1: Comparison of simulation result and experimental results

	Cell condition expressed by SOC [%]						Energy [Wh]		
Scenario	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Simulation	Experiment	Nominal
1	65	100	100	100	100	20	15.2	15.15	15.25
2	50	100	100	100	100	95	17.19	16.89	17.14
3	45	100	100	100	100	75	16.4	16.04	16.35

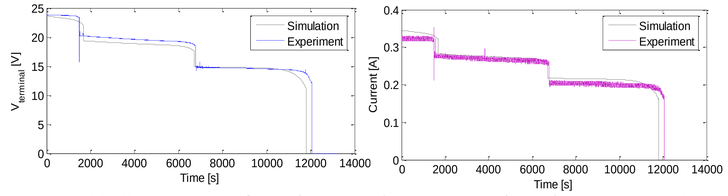


Fig 11. Comparison of simulation and experimental results in scenario 1

Proposed Design

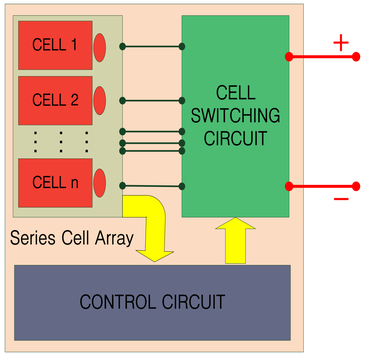


Fig. 1. Proposed series-connected reconfigurable multicell battery design

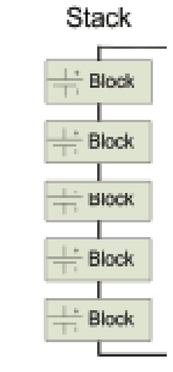


Fig. 2. Fixed multicell battery connection

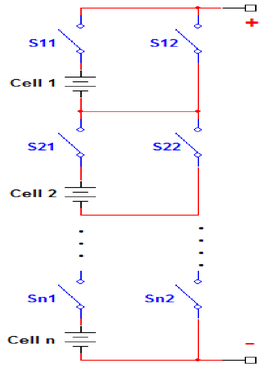


Fig. 3. Cell switching circuit topoloty

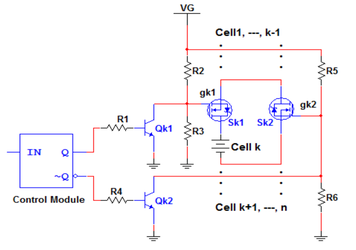


Fig. 6 switching implementation for Cell k

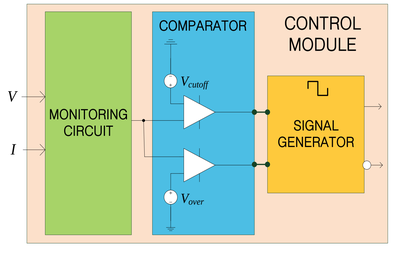


Fig. 7 Schematic diagram of the control module

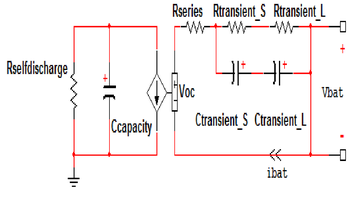


Fig. 4 Electrical battery cell model

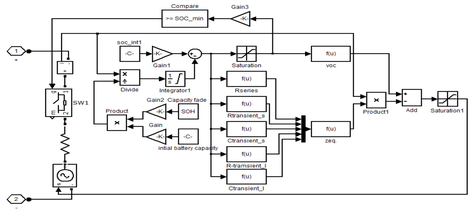


Fig. 5 Proposed MATLAB/Simulink battery model

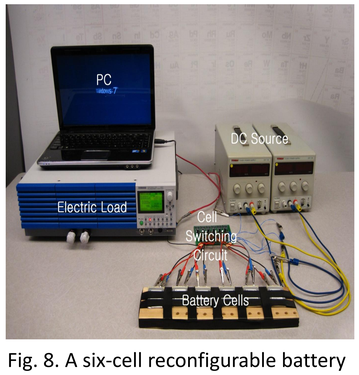


Fig. 8. A six-cell reconfigurable battery prototype and experimental setup

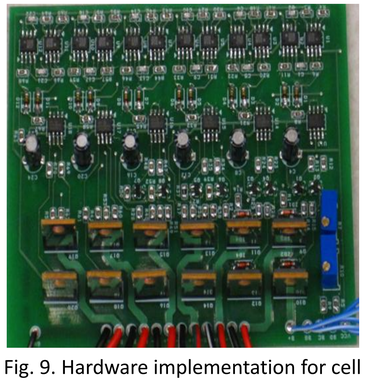


Fig. 9. Hardware implementation for cell switching circuit and control module

Conclusions

A novel series-connected, reconfigurable, multicell battery design has been proposed and validated by a six-cell prototype. In the proposed cell switching circuit topology, each cell only uses two switches to fully control its operation independently. The switching circuit and the control circuit have been designed and implemented by using high-efficiency semiconductor devices. The proposed design can maximally utilize the battery's capacity and is tolerant to failures of single or multiple cells, thereby maximizing the life span and enhancing the reliability of the battery. By using the proposed design, additional monitoring, control, protection, and optimization functions can be readily added , leading to a smart battery.