Cell Level Distributed Power Management

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Project Goal

Investigates processing of energy at the cell level (battery, cell) battery energy storage system by power conditioning circuits (a) Battery management system including charge equalization and thermal protection (b) Improved safety and reliability through battery cell level analytics and (c) Reliable energy storage can significantly improve the grid reliability and resilience.

Diagram of Distributed Power Processing Configuration

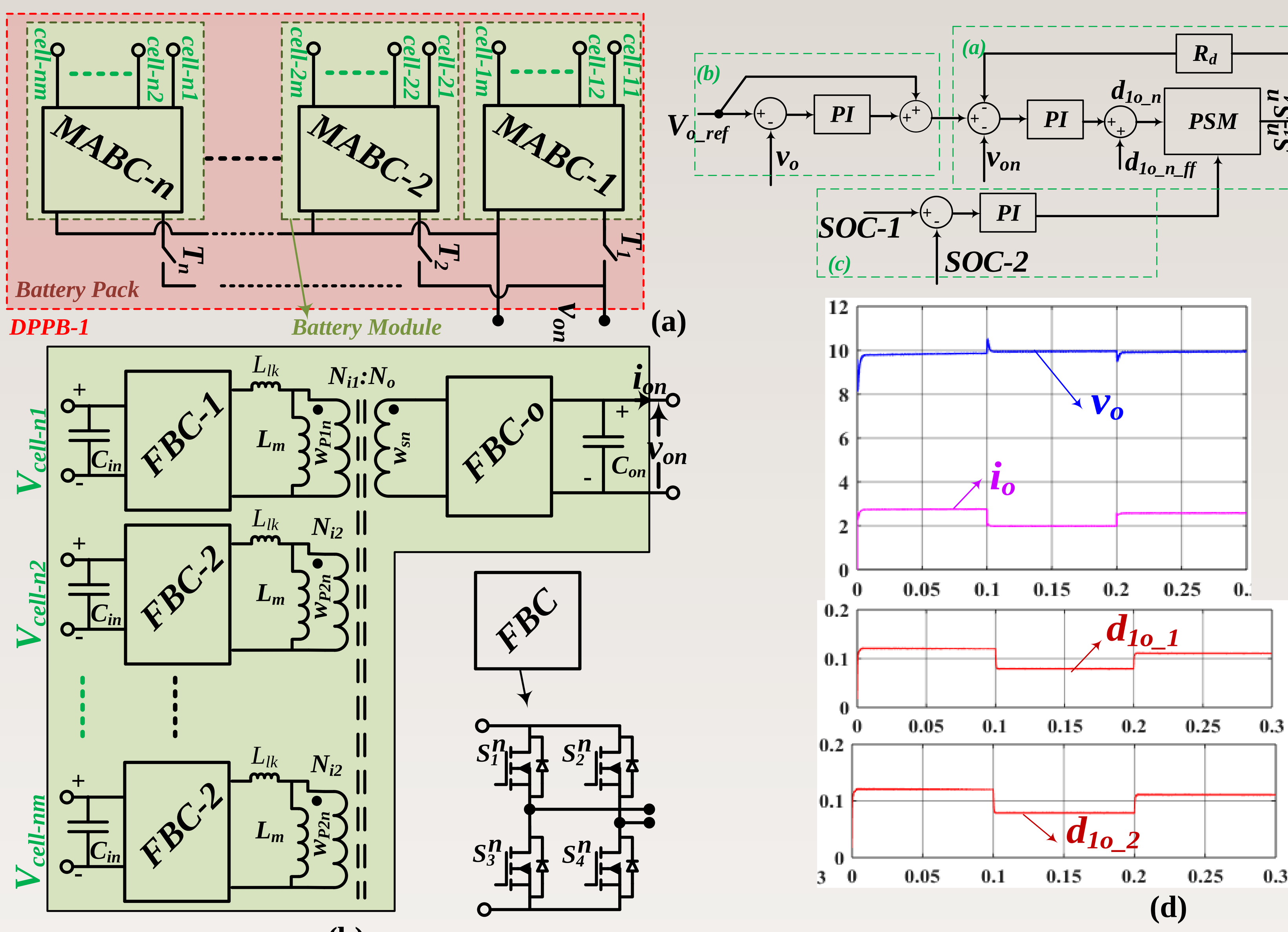


Fig. 1. (a) Distributed Power Processing structure based BESS (DPP-BESS); (b) MABC; (c) Local control strategy for the MABC-n; (d) Simulink validations of two parallel MABC

Accomplishments for Year-1

- Design and analysis of Dual Active Bridge Converter (DABC) based Distributed Power Processing (DPP)
- Complete the prototype of Micro-DABC for the Li-ion battery cell

Accomplishments for Year-2

- Design and analysis of Multi-active Bridge Converter based DPP (MABC-DPP)
- Voltage droop algorithm for co-ordination of multiple parallel sources
- Develop the prototypes of Si and GaN based DABC and tested in open loop at 0.1MHz with Li-ion battery cell
- Finite Element Analysis of High Frequency Transformer

Objectives for Year-3

- Closed loop voltage regulation of DPP configurations
- Implementation of Real Time simulations of MABC based DPP on eFPGAsim OP5700
- Develop the lab prototype of Si and GaN based TABC with two battery cells

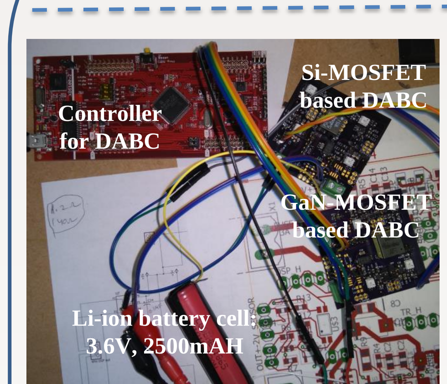
Features of MABC-DPPB

- Monitoring voltage, SOC, Temperature of each cell
- Isolate the faulted, overcharged, deep discharged and overheated battery cells in the module/pack.
- Independent charge/discharge control of each cell based on cell health.
- Efficiency improvement of MABC at low power level

Control strategy

- To ensure the uniform current sharing of the parallel MABCs by using the droop concept
- Voltage regulation issue can be mitigated by using the secondary voltage controller
- Equal SOC regulation at Battery module/pack level for improving the life time and SOH and
- Eliminate the issue of ZVS limit at low power level by controlling MABC output switches $\{T_1, T_2, .., T_n\}$

Year-3 Experimental & Real Time Simulation Test beds



- Implemented the Real Time Simulations of MABC based DPP on eFPGASim (OP5700). Matlab/Simulink models of Li-ion Battery cells are on CPU of OPAL-5700 with executing at the rate of 5US, and Power electronic circuit (i.e. TABC) is on eFPGA with executing rate of 0.23US
- MABC is able to properly regulate the output voltage (i.e. dc bus voltage).

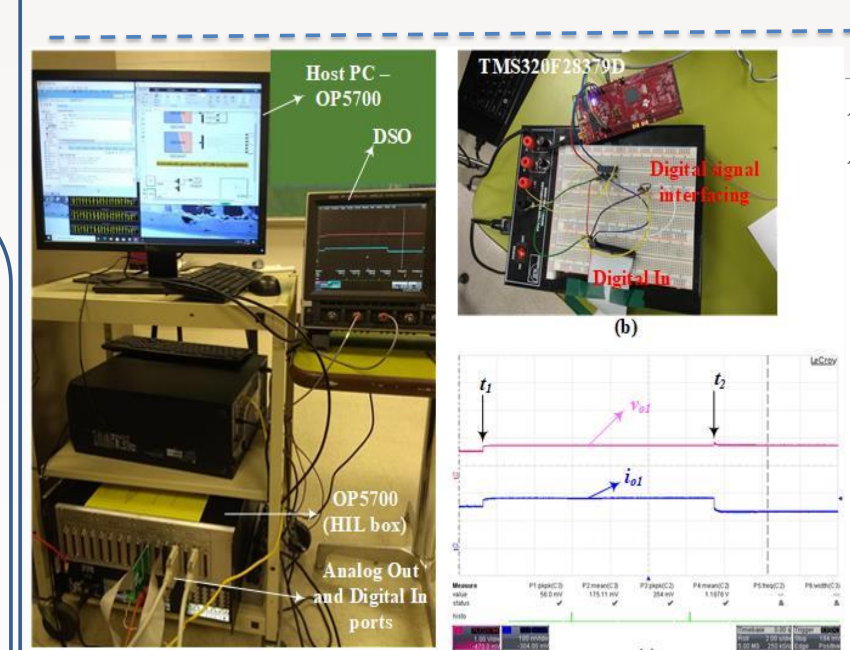


Fig. 2. Real Time Simulation setup; (b) DSP controller for the C-HIL; (c) O/P of TABC-1

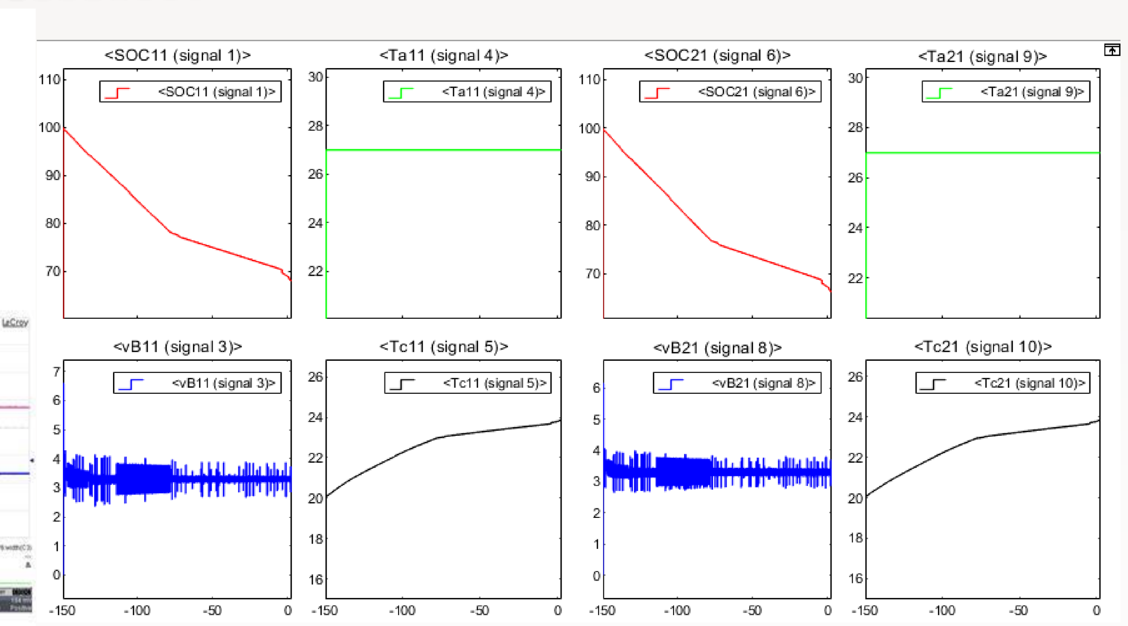


Fig . 3. TABC-1 Battery cell-11 and cell-21: RT simulation profiles of SOC, Battery voltage (vB), Ambient (Ta) and Cell (Tc) temperature.

Closed loop voltage regulation of Lab prototype validations are underway.

Future work

- Efficiency analysis and optimal power control of MABC
- Health monitoring of DPP based battery
- Complete lab prototype and real time simulations of (eFPGAsim OP5700) of MABC based DPP.
- Improve the design high frequency transformer and analyze the performance with different advanced core materials.

Recent Publications

[1] N. Pragallapati, S. K. J. Ranade, M. Jacob and S. Atcitty, "Distributed TABC based Bi-Directional Converter for Cell/Sub-Modular Level Battery Energy Storage System," *2019 IEEE Texas Power and Energy Conference (TPEC)*, Texas, 2019.
[2] N. Pragallapati and S. K. J. Ranade, "Cascaded H-Bridge MLI based Grid Connected Cell Level Battery Energy Storage System," 2020 First International Conference on Power, Control and Computing Technologies (ICPC2T), Raipur, India, 2020, pp. 359-362.

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