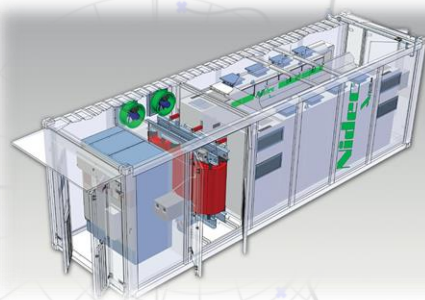




Battery management system - BMS

Prof. Allan Fagner Cupertino
afcupertino@ieee.org



Tópicos a serem abordados

Por que o BMS é necessário?



Funções do BMS;



Arquiteturas de BMS;

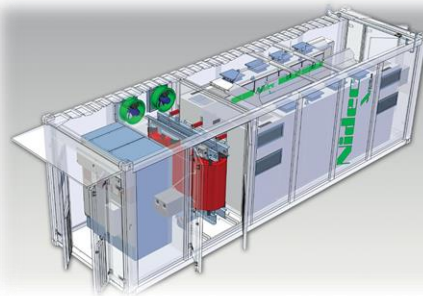
Estrutura interna.



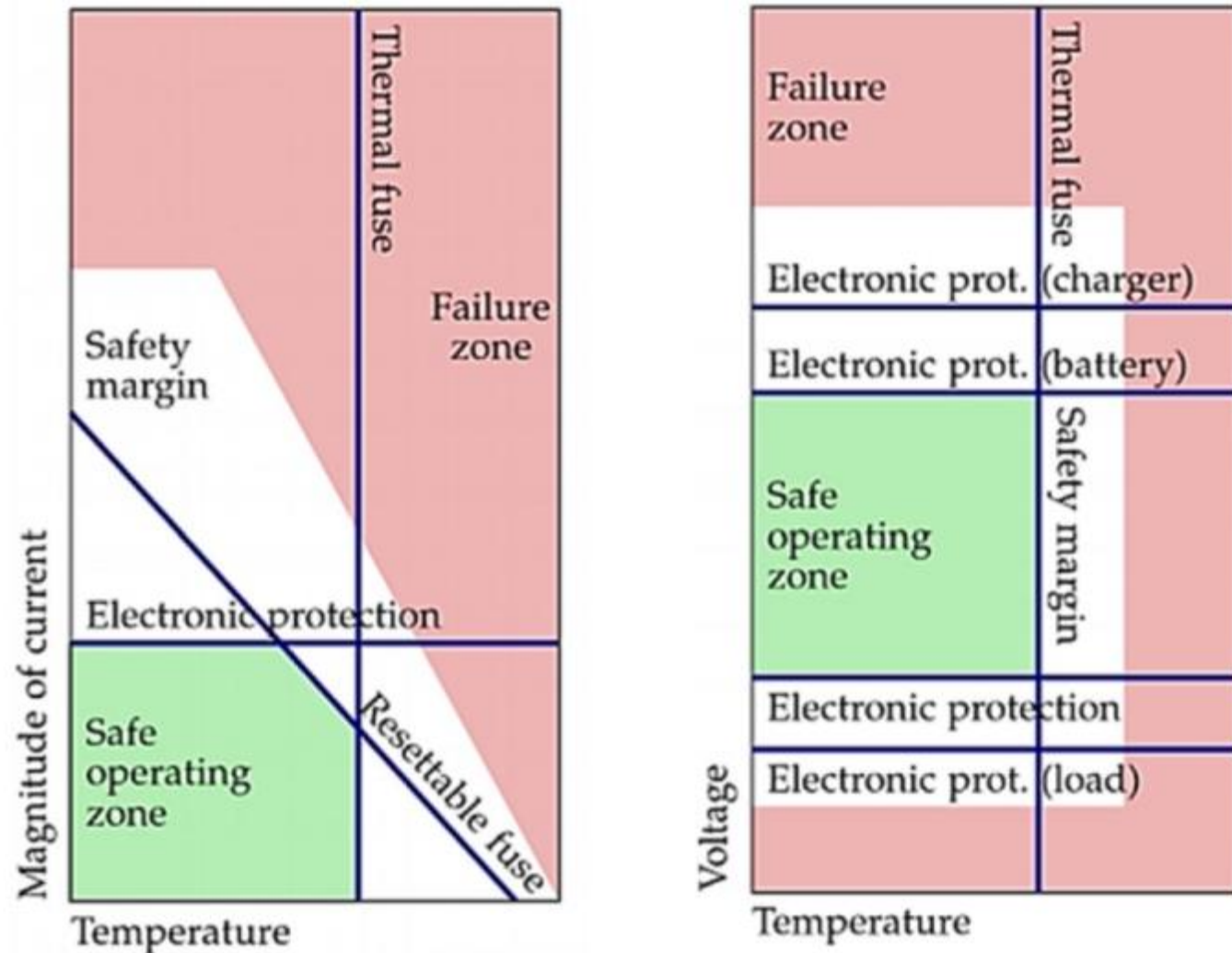


Por que utilizar o BMS?

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Por que o BMS é necessário?



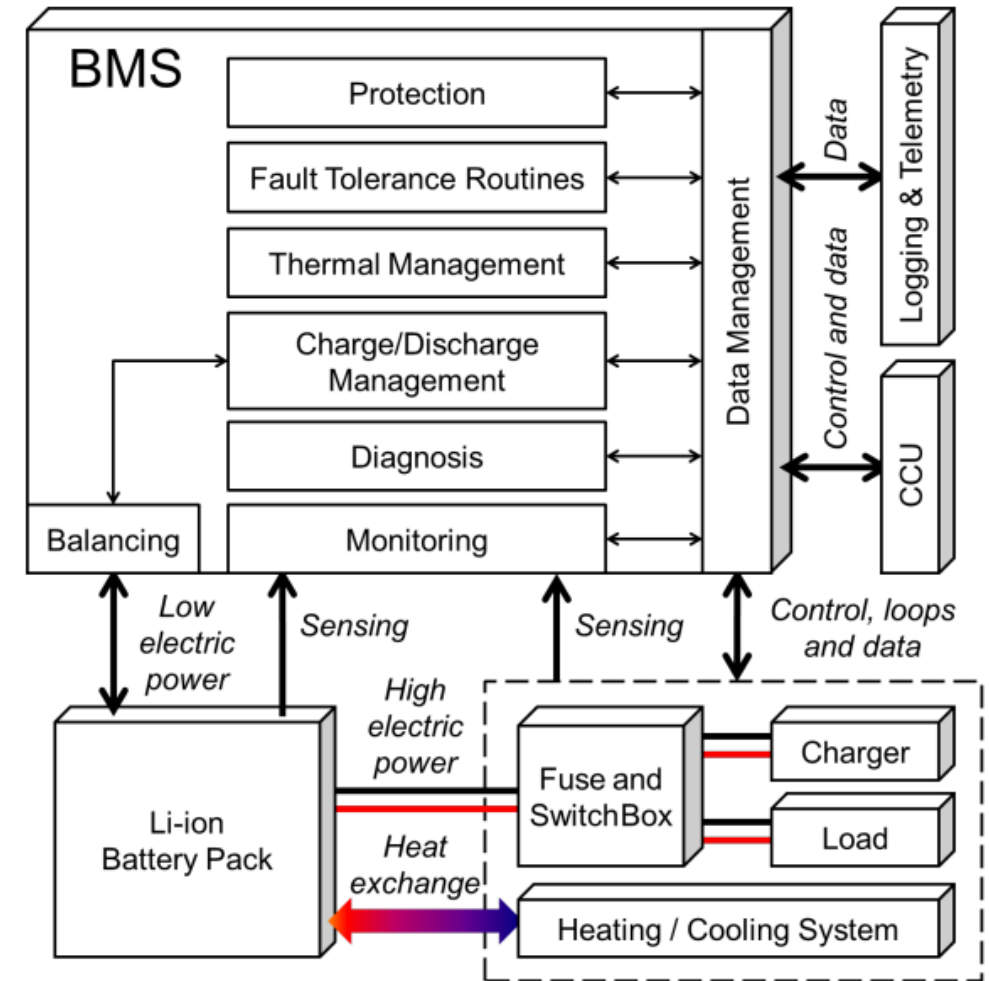
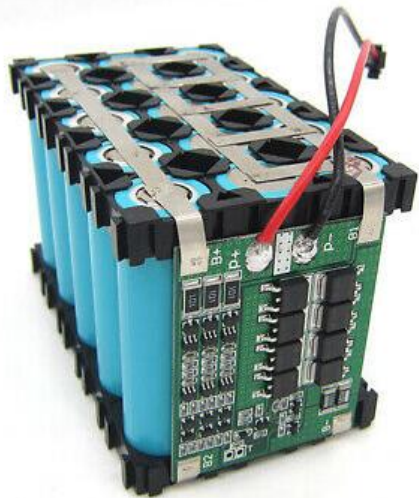
Fonte: S. Park et. al. "Review of state-of-the-art battery state estimation technologies for battery management systems of stationary energy storage systems". Journal of Power Electronics. 2020.

Por que o BMS é necessário?



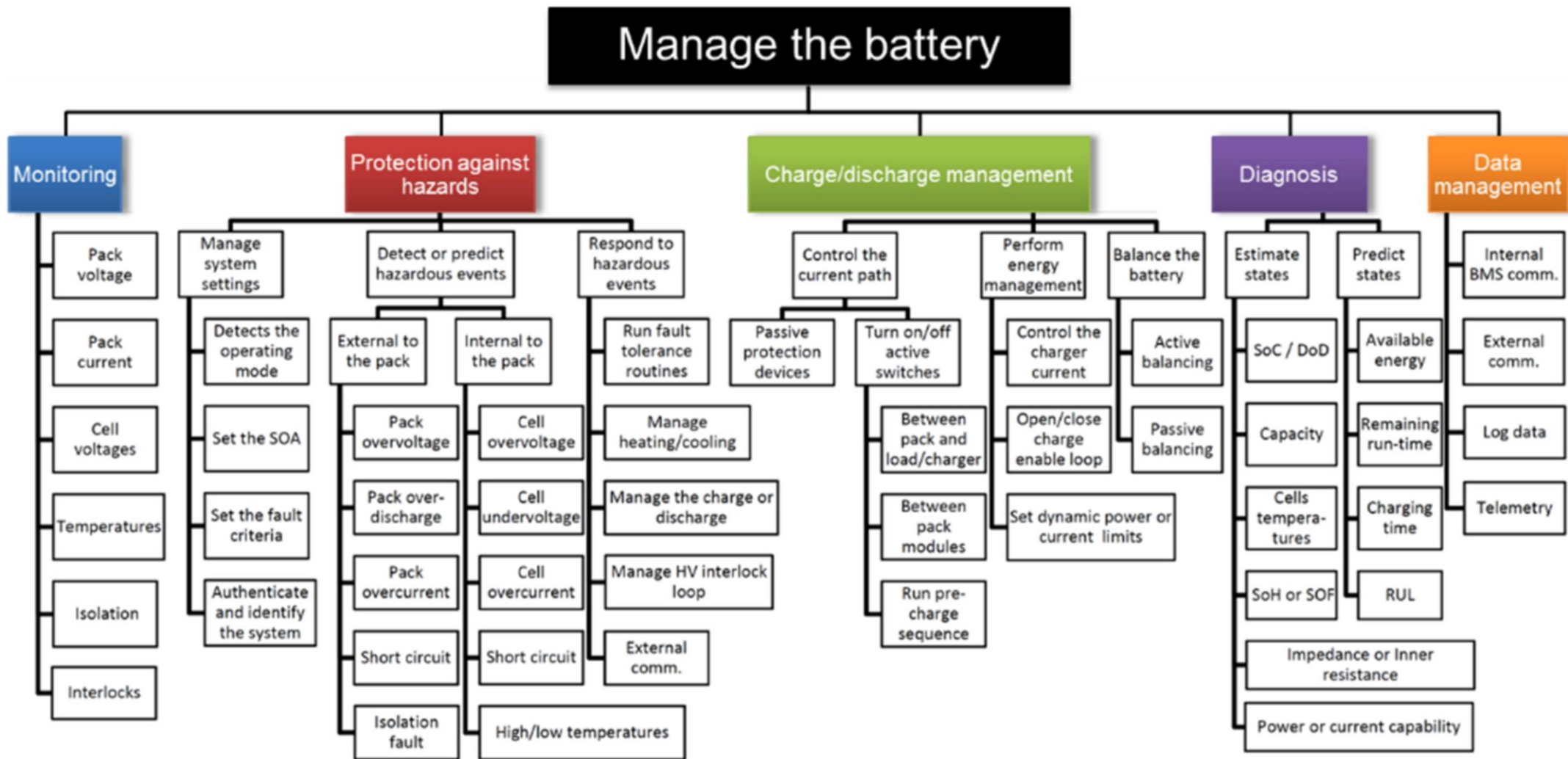
Funcionalidades do BMS

“A battery management system (BMS) turns a collection of dumb cells into an intelligent and safe battery pack.” Lithium Balance.



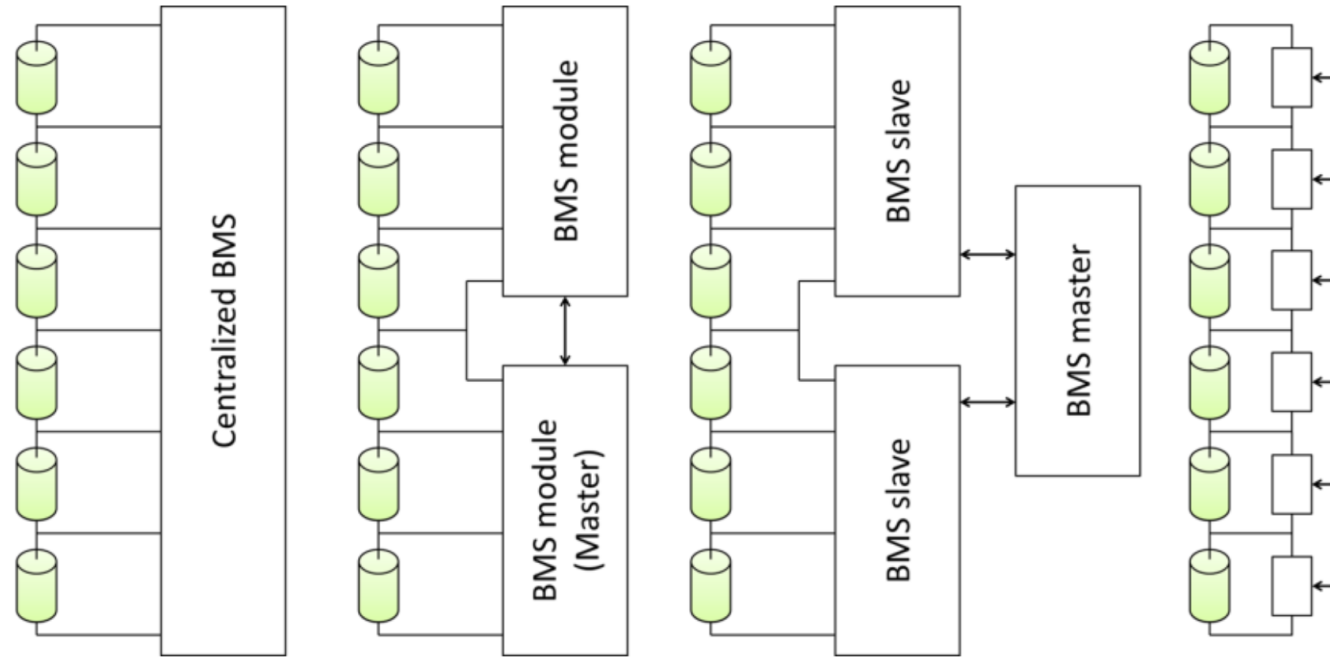
Fonte: J. V. Barreras et. al. “Fuse and Switch Box Design, Modeling and Characterization in HIL Simulation Environment for BMS Testing” International Conference on Sustainable Mobility. Applications (SMART2015), 2015

Funções detalhadas



Fonte: J. V. Barreras. “Practical Methods in Li-ion Batteries for Simplified Modeling, Battery Electric Vehicle Design, Battery Management System Testing and Balancing System Control “. PhD Thesis. Aalborg University

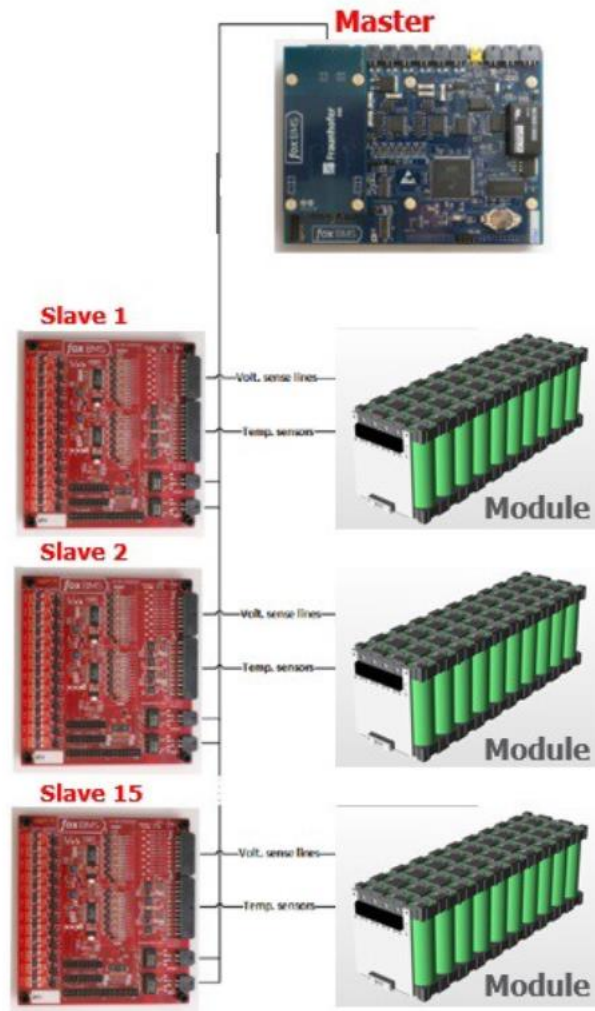
Arquiteturas de BMS



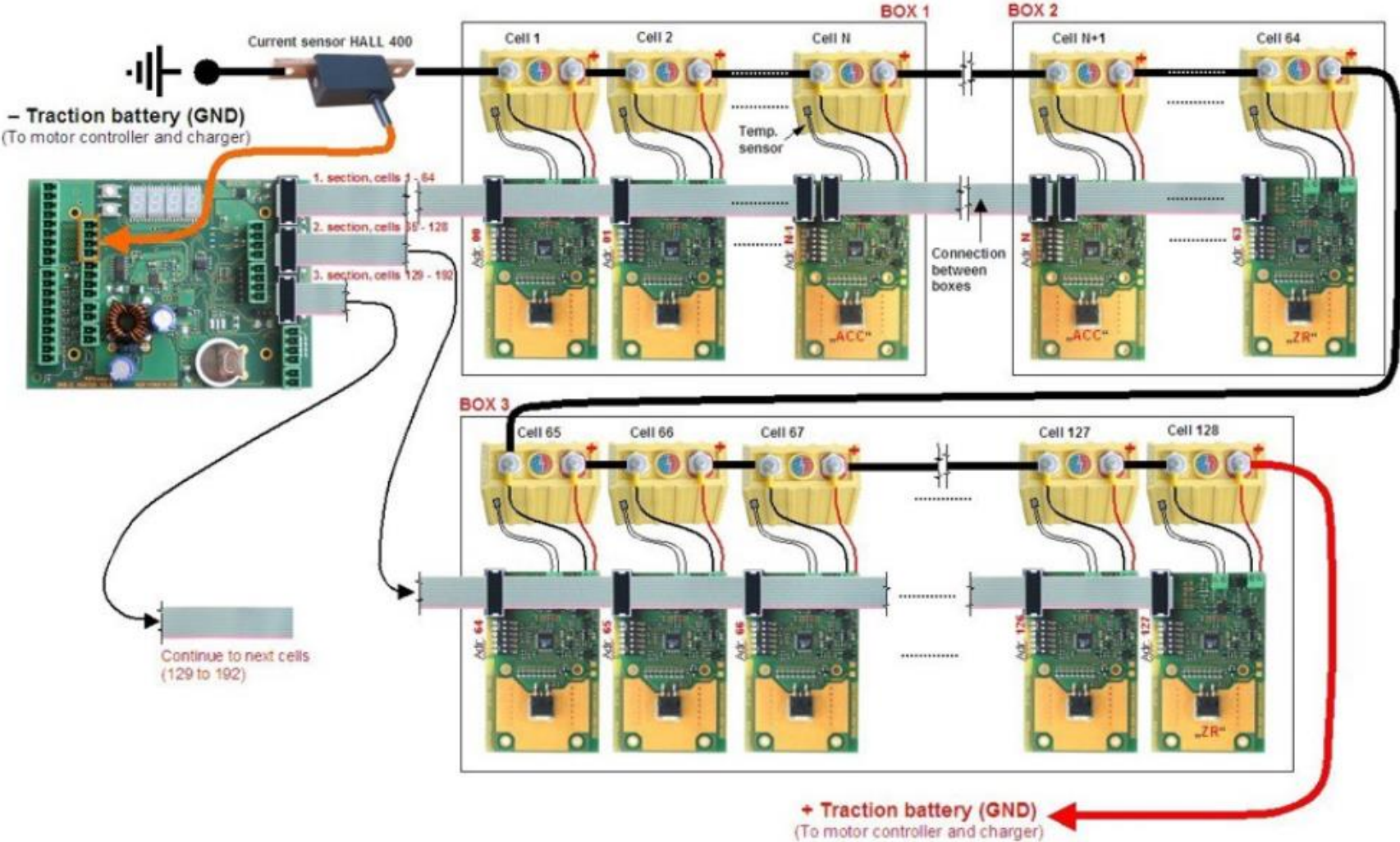
	<i>Measurement Quality</i>	<i>Noise Immunity</i>	<i>Versatility</i>	<i>Safety</i>	<i>Electronics Cost</i>	<i>Assembly Cost</i>	<i>Maintenance Cost</i>
Centralized	✓✓	✓✓✓	✓	✓	✓	✓✓	✓
Master-Slave	✓✓	✓✓✓	✓✓	✓	✓✓✓	✓✓	✓
Modular	✓✓	✓✓✓	✓✓	✓	✓✓✓	✓✓	✓
Distributed	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓	✓✓

✓✓✓ = Best; ✓✓ = Better; ✓ = Good

Exemplos de BMS



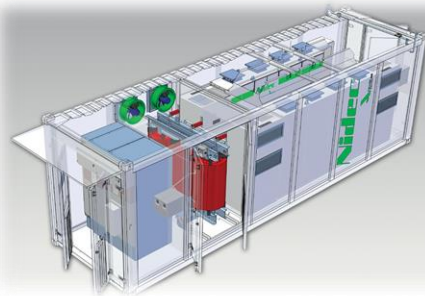
Exemplos de BMS





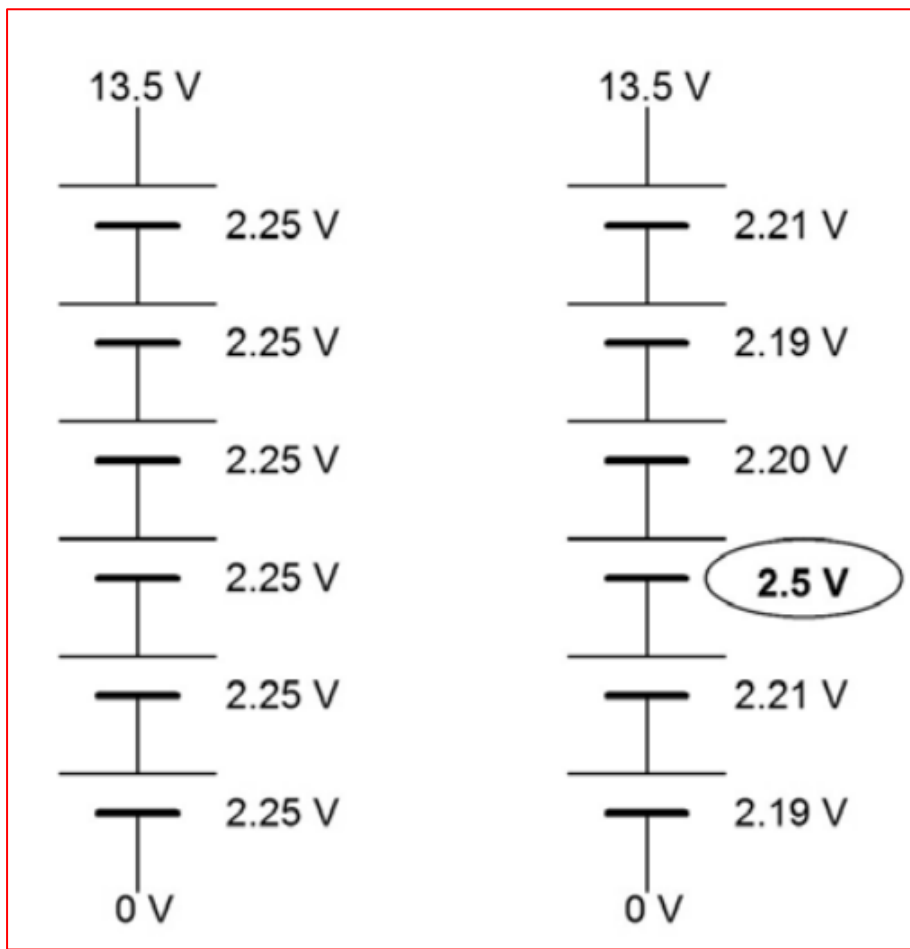
Balanceamento das tensões das células

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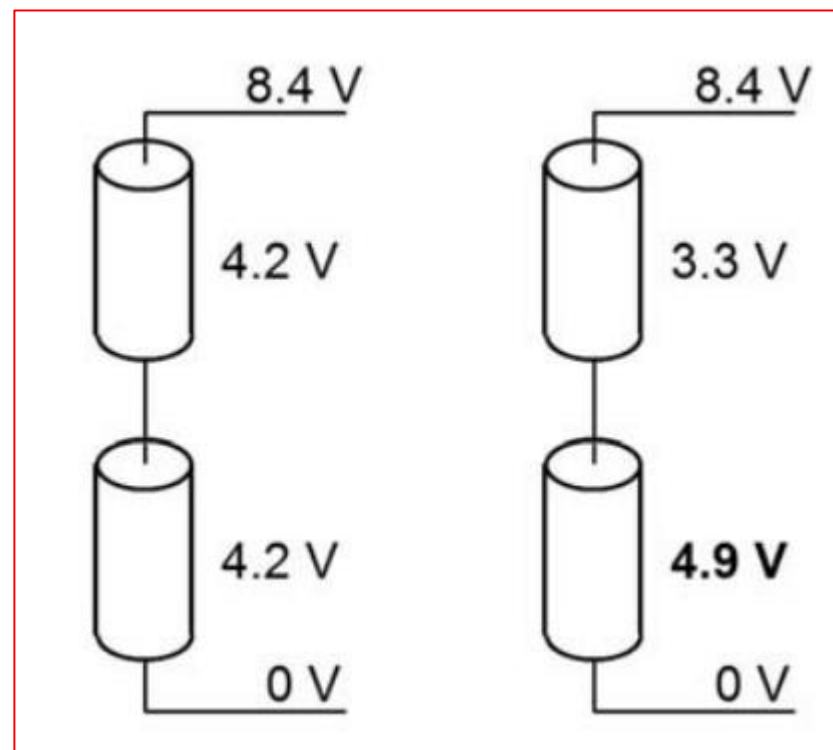


Exemplo – Desbalanceamento das tensões

Chumbo ácido

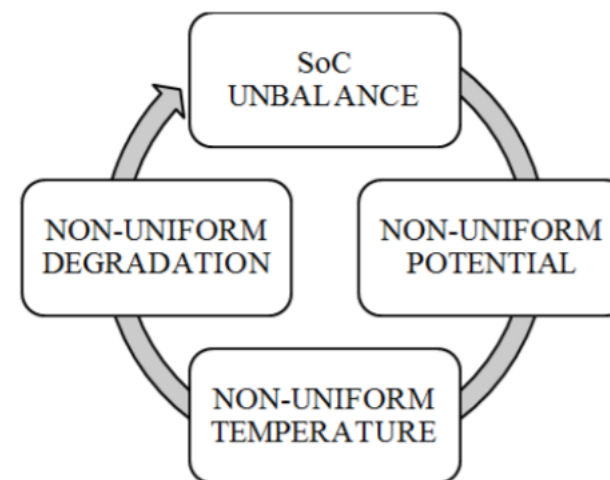
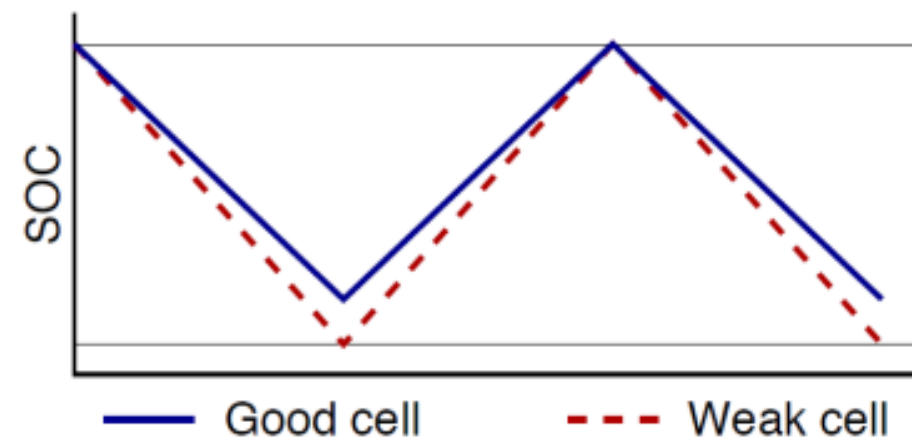
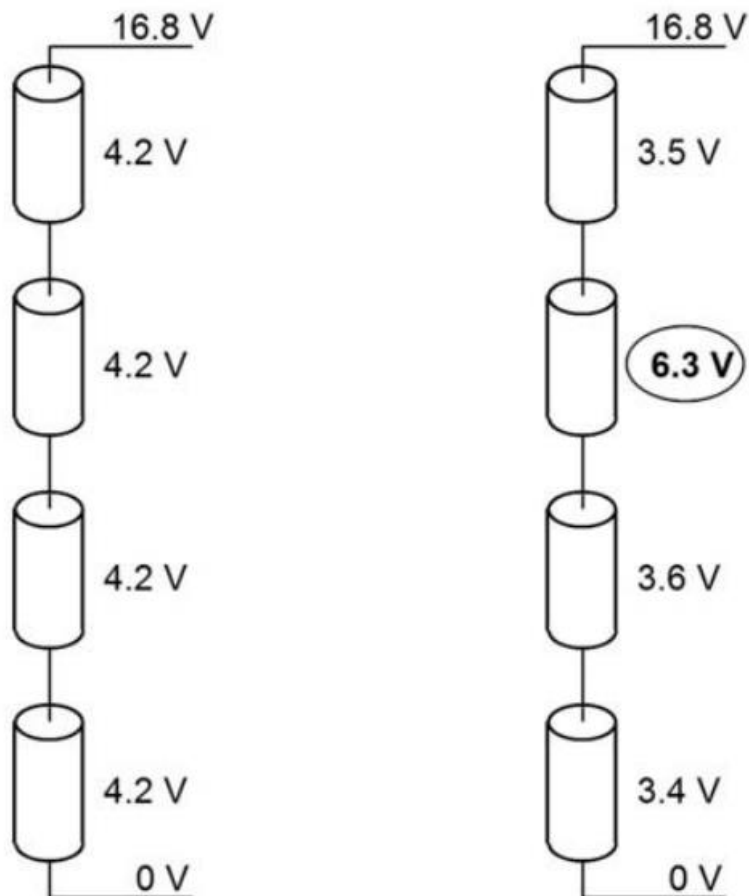


LiPo



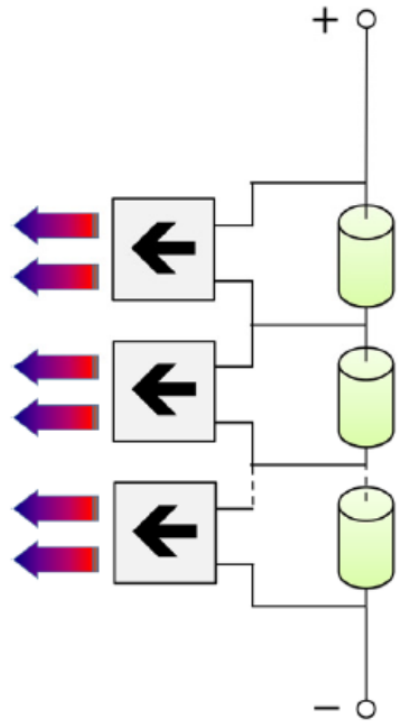
Fonte: D. Andrea. "Battery Management Systems for Large Lithium-Ion Battery Packs". Artech House. 2010.

Exemplo – Desbalanceamento das tensões

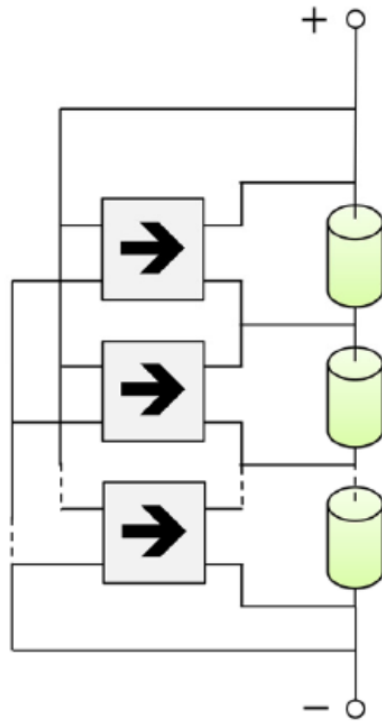


Fonte: D. I. Stroe. "Storage Systems based on Lithium-Ion Batteries for Grid Support and Automotive Applications." PhD Course. Aalborg University. 2018

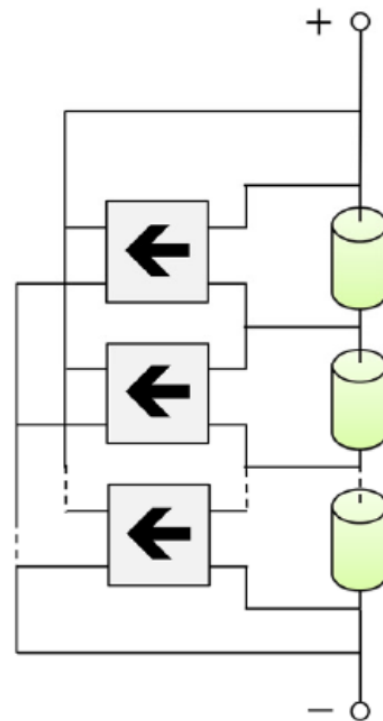
Estratégias de balanceamento



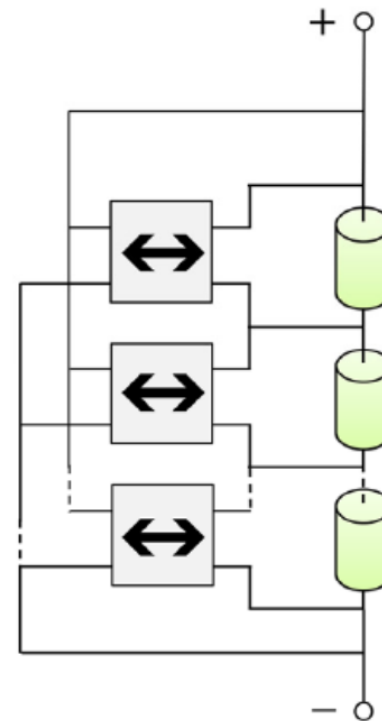
Cell-to-heat
(i.e. passive)



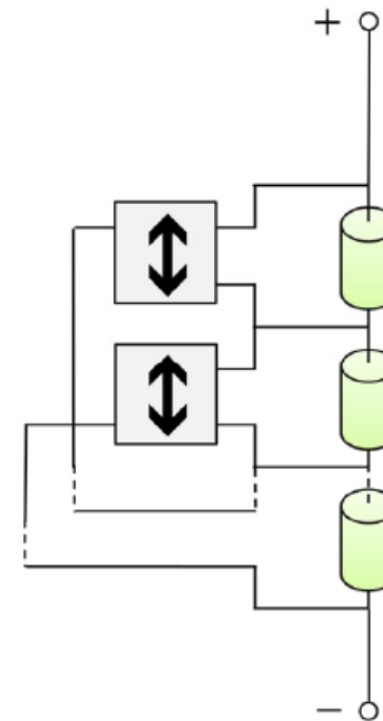
Pack-to-cell



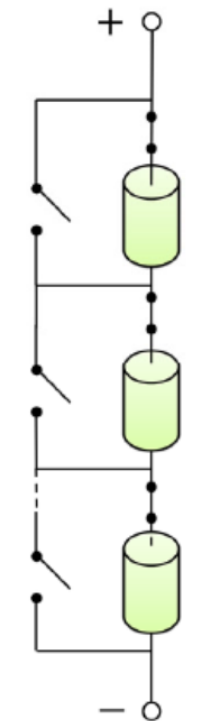
Cell-to-pack



Cell-to-cell
shared



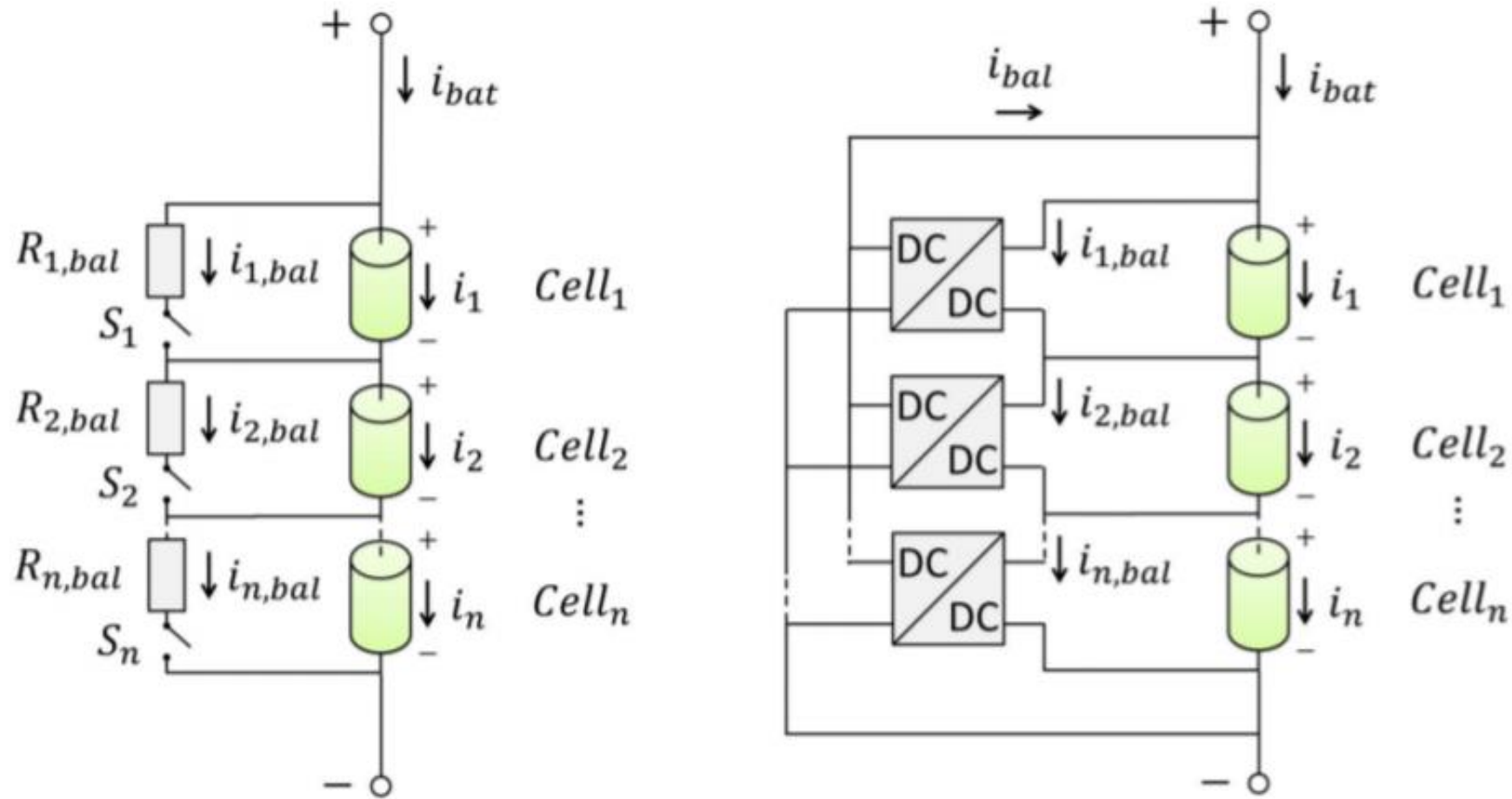
Cell-to-cell
distributed



Bypass

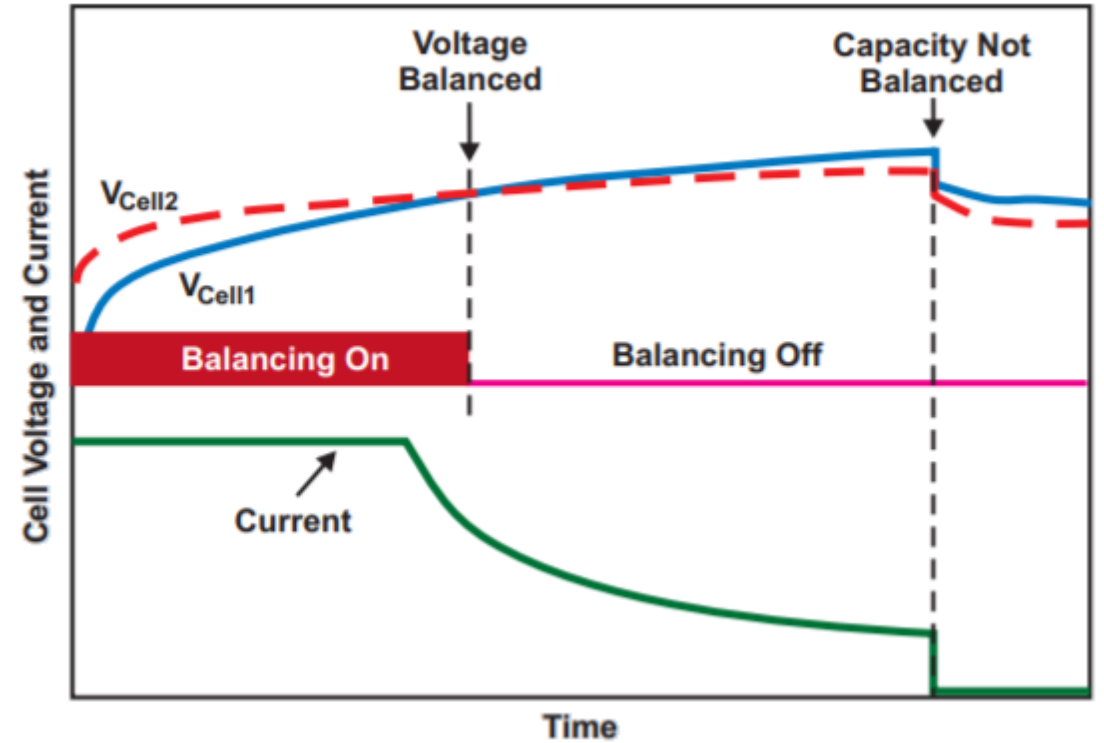
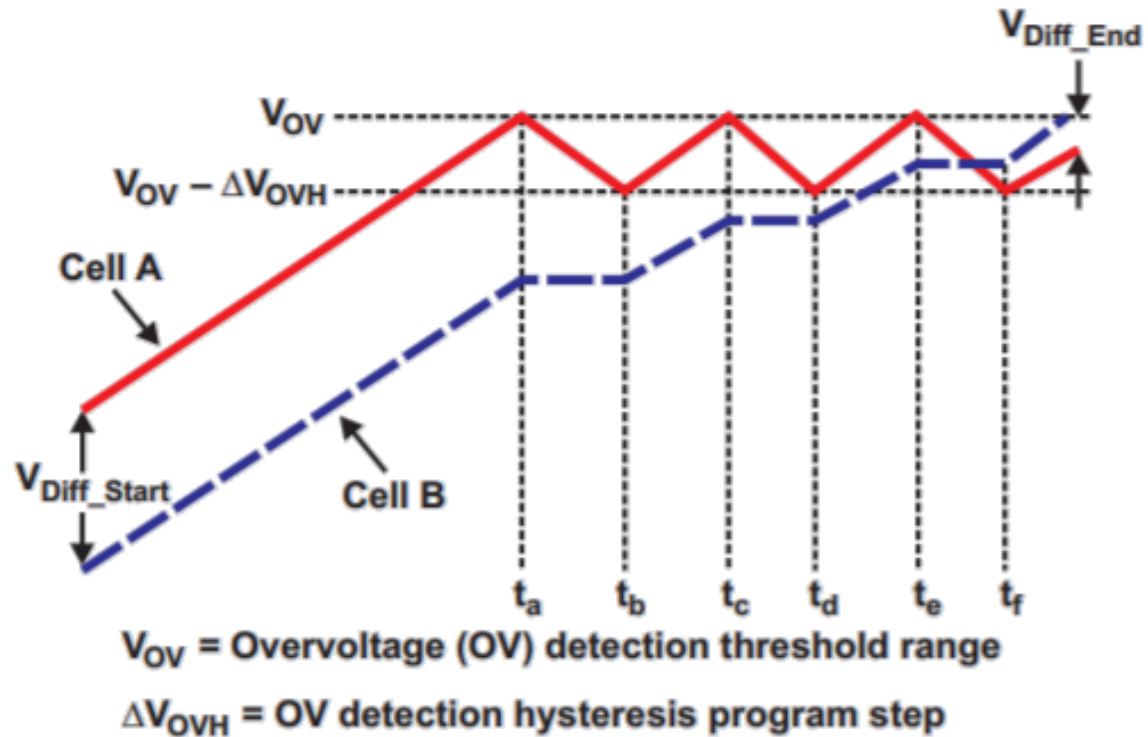
Fonte: J. V. Barreras et. al. “Multi-Objective Control of Balancing Systems for Li-Ion Battery Packs: A Paradigm Shift?” Vehicle Power and Propulsion Conference. 2014.

Estratégias de balanceamento



Fonte: J. V. Barreras et. al. "Multi-Objective Control of Balancing Systems for Li-Ion Battery Packs: A Paradigm Shift?" Vehicle Power and Propulsion Conference. 2014.

Balanciamento de tensão ou de estado de carga?



Fonte: Sihua Wen. "Cell balancing buys extra run time and battery life" Texas instruments. 2009.

Balanceamento de tensão ou de estado de carga?

❑ Balanceamento por tensão

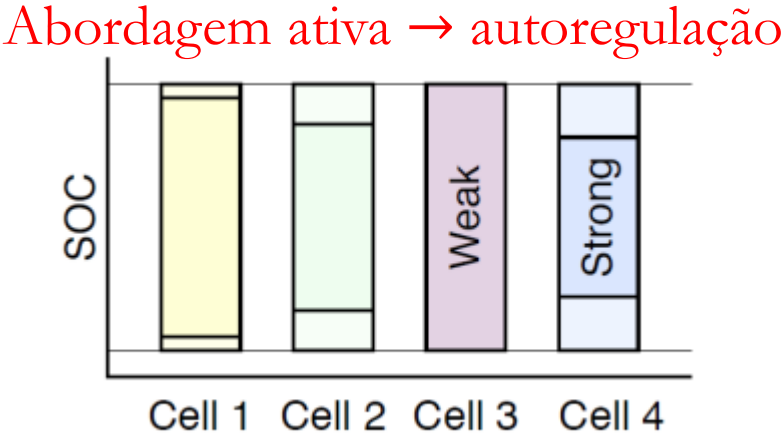
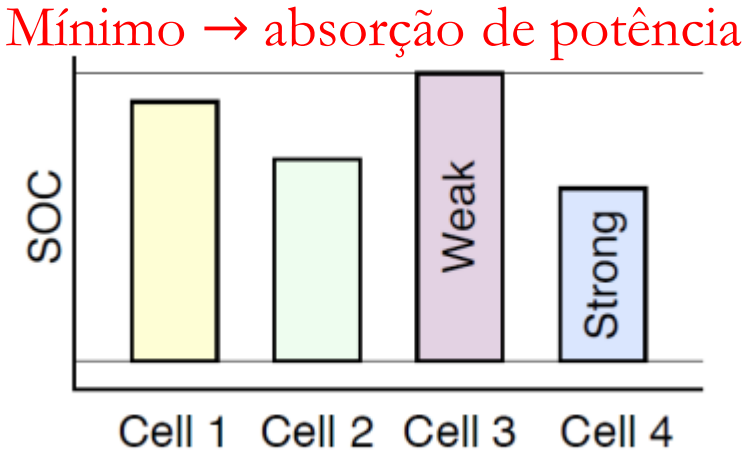
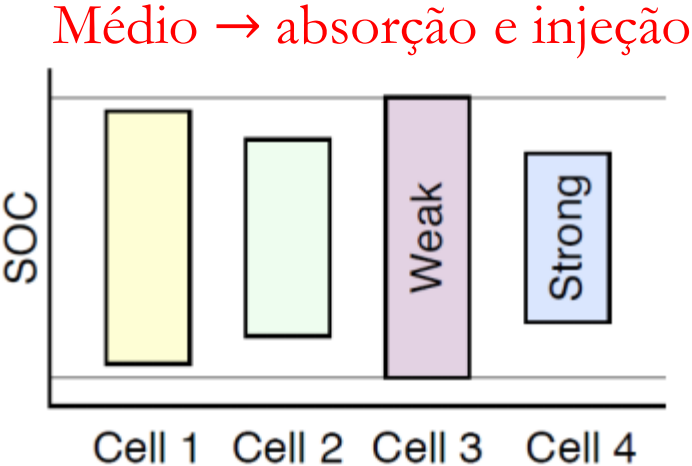
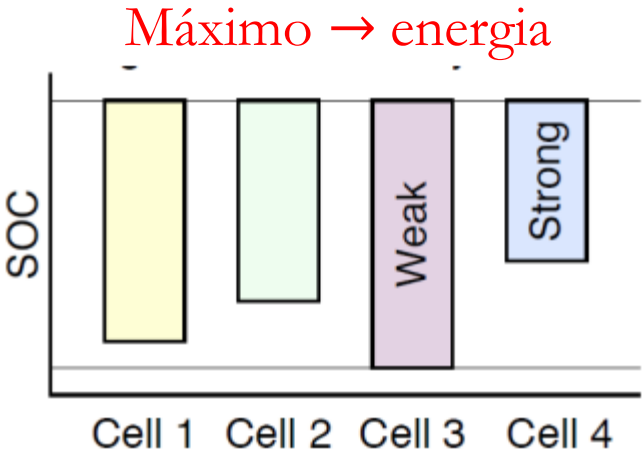
- Estratégia: medição da tensão de cada célula;
- Simples e melhor para situações em que as células são similares;
- Ruim para certas químicas.

❑ Balanceamento por SOC

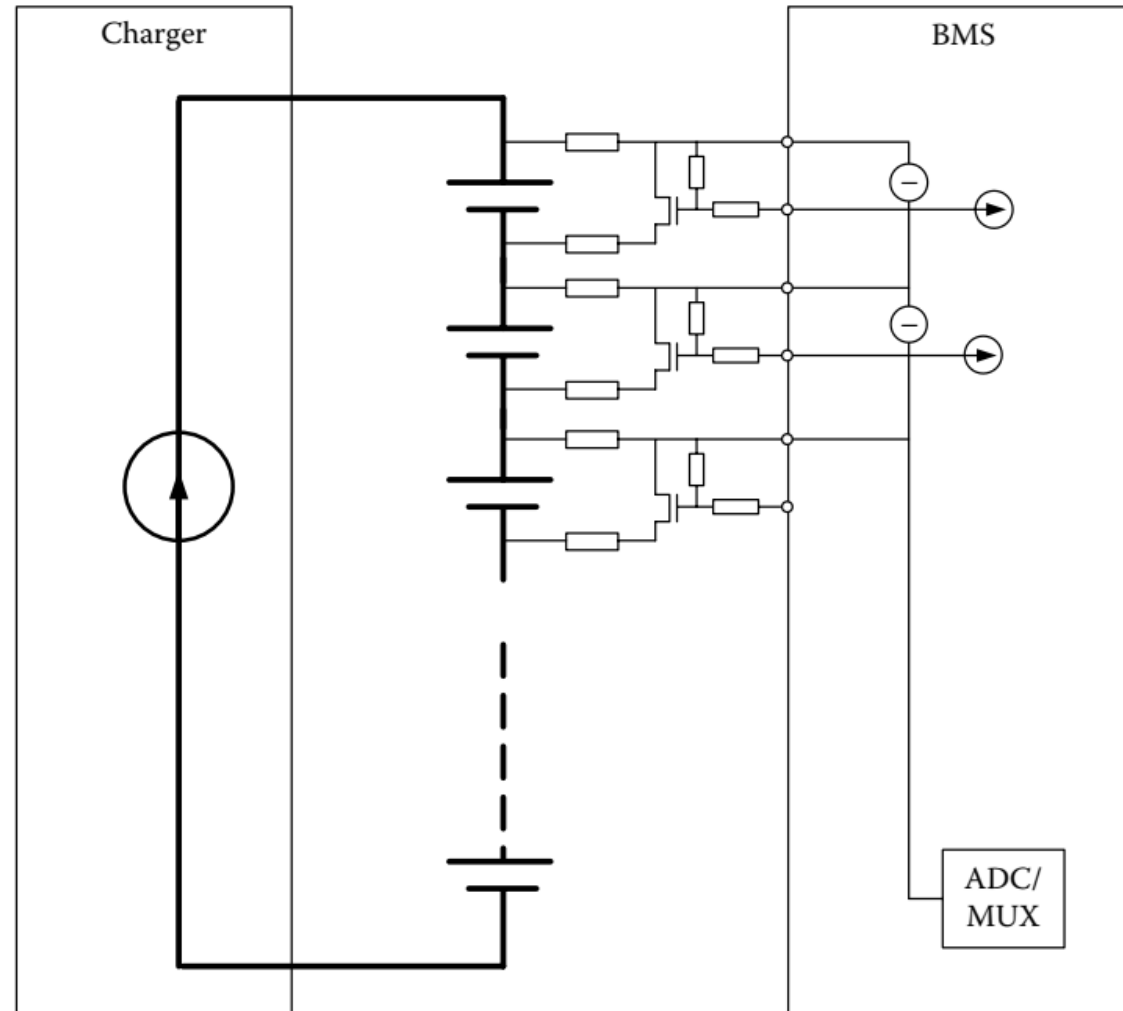
- Estratégia: Estimar o estado de carga de cada célula, capacidade e energia consumida pelo BMS;
- Melhor para células com impedâncias diferentes;
- Maior complexidade.

Fonte: J. V. Barreras et. al. “Multi-Objective Control of Balancing Systems for Li-Ion Battery Packs: A Paradigm Shift?” Vehicle Power and Propulsion Conference. 2014.

Métodos de balanceamento



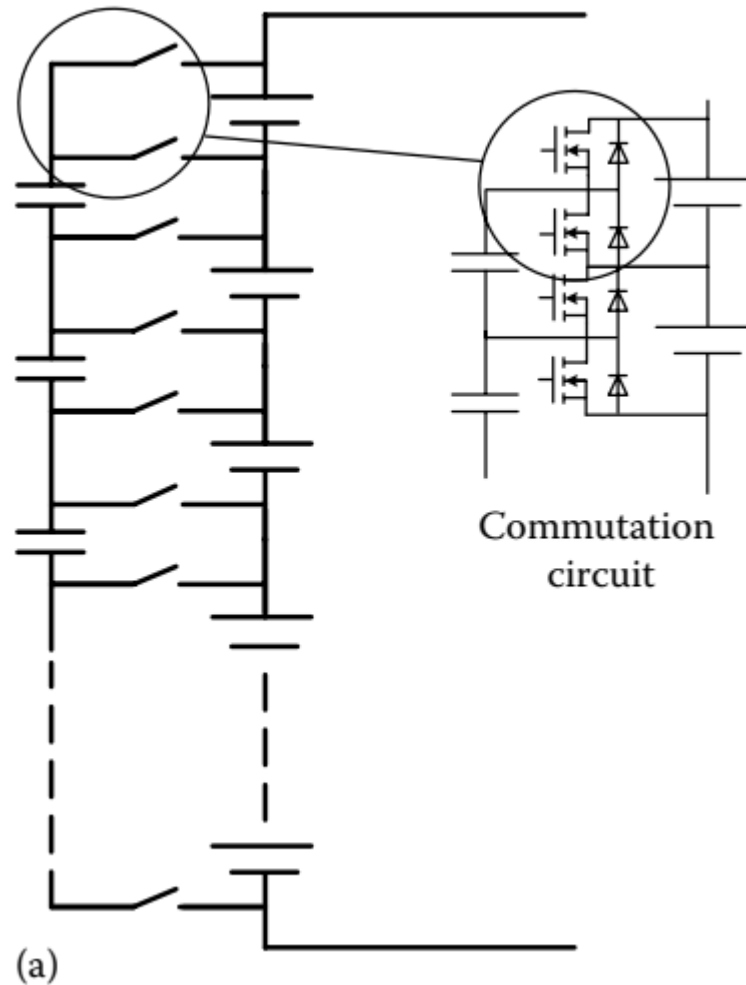
Balanciamento dissipativo



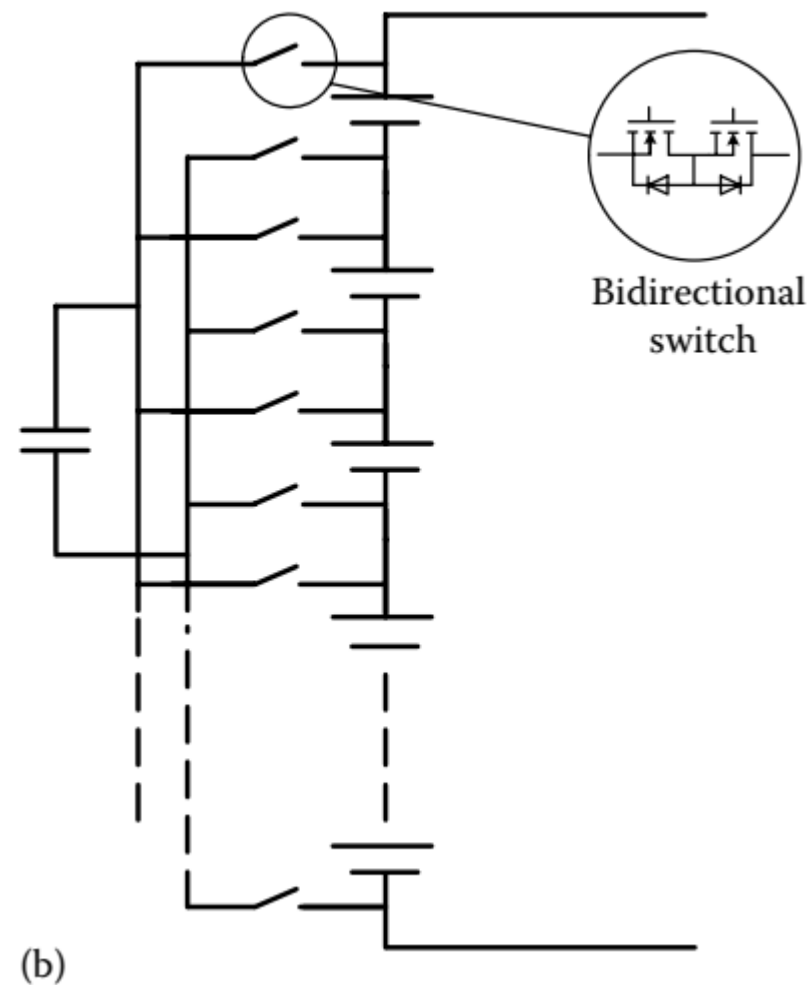
Fonte: A. Rufer. "Energy Storage: Systems and Components," CRC Taylor & Francis Group, 2018.

Balanceamento ativo baseado em capacitores

Capacitor flutuante

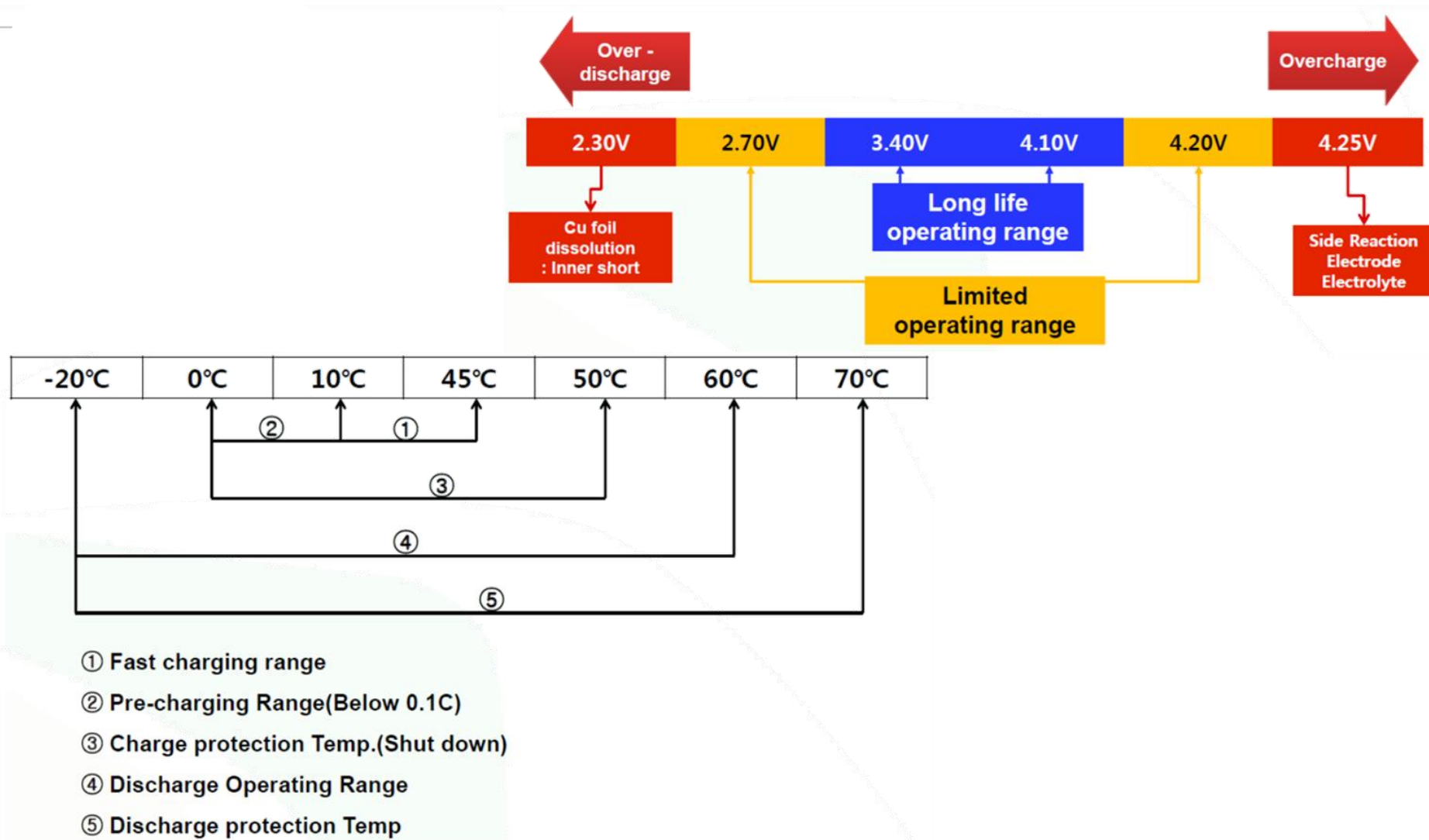


Capacitor chaveado



Fonte: A. Rufer. "Energy Storage: Systems and Components," CRC Taylor & Francis Group, 2018.

Monitoramento



Exemplo de software de monitoramento

The screenshot displays the Diagnostic Software 6.9.0 - Lithium Balance A/S interface. The top status bar shows 'Start up' and 'Errors: 0 | Warnings: 0'. The 'Pack data' section shows SOC at 0%, Current at 0 A, and Voltage at 0 V. The 'System settings' tab is active, showing various parameters for the battery management system.

System status: Start up, Errors: 0 | Warnings: 0

IO-1 to IO-8: Gate, MAIN+ relay, MAIN- relay, Charge enable, Prech. relay, Disch. enable, Error LED, Fan Control, Charger Relay

Pack data:

SOC	Current	Voltage
0 %	0 A	0 V
Highest cell: 0 mV	Lowest cell: 0 mV	Average cell: 0 mV
Highest temp.: 0 °C	Lowest temp.: 0 °C	Average temp.: 0 °C

System settings:

Version: BMCU 20000 0A.06.d.009, SUB 20000 0A.06.d.009, SN, BMCUboot 6, SUBboot 6

Global cell settings:

Cell over voltage	3770 mV
Cell overshoot window	50 mV
Cell target voltage	3600 mV
Charge complete window	100 mV
Charger off window	20 mV
Charge regulating voltage	3500 mV
Cell under voltage	2800 mV
Cell end of life voltage	2200 mV

General settings:

Number of LMU's	32
Shunt resistance	250 $\mu\Omega$
Current offset (mA)	0 mA
Precharge resistor size	50 Ω
Allowed precharge level	5 %
Minimum precharge time	1.5 sec
Current Sensor	Shunt
Settings Checksum Offset	0 bit

Charger settings:

Trickle charge current	0.2 A
Trickle charge temperature	0 °C
Charge current	5 A
Charger minimum current	0.1 A
Charge voltage	925 V
Charger regulation loop time	1 sec
Charger regulation type	Lin
Number of chargers	1
Charge current low power mode	5 A
Charge complete only when balanced	<input type="checkbox"/>

Pack settings:

Initial total capacity	100 Ah
Calculated total capacity	100 Ah
State of health	0 %
Parallell strings	1
Max. discharge current	10 A
Max. regen. current	0.5 A
Max volt diff (charge)	3 %
Max volt diff (discharge)	10 %

Warning levels:

High cell voltage	3650 mV
Low cell voltage	2900 mV
High cell temperature	50 °C
Low cell temperature	5 °C
High LMU temperature	10 °C
Low LMU temperature	75 °C
High current IN	4 A
High current OUT	95 A
Pack resistance diff.	100 m Ω
High pack resistance	1000 m Ω
Cell resistance diff.	10 m Ω
High cell resistance	10 m Ω
High BMCU supply voltage	15 V
Low BMCU supply voltage	9 V
Low SOC	10 %

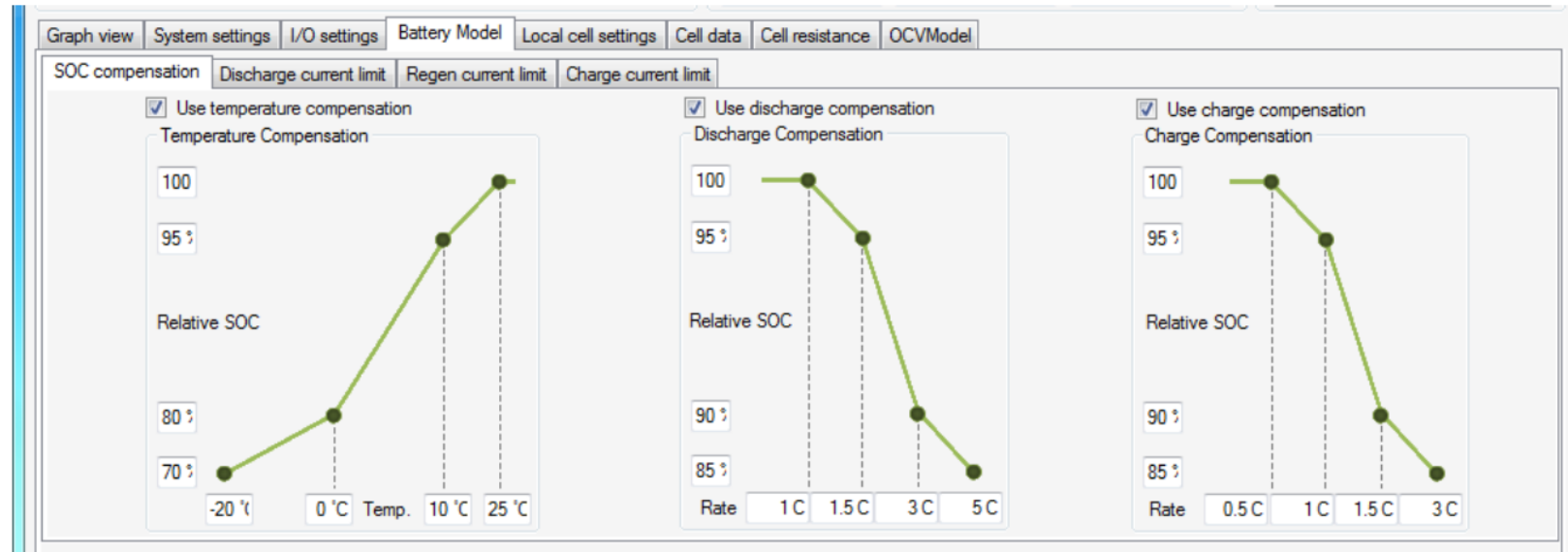
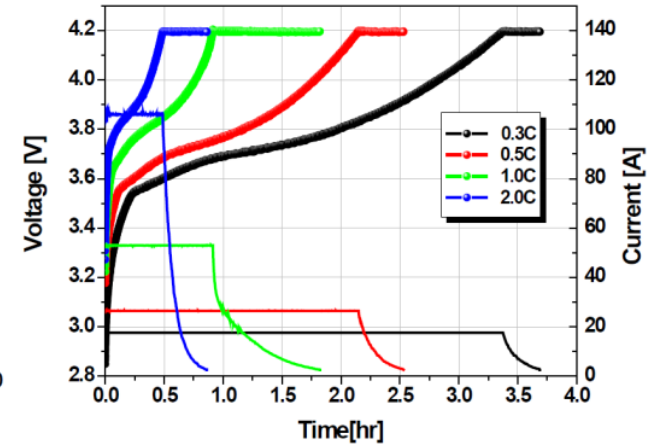
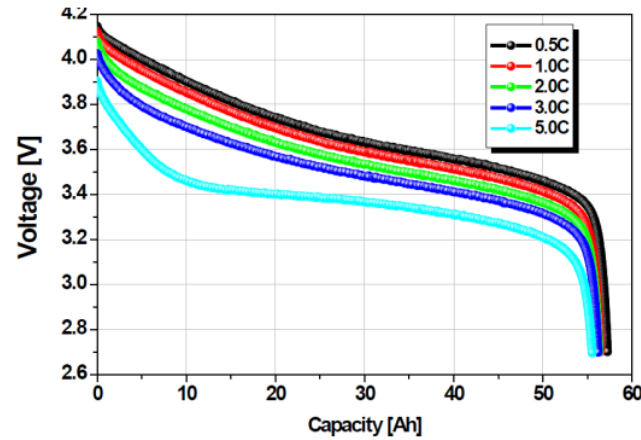
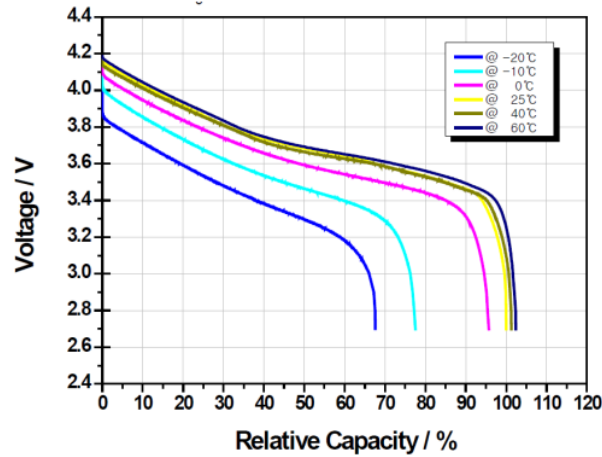
Cell temperature:

Min. charge temperature	0 °C
Max. charge temperature	0 °C
Min. discharge temperature	0 °C
Max. discharge temperature	0 °C

Ready

Fonte: Lithium Balance Diagnostic Software

Exemplo de software de monitoramento



Fontes:

[1] Lithium Balance Diagnostic Software

[2] Kokam

Obrigado pela Atenção



Bons estudos!



Dúvidas: afcupertino@ieee.org



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