pcim ASIA

Combined Scheme of Lithium-ion Battery Equalization with Energy Support Capabilities for Electric Vehicle Applications

E. Tsioumas, N. Jabbour, and C. Mademlis
School of Electrical and Computer Engineering
Aristotle University of Thessaloniki, Greece

EMLab

ARISTOTLE UNIVERSITY OF THESSALONIKI

OUTLINE OF THE PRESENTATION

- Overview of the control problem
- Aim of the paper
- Proposed hybrid Energy Storage System
- Equalization and Energy Support Algorithms
- Simulation results
- Conclusions

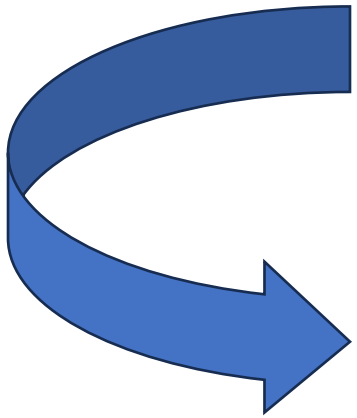
I. Overview of the Control Problem

The Li-ion batteries concentrate several ***competitive advantages*** against other battery chemistries, such as:

- low self-discharge characteristics,
- high discharge/charge rate of current, and
- high-energy density

However, they ***have several drawbacks***, such as:

- the limited calendar life,
- safety issues,
- high cost and also,
- their performance should be carefully monitored and controlled, since they are sensitive with the temperature, overcurrent and overvoltage/undervoltage



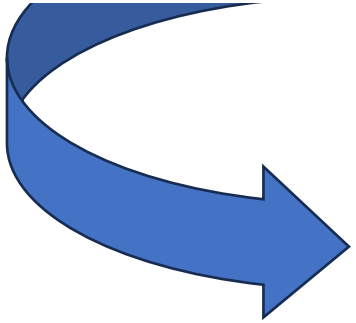
Objectives to improve the energy sustainability in Electric Vehicle applications:

- extension of the Li-ion batteries lifespan and
- reduction of the charging time to reach 80% SoC (state-of-charge) in less than 20min

I. Overview of the Control Problem

Since the nominal voltage of a Li-ion battery cell is relatively low, ...several cells are usually ***series connected*** to provide the needed voltage.

… the reason for ***imbalance problems*** between the battery cells which are owed to differences in the operating characteristics, such as self-discharge rate, coulomb efficiency, and energy capacity.
The above, along with a potential increase in the internal resistance may lead to considerable ***reduction of the energy storage and power response capabilities***.



- to reduce the imbalances between the cell operation and
- keep their operation within acceptable limits of temperature, current, and voltage

I. Overview of the Control Problem

pcim ASIA

Cell-to-cell equalization methods :

- ***non-dissipative*** and
- ***dissipative***

Common characteristic for their implementation ... is the requirement for the real-time knowledge of the battery cells parameters (SoF, SoC, SoH).

From the ***impedance***, several useful information for the electrochemical condition of a Li-ion battery cell can be extracted.

It can be estimated through the ***Electrochemical Impedance Spectroscopy (EIS) technique***

- ***single frequency*** and
- ***broadband***.

I. Overview of the Control Problem

pcim ASIA

Cell-to-cell equalization

Cell-to-cell equalization methods :

- ***Energy dissipative***

the equalization energy is ***consumed*** by an ohmic resistance and they are categorized as ***passive*** and ***active***

a resistance is connected in parallel with each battery cell to absorb the excess energy

a power switch with an ohmic resistance in series connection is used to regulate the rate of the energy absorption

***(Passive vs active**: simpler and cost effective but less efficient)*

- ***Energy non-dissipative***

the equalization energy is ***exploited*** by the other cells of a battery stack
(*more efficient, however, more expensive and complicated in the implementation and, thus, more vulnerable to faults*)

II. AIM OF THE PAPER

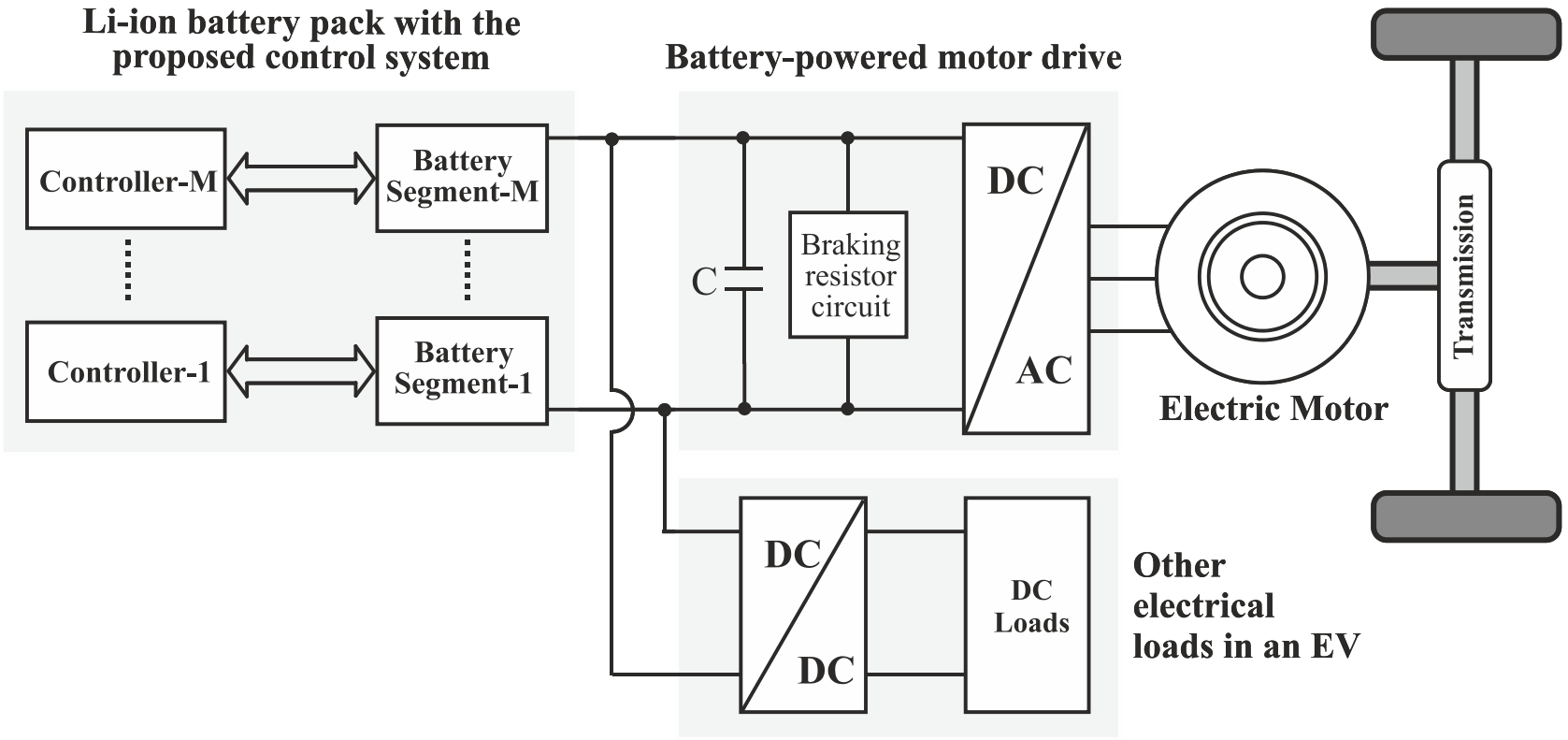
pcim ASIA

… an advanced DC microgrid topology and the respective control algorithm that provides enhanced equalization and dynamic performance of the Li-ion battery storage system in electric vehicle applications.

Characteristics:

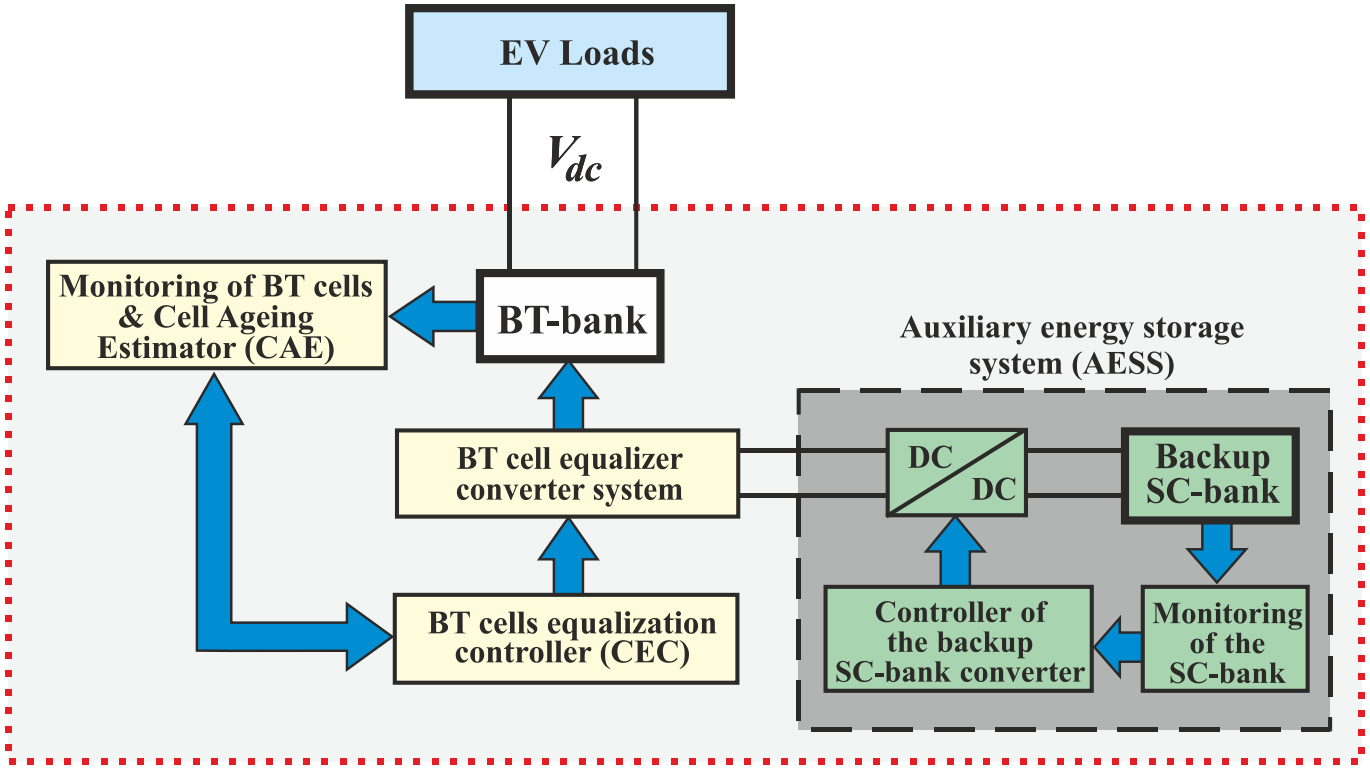
- **It is a hybrid energy storage system** that consists of Li-ion batteries for the main energy reservoir in back-to-back connection with an auxiliary energy storage system (AESS) of supercapacitors (SCs) or Li-ion battery cells.
- **The AESS** *improves the battery cell-to-cell equalization* and *provides energy support to any weak or problematic cells* and also, *enhances the dynamic performance of the vehicle* by providing reinforcing energy during a fast vehicle acceleration and energy saving by absorbing any excess energy during abrupt braking of a vehicle.
- **A DC-DC converter combined with a matrix switch system** is used to manage the energy flow of the AESS.
- **Selective simulation results** are presented to validate the operating improvements of the proposed DC microgrid control scheme with Li-ion battery

III. Proposed hybrid Energy Storage System



Overview of the proposed battery management system in a typical DC microgrid topology with the electric motor drive of an EV

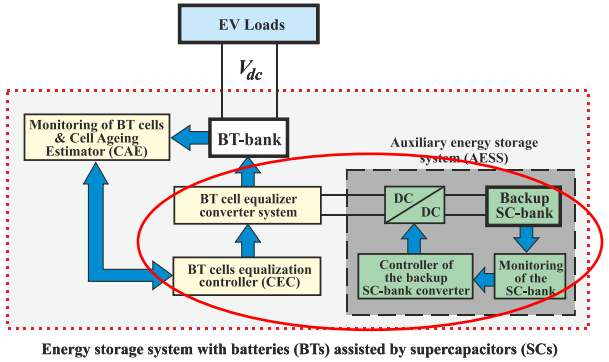
III. Proposed hybrid Energy Storage System



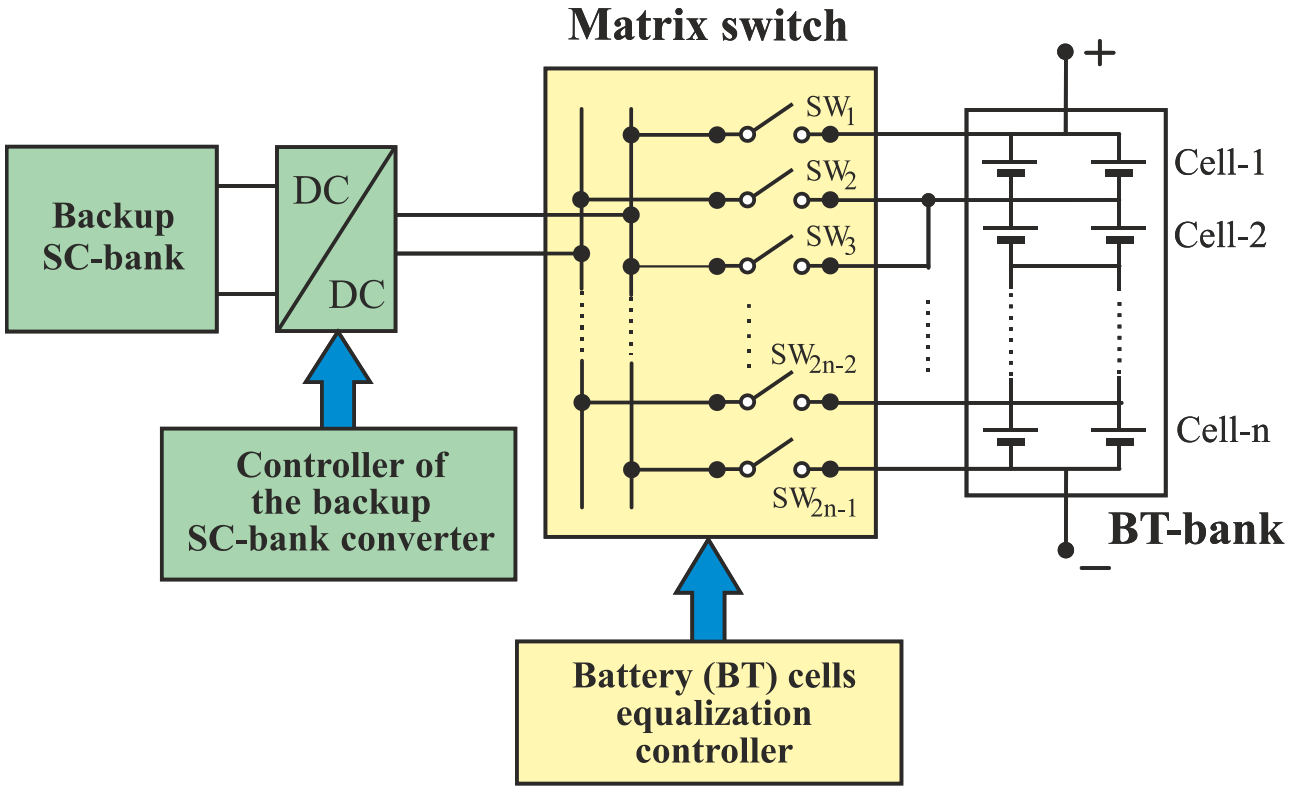
Energy storage system with batteries (BTs) assisted by supercapacitors (SCs)

DC microgrid topology of the BSS with auxiliary energy storage system (AESS) of supercapacitors (SCs) for electric vehicle applications

III. PROPOSED HYBRID ENERGY STORAGE SYSTEM

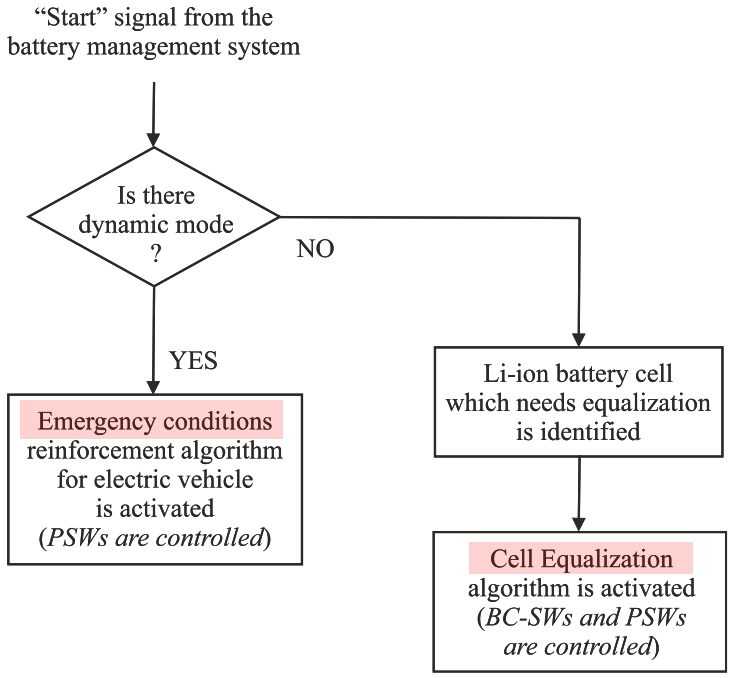


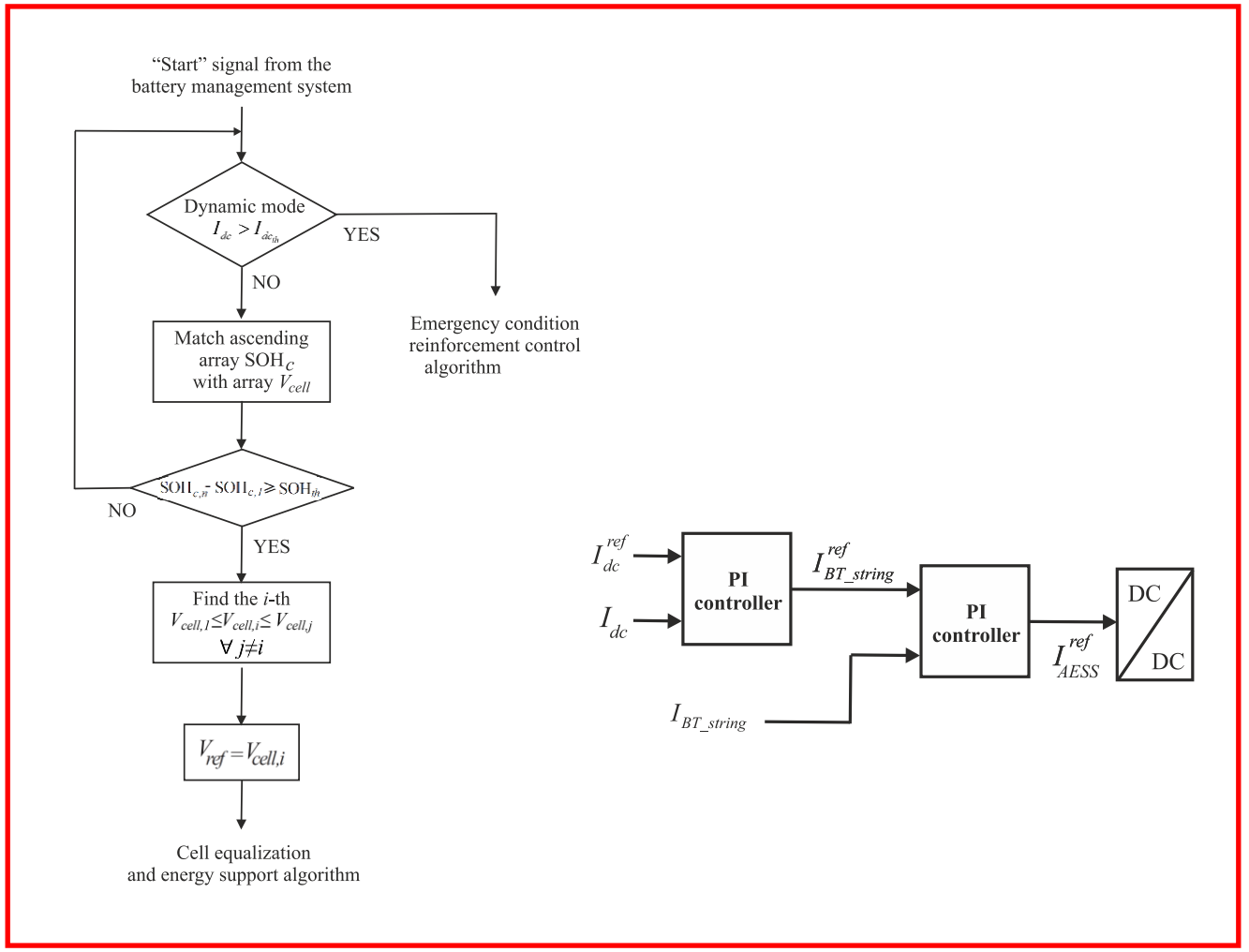
Energy storage system with batteries (BTs) assisted by supercapacitors (SCs)



Structure of the proposed equalization scheme for the hybrid energy storage system

III. EQUALIZATION AND ENERGY SUPPORT ALGORITHMS





V. Simulation Results

pcim ASIA

TABLE I

PARAMETERS OF THE LI-ION BATTERY AND THE SC-BASED AESS

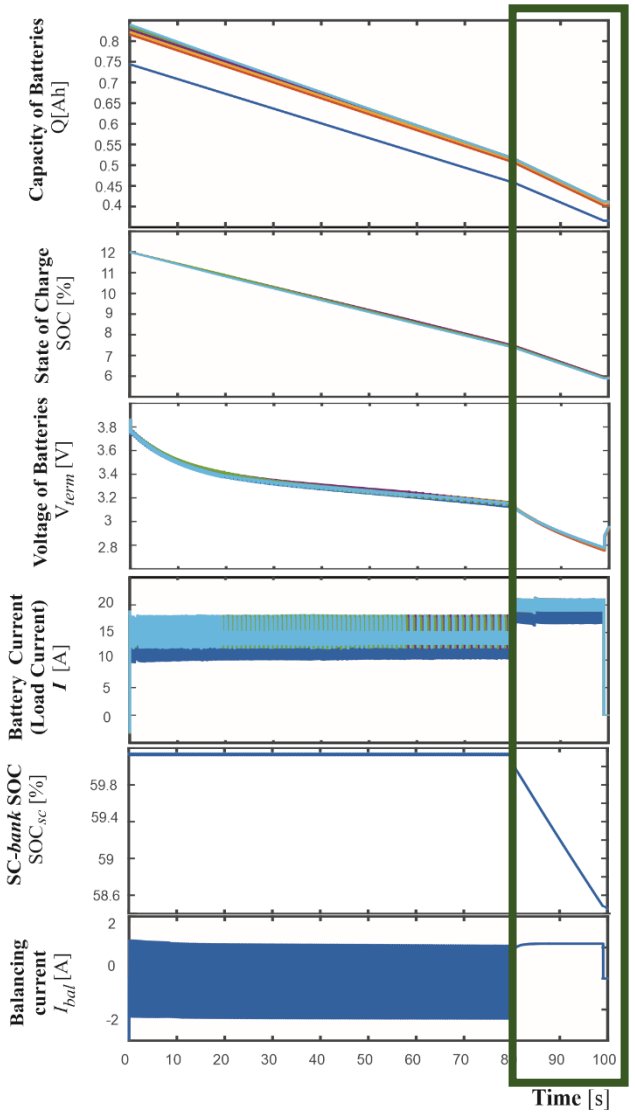
Li-ion battery parameters	
Nominal Capacity	7 Ah
Nominal Voltage	3.7 V
Internal Resistance	5.2 mΩ
SC-Bank parameters	
SC-bank equivalent capacitance	C_{SC}=200 F
SC-bank rated voltage	8.1 V
SC-bank max continouus current ($\Delta T=15^{o}C$)	50 A (RMS)

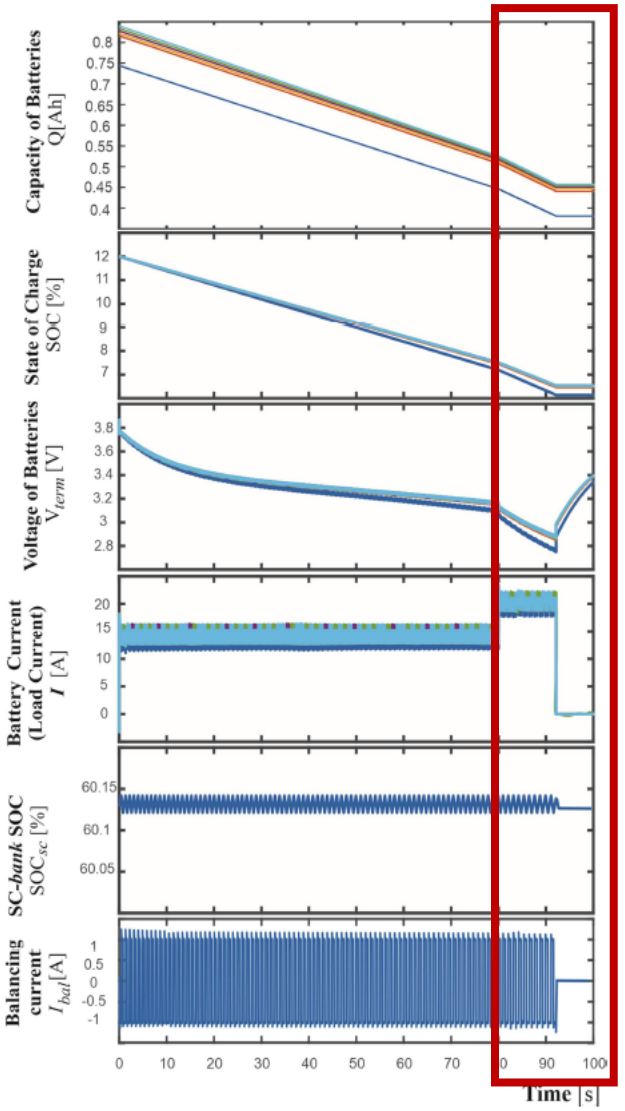
V. Simulation Results

pcim ASIA

*Performance of the **proposed** **DC microgrid** scheme with a Li-ion BT pack of 6 cells and a SC-bank for the AESS*

Initial voltage of the SC-bank of the AESS is 7V





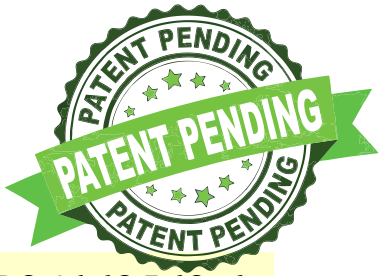
*Performance of the DC microgrid with a Li-ion BT pack of 6 cells with a **conventional** **system** where only cell equalization is provided without energy support and dynamic enhancement of the BSS.*

Initial voltage of the SC-bank of the AESS is 7V.

VI. CONCLUSIONS

pcim ASIA

- ***An advanced DC microgrid topology and the respective control algorithm*** for a hybrid energy storage system with Li-ion BTs and SCs that can enhance the BT cell equalization and improve the dynamic performance of an electric vehicle.
- ***An auxiliary energy storage system (AESS)*** has been utilized and a ***non-dissipative equalization technique*** has been adopted that is managed by the Cell Equalizer Controller (CEC).
- The energy flow through the AESS is regulated by a ***DC-DC converter combined with a matrix switch system*** which connects the AESS with any battery cell that needs support detected by the Cell Ageing Estimator (CAE).
- ***Simulation results*** comparing the proposed control scheme with a conventional system where only cell equalization is provided without energy support and dynamic enhancement of the BSS.



EP EP24169562.6
&
US 18629976
'*Hybrid energy storage system of batteries and supercapacitors*'.