Operational experience and system modelling of Dual Chemistry Energy Storage Systems

Flexible Electricity Storage Solutions
Dual Chemistry LiB/VRLA Systems

GS-Yuasa Europe

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Presentation Structure

1. The need for Energy Storage & ***Hybrid Energy Storage***
2. Lead acid and Li-ion ADEPT Hybrid System
3. Battery Modelling of Hybrid Energy Storage
4. Conclusions

Distributed Energy Storage

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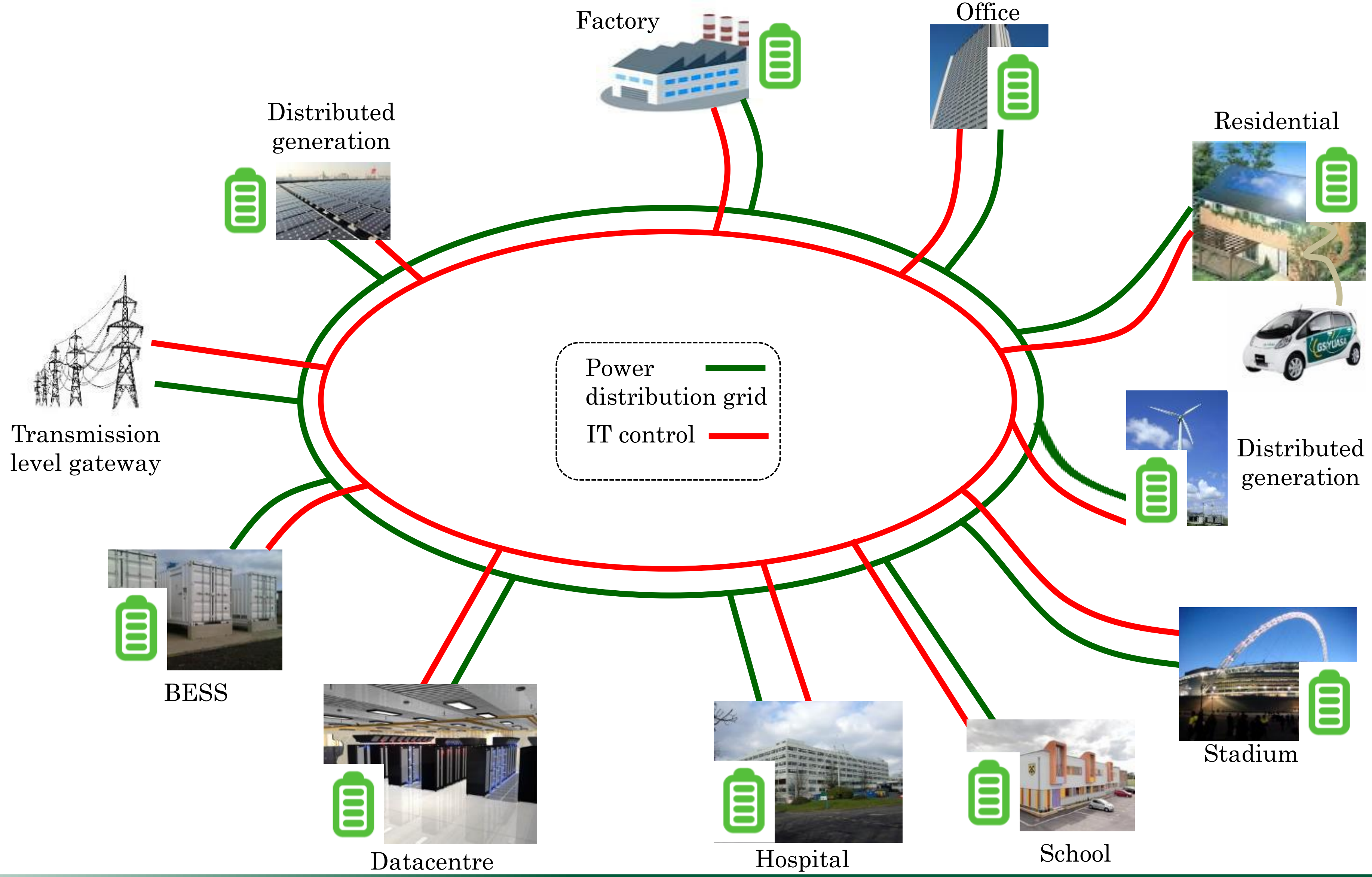

Energy Storage Power Grid Services

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Low carbon power systems require storage across wide time spectrum

Storage Service	Operating Period	Storing Period
Power quality improvement	msec - minutes	minutes – weeks
Frequency response services	msec - minutes	hours
LV power flow optimisation	seconds - hours	hours
Peak demand shaving	hours	hours - days
Constraints management	hours	hours - days
Asset reinforcement deferral	hours	hours - days
Arbitrage	hours - days	days - weeks

An ESS that can provide multiple services is more commercially attractive

Time Dependence of Battery Technologies

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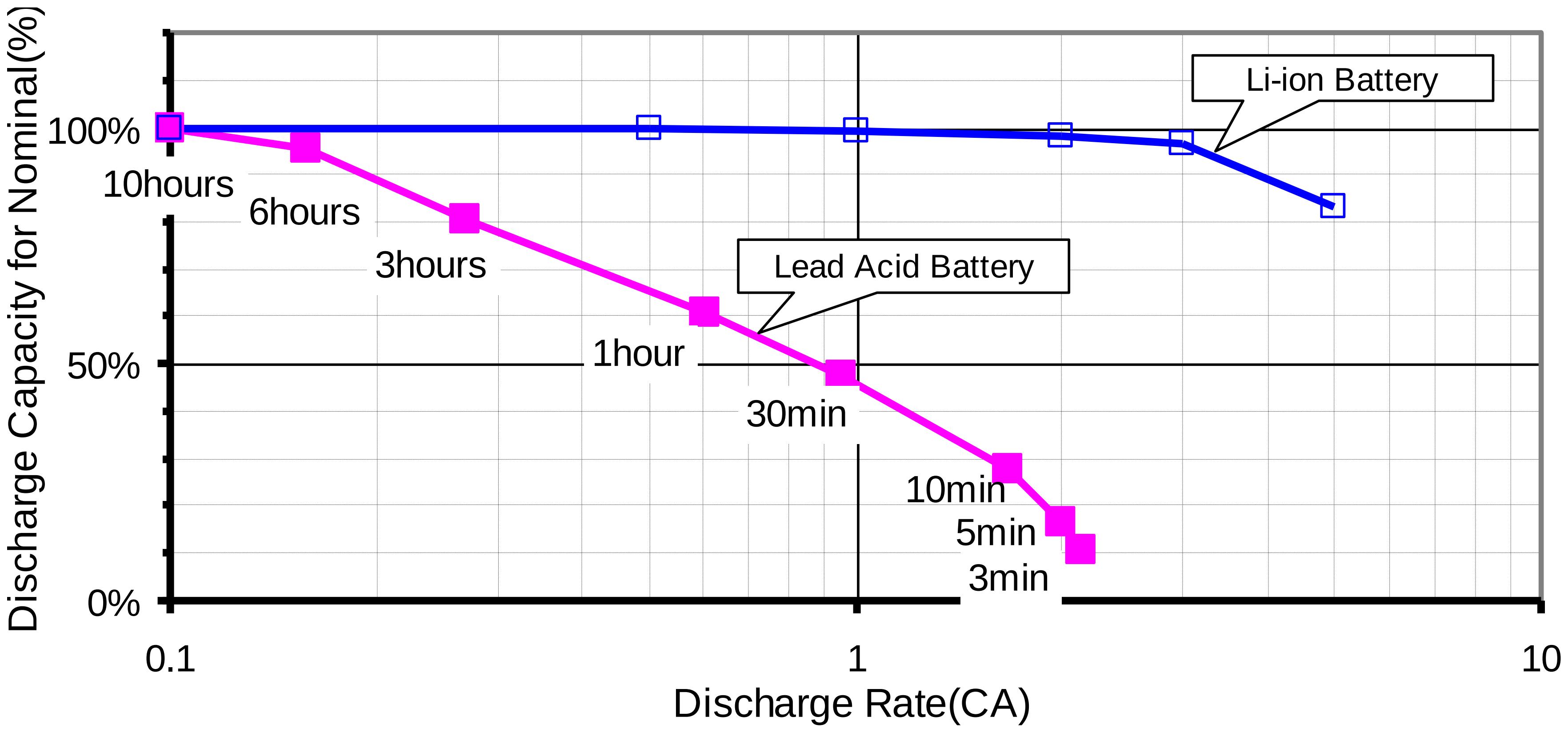

Time Response of Energy Storage Technologies

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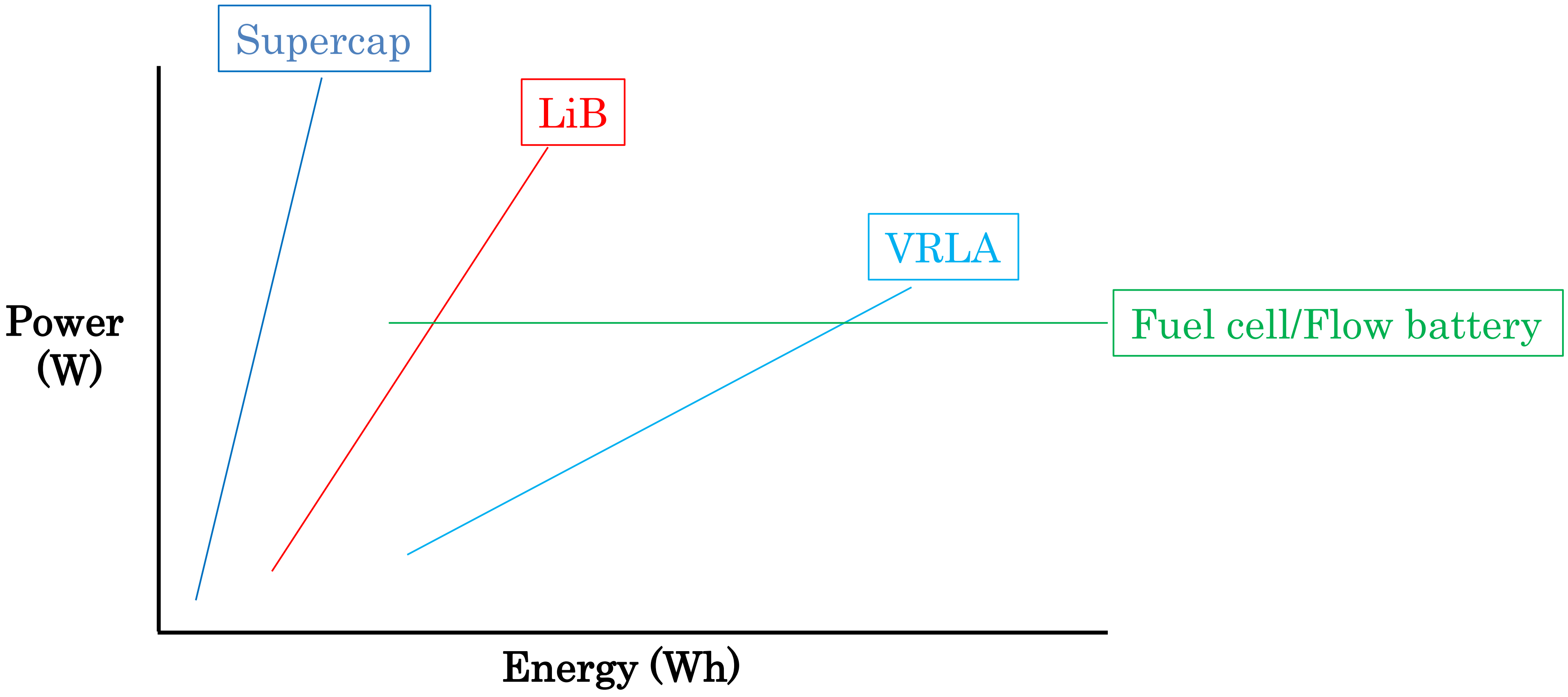
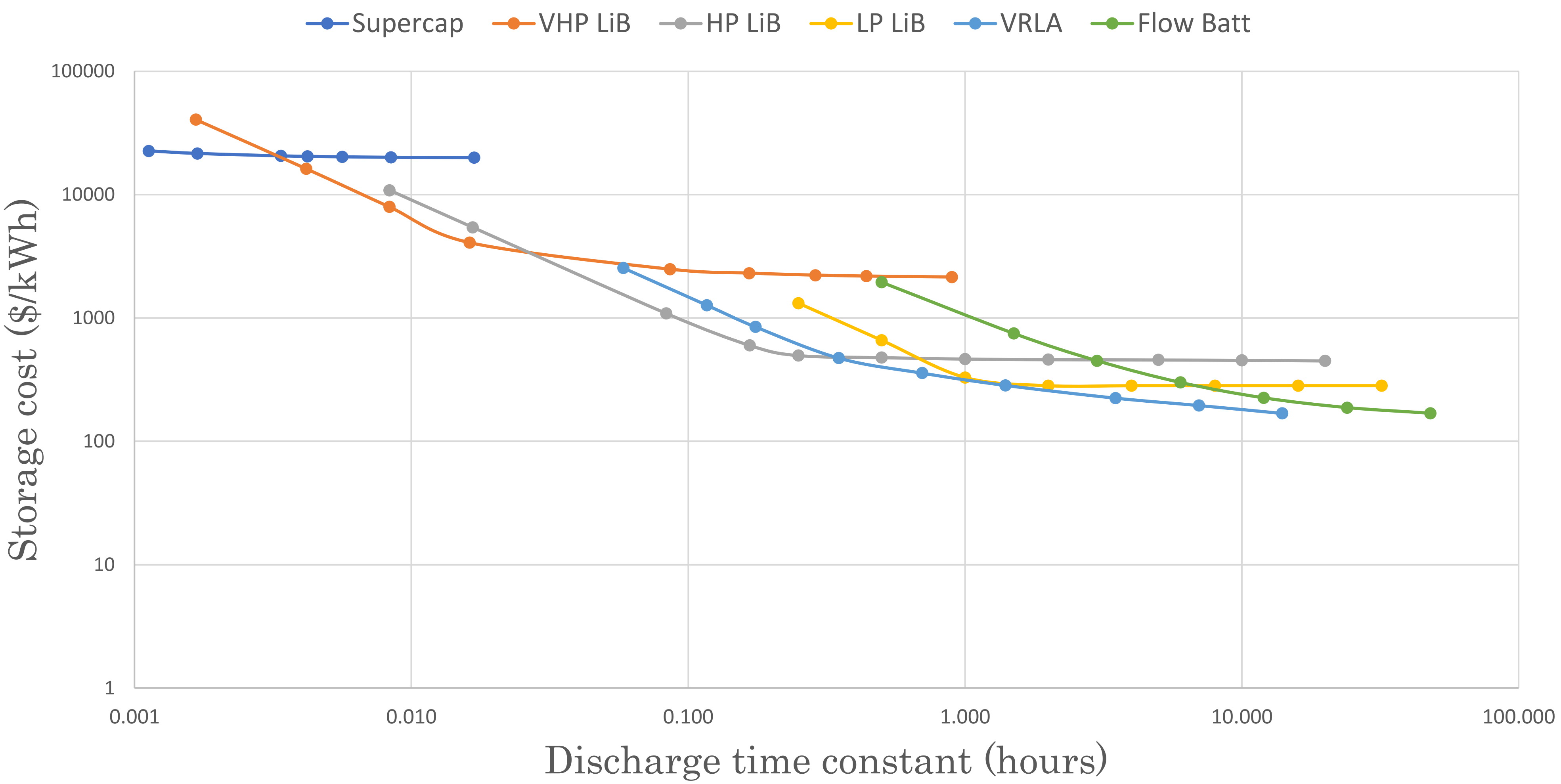


$$\frac{\text{Delivered Energy (Wh)}}{\text{Power level (W)}} = \text{Time constant (h)}$$

Highest power capability has shortest time constant

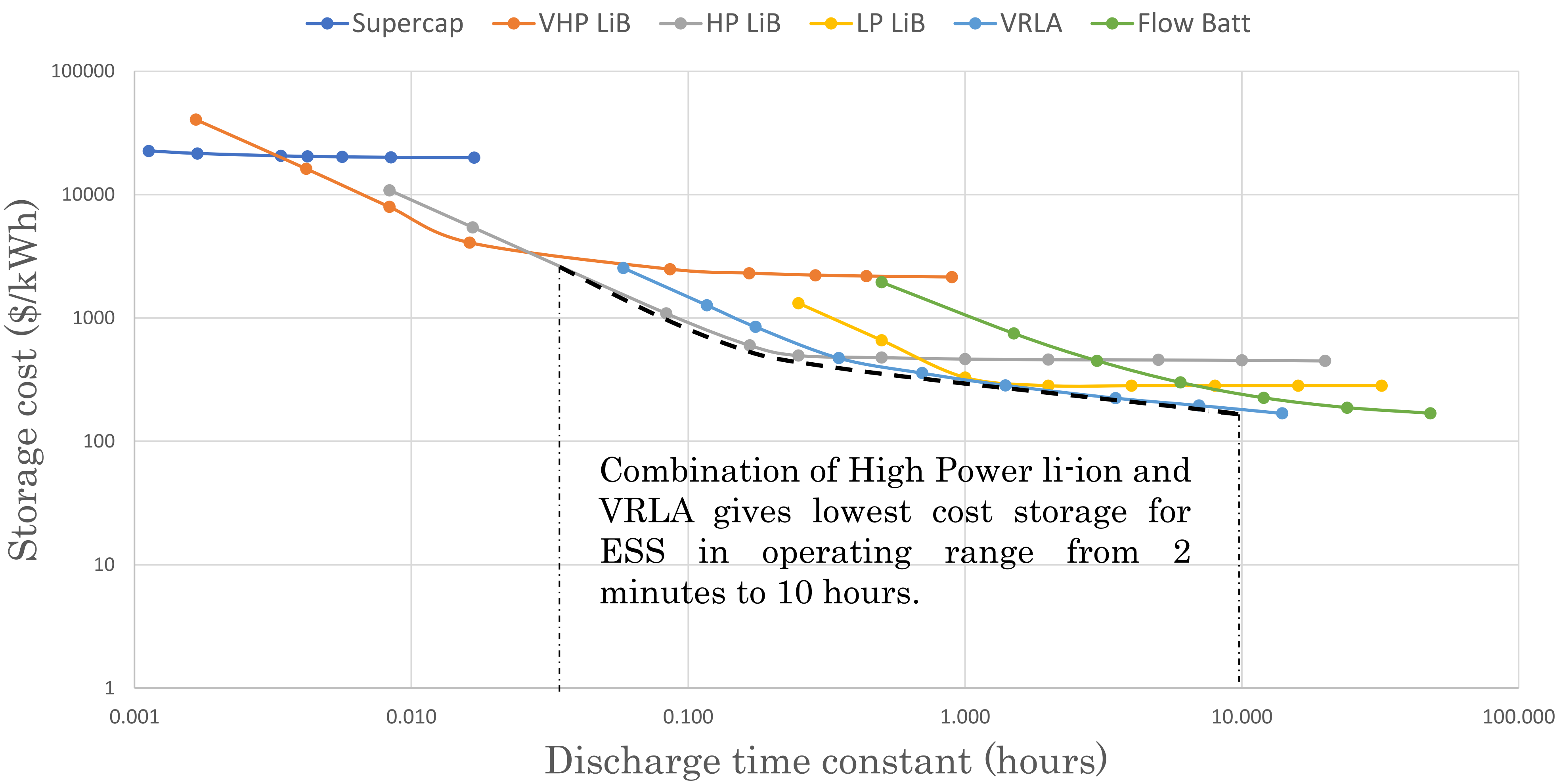
ESS Cost vs Discharge Time Constants

Powering the Next Generation



ESS Cost vs Discharge Time Constants

Powering the Next Generation



Complementary Technologies

Lithium ion strengths

- Cycle Life
- High Discharge Rate
- High Charge Rate
- Partial SOC operation
- High Efficiency
- High Energy Density

Lead acid strengths

- Economical
- Simple Control
- Abuse Tolerant
- Sustainable Materials
- Abundant Raw Materials
- Low Embodied Energy

GS Yuasa Li-ion & VRLA Hybrid ESS

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ADEPT
500V Dual Chemistry
Li-ion battery capacity: 75kWh
VRLA capacity: 200kWh

LiB cabinets

SLR racks

GS Yuasa Portsmouth Port Battery System

ADEPT Micro-grid Schematic

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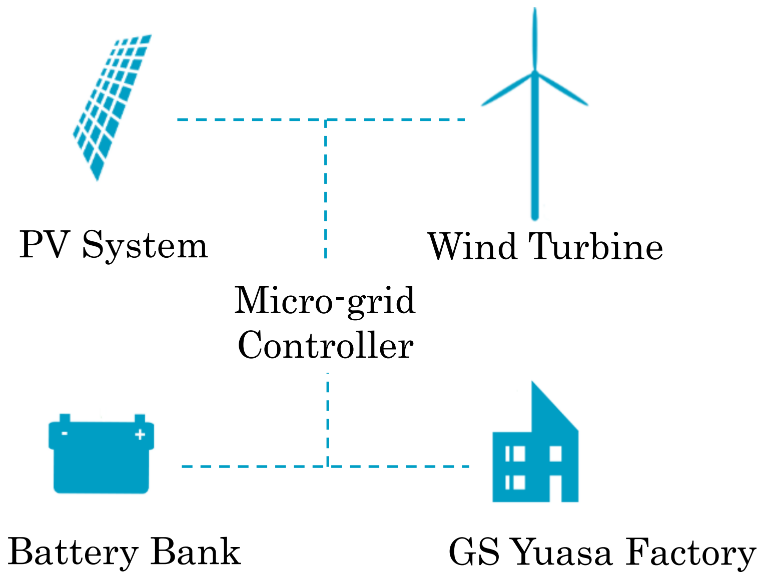
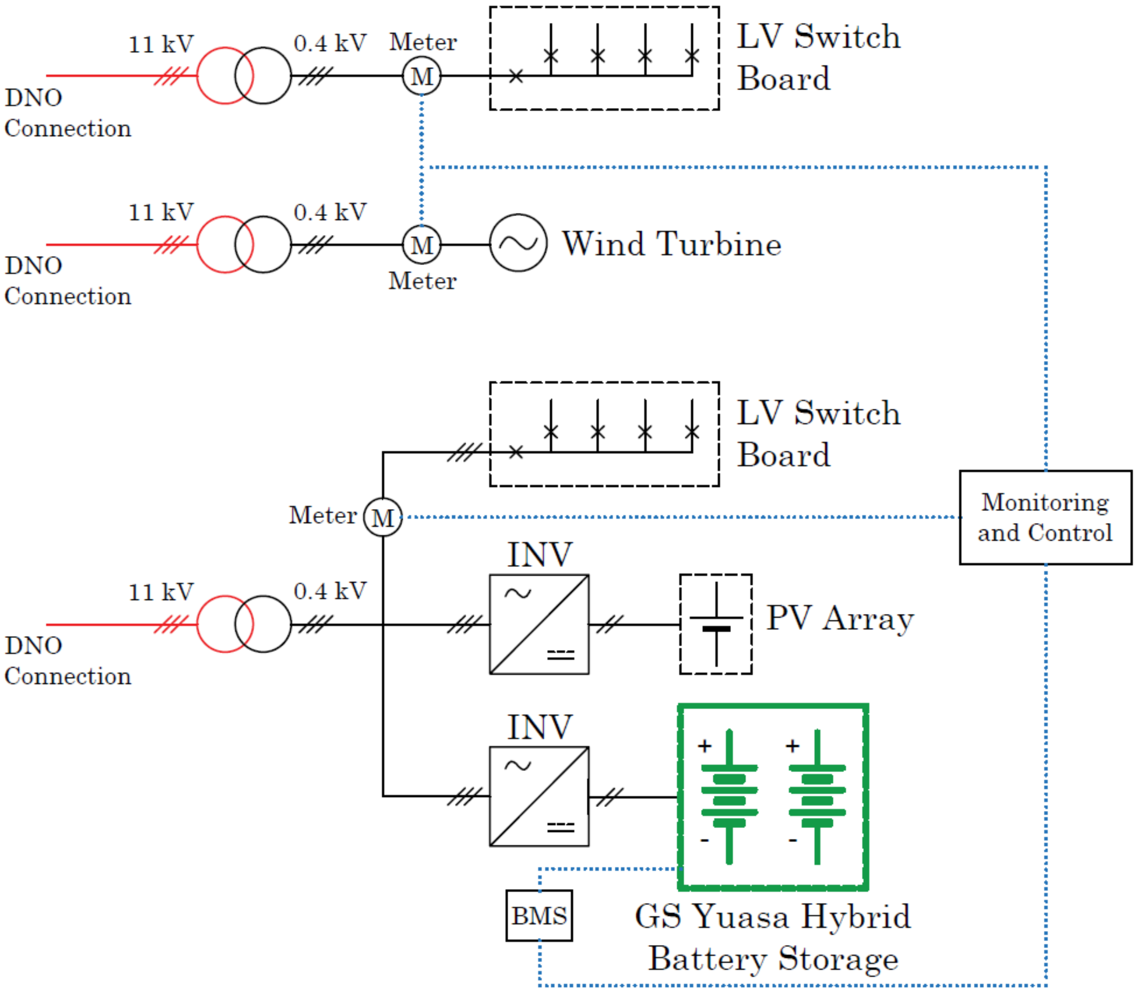


Rassau Industrial Estate



Micro-grid Schematic

Graphics by TU Delft

Cell Operating Voltage Comparison

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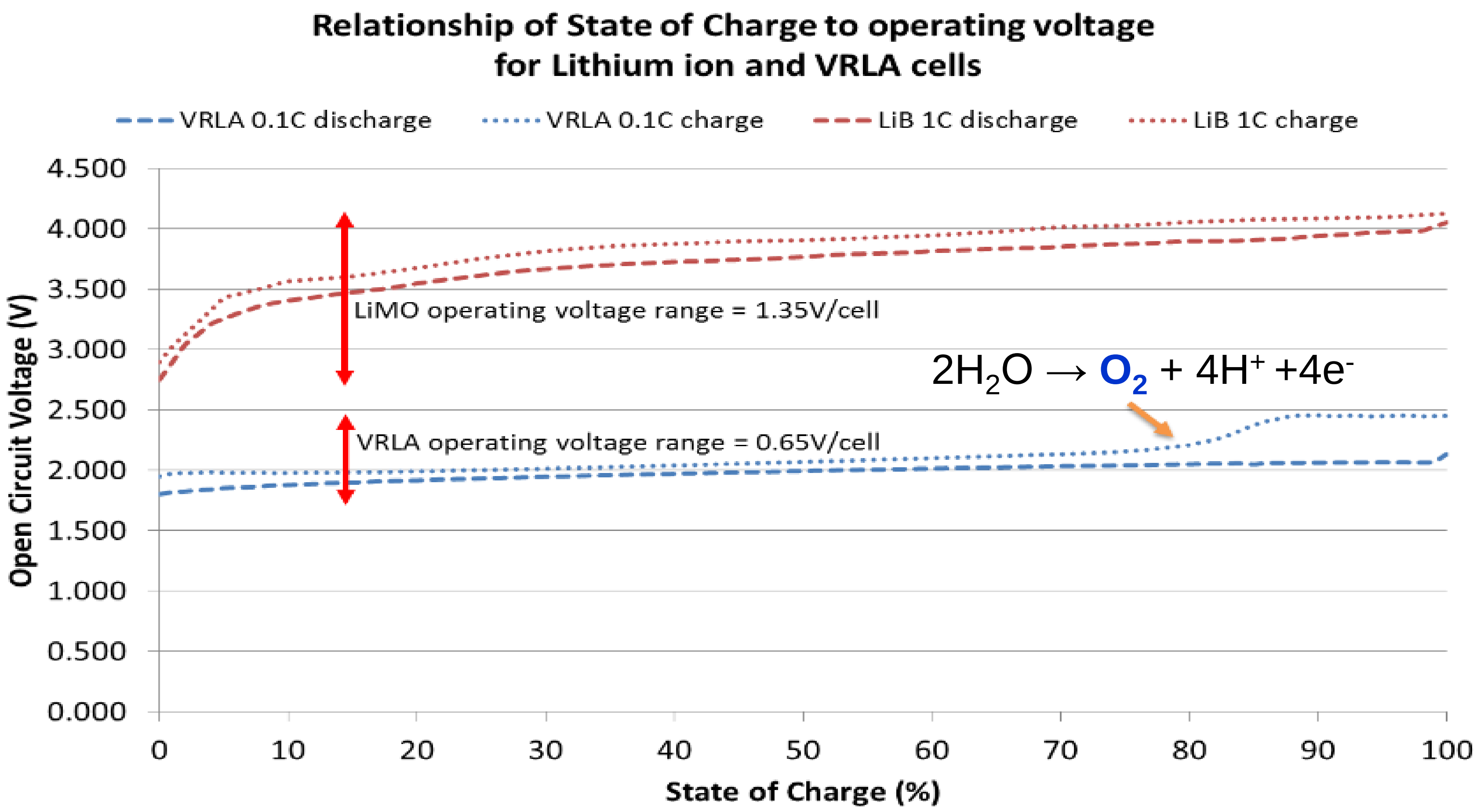

Cell Operating Voltage Comparison

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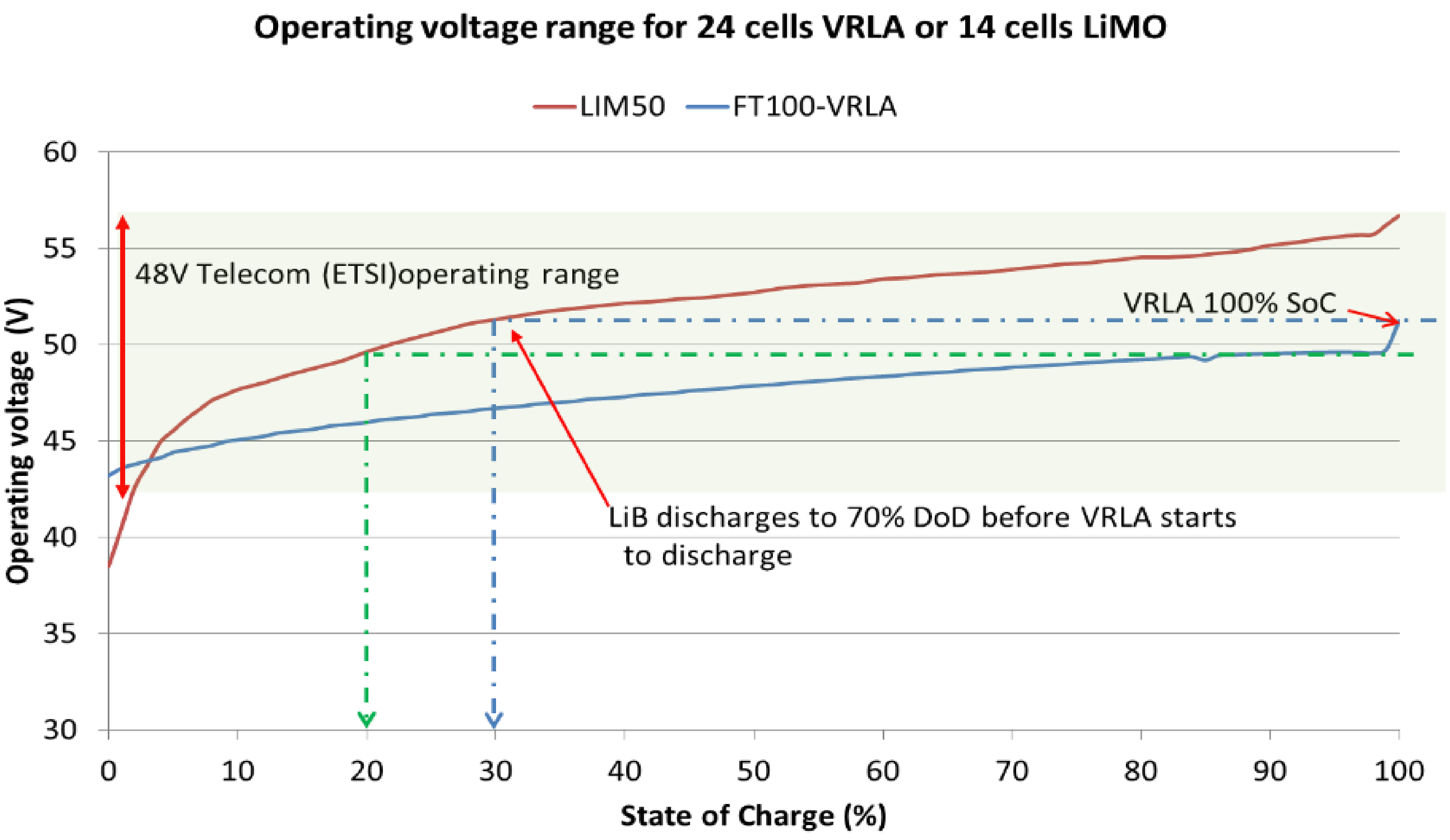
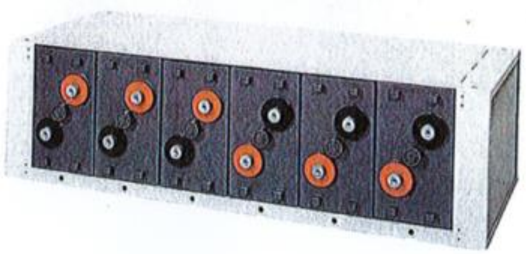


Vop – SoC relationship in 48V system example

Dual Chemistry Cell Components

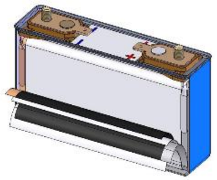
VRLA construction

	SLR500/1000
Electrolyte management	VRLA-AGM
Electrode form	Flat Plate
Electrode alloy	Pb-Ca-Sn
Negative active material	Carbon Loaded
Positive active material	High Density
Container	PP (UL94-V2)
Module support	Steel Envelope

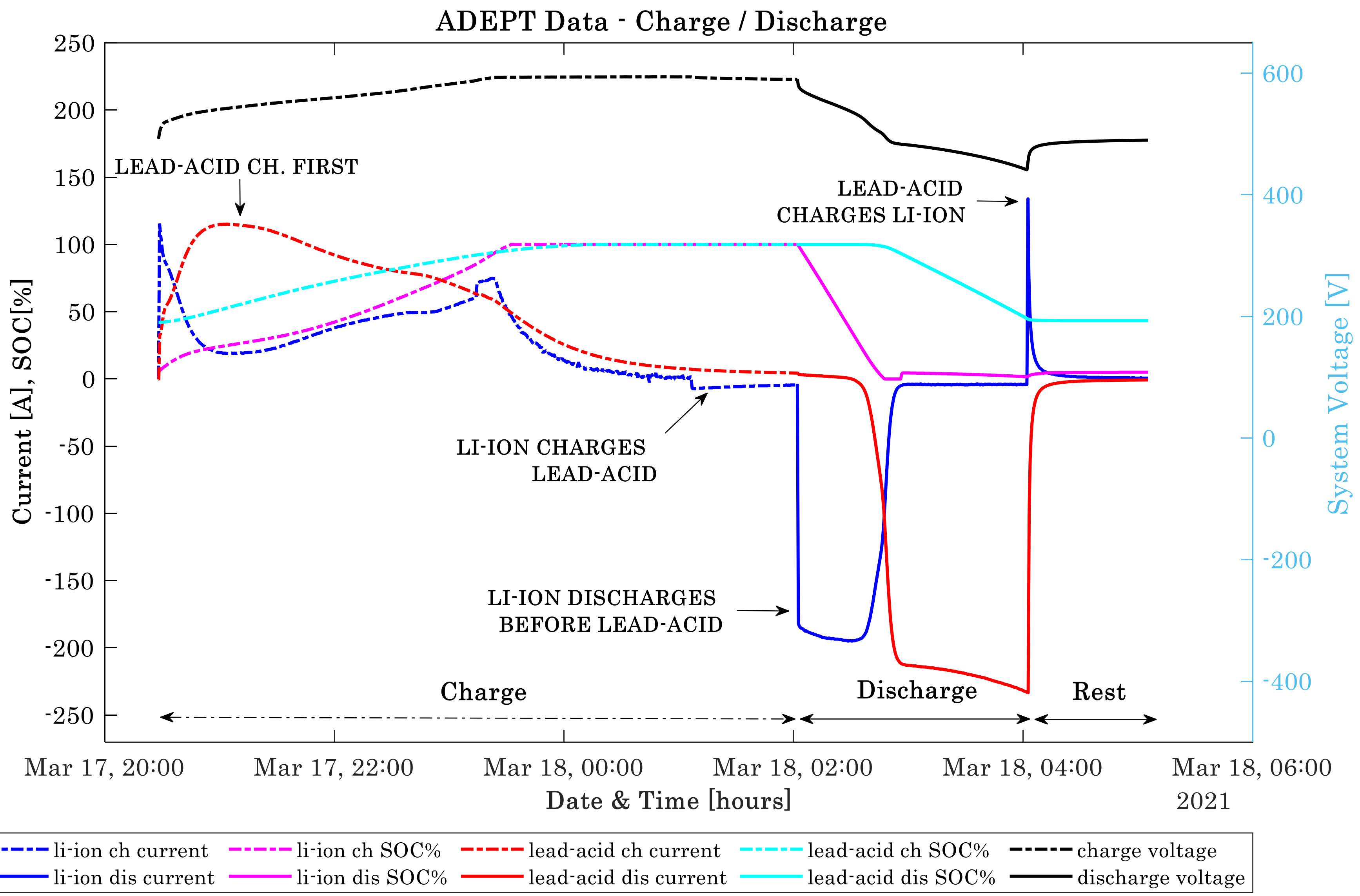


LiB Construction

	LIM50EL-12 modules
Electrolyte management	Organic carbonate-LiPF6
Electrode form	Spiral wound
Negative active material	Carbon
Positive active material	Manganese oxide spinel
Container	Stainless steel
Module support	Steel frame with monitoring system



DC Power Sharing – ADEPT



ADEPT ESS Operation Dec 2018 - Oct 2021

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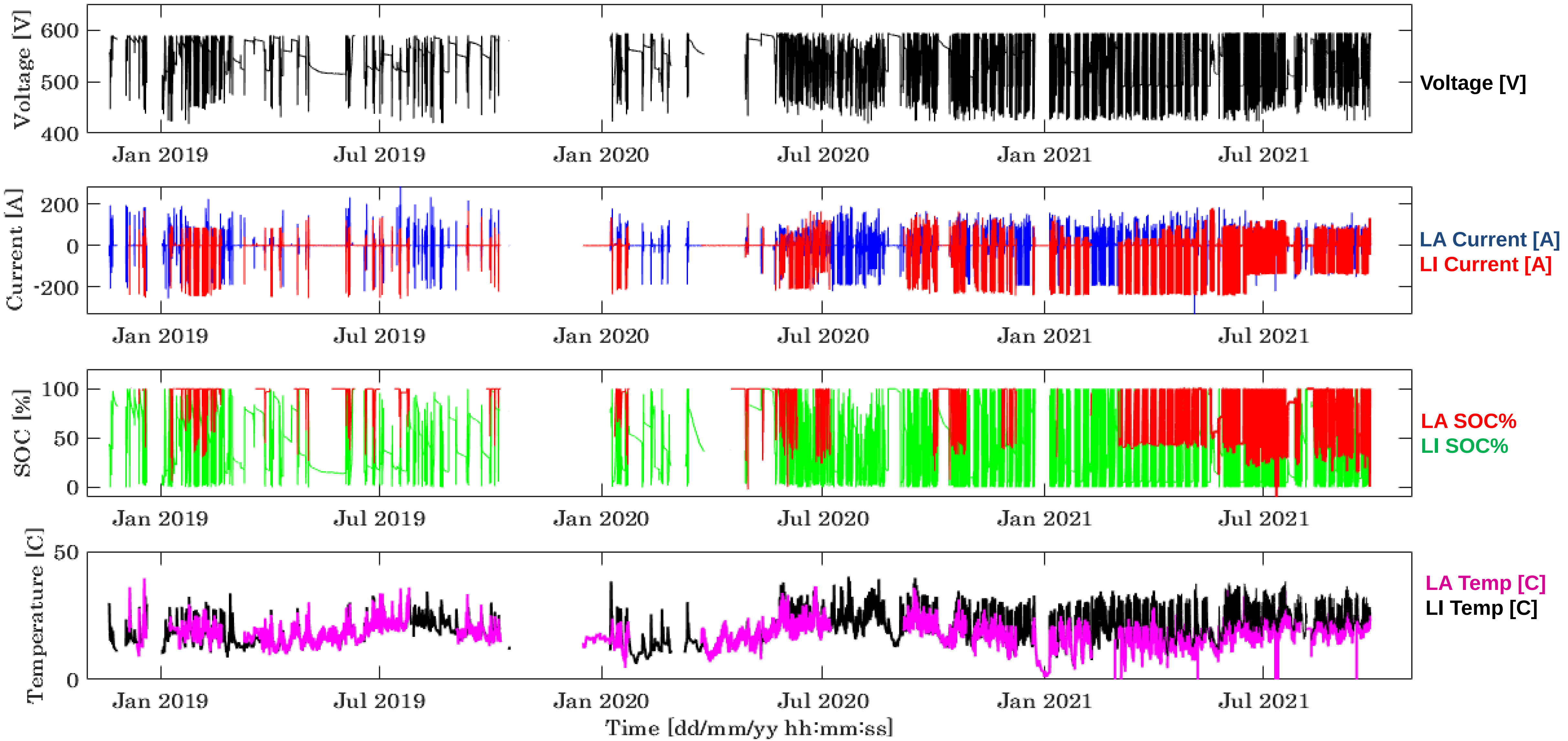

ADEPT – Battery Capacity Evolution

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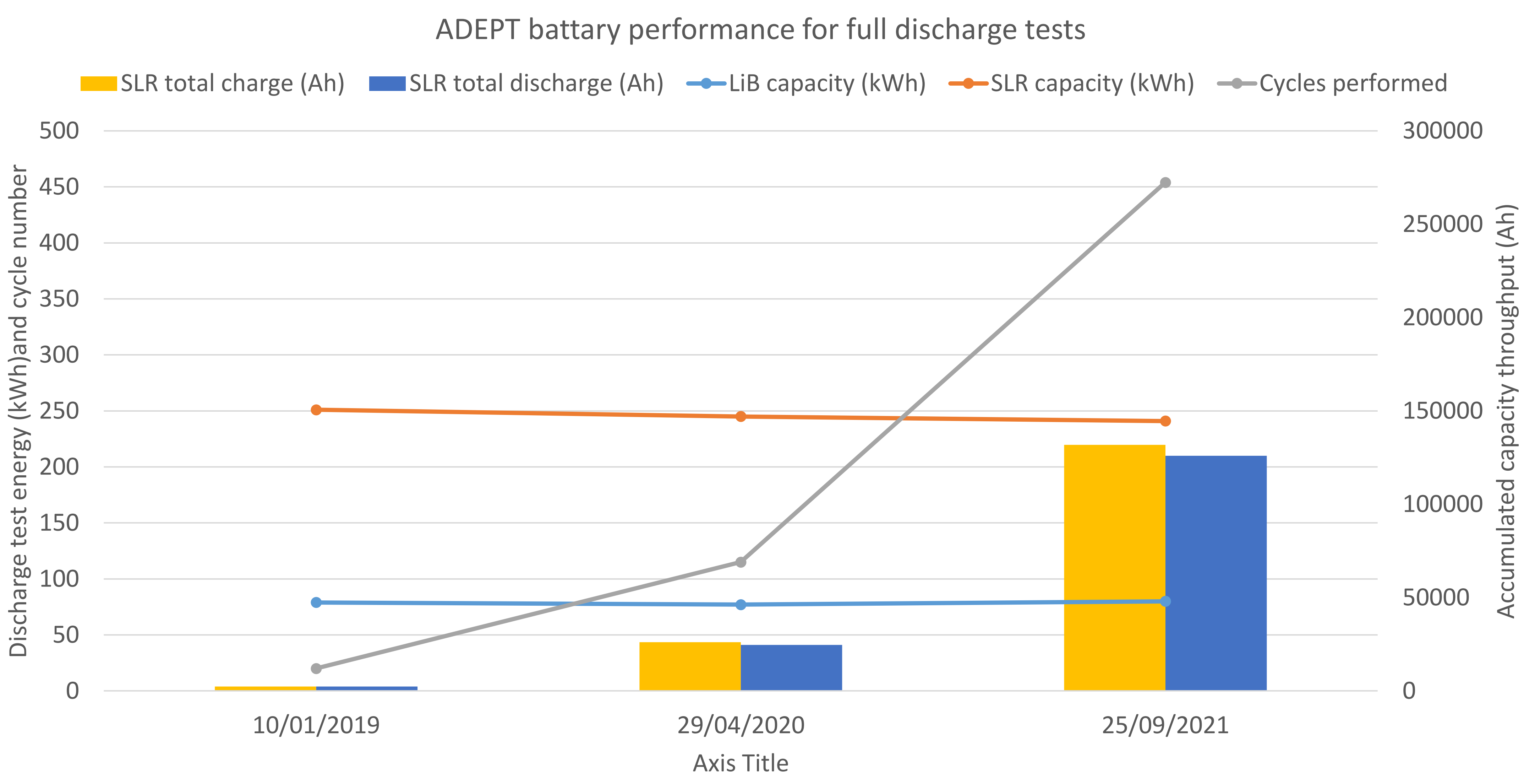
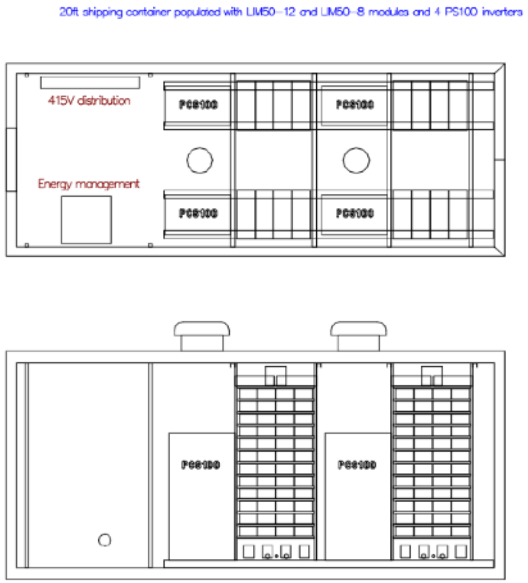
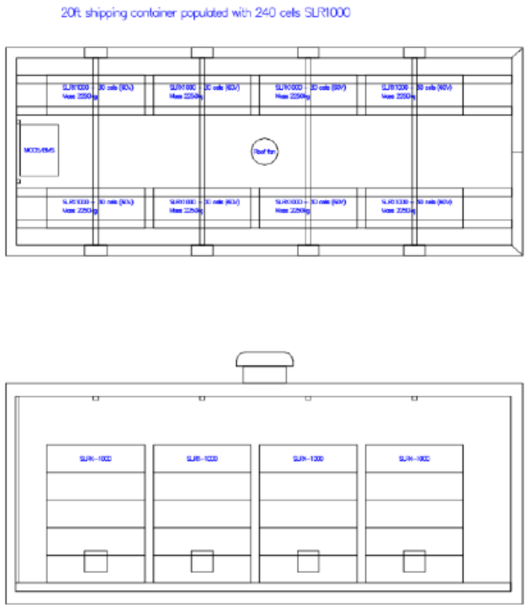


GEMINI Dual Chemistry ESS

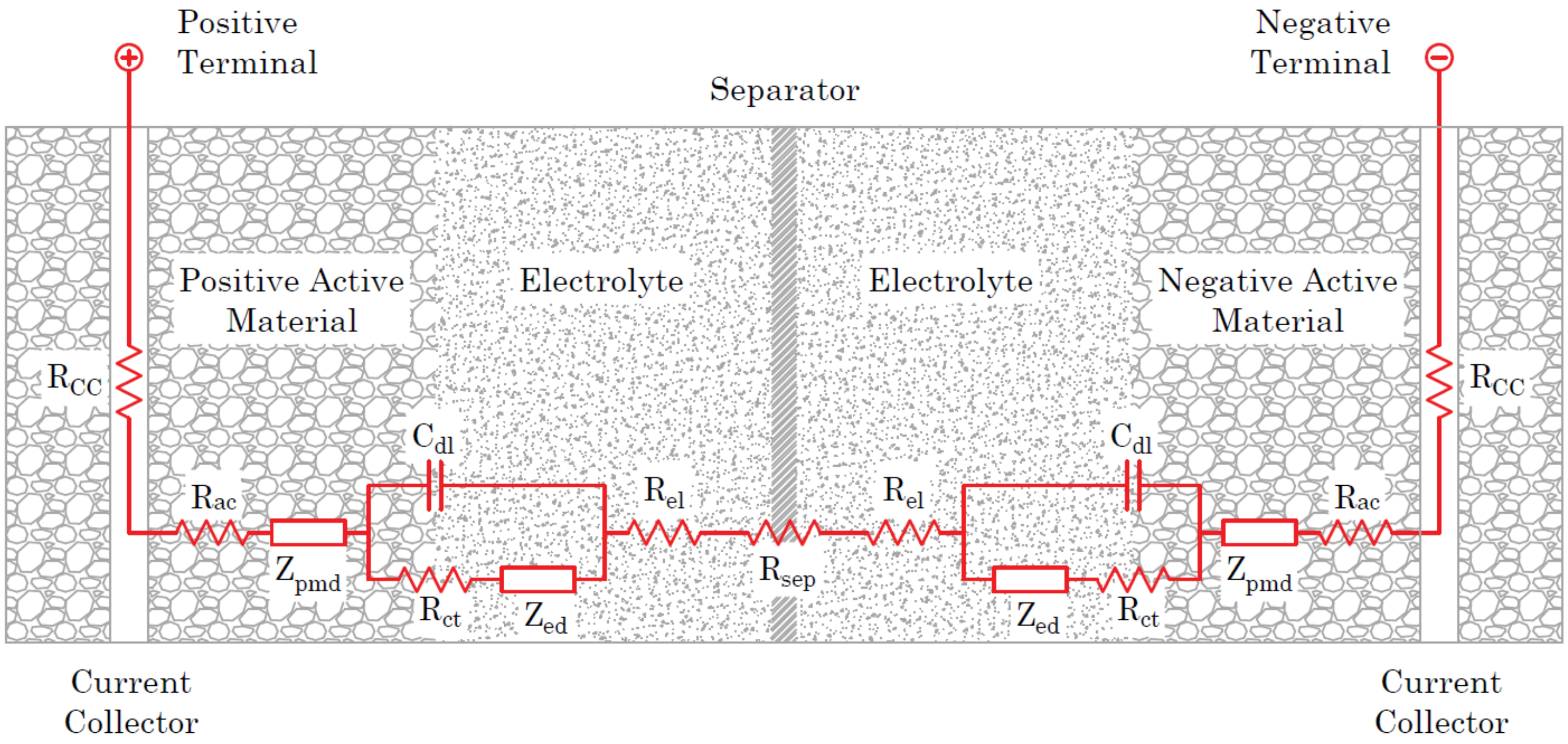


Lithium-ion modules
+
Power Conversion
+
Energy Management

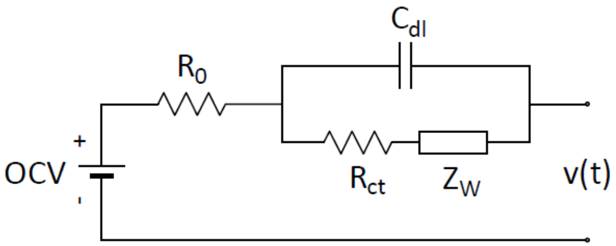


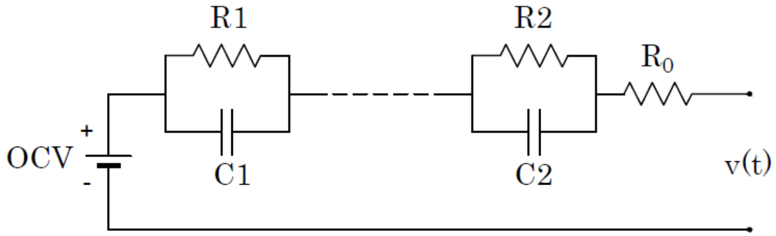
Lead Acid modules
+
Battery monitoring

Hybrid Battery Modelling



- R_{el} - active electrolyte resistance;
- R_{ct} - charge transfer resistance;
- C_{dl} - double layer capacitance;
- Z_{pmd} - constant phase elements;
- Z_{ed} - constant phase elements;
- R_{CC} - conduction element;
- R_{ac} - conduction element;





Battery Modelling – Testing

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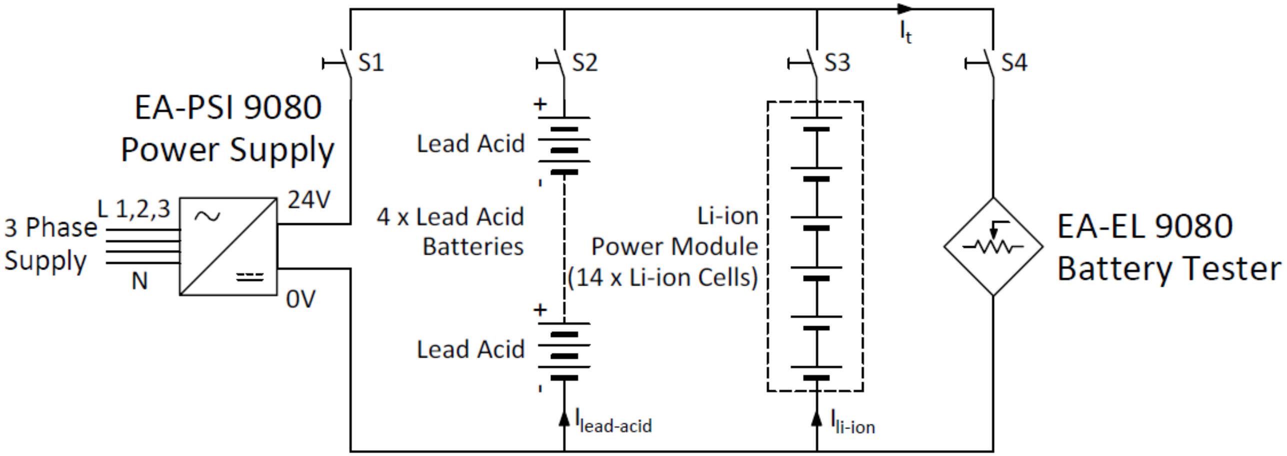


Open circuit voltage (OCV) tests to calculate:

- Coulombic Efficiency, Energy Efficiency
- Capacity (Ah), Energy Capacity (kWh)
- OCV as function of SOC

Pulse Discharge tests to calculate;

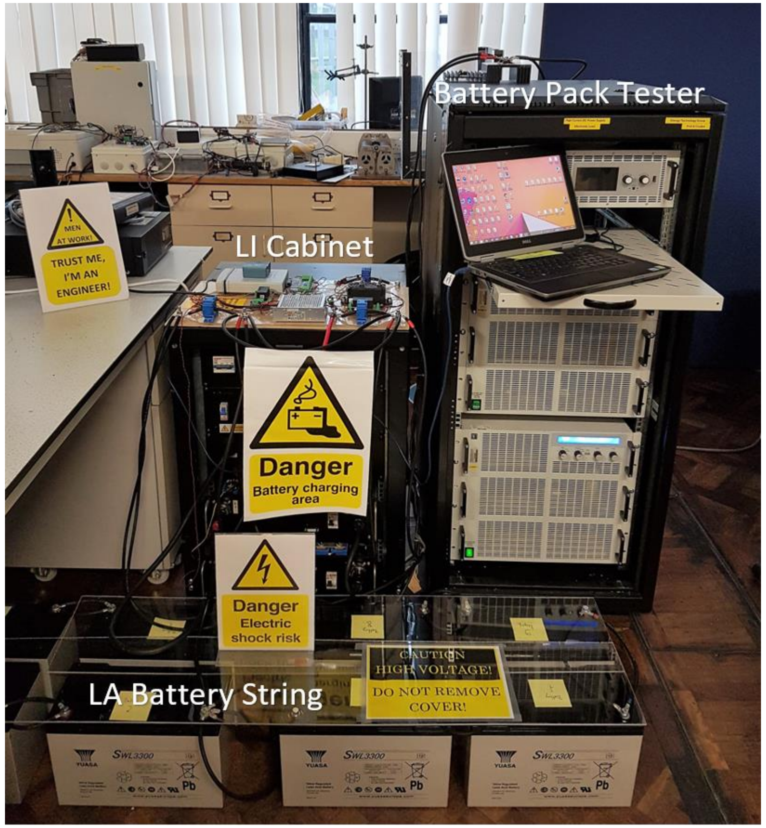
- Internal Resistance and RC time constants

Hybrid Charge / Discharge – Constant Current

- Current & Power Distribution

Hybrid Charge / Discharge – Pulse Discharge

- Dynamic Current and Power Distribution
- Energy Transfer

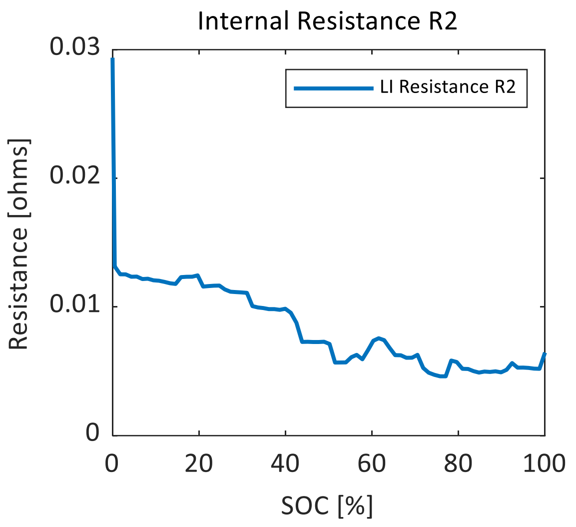


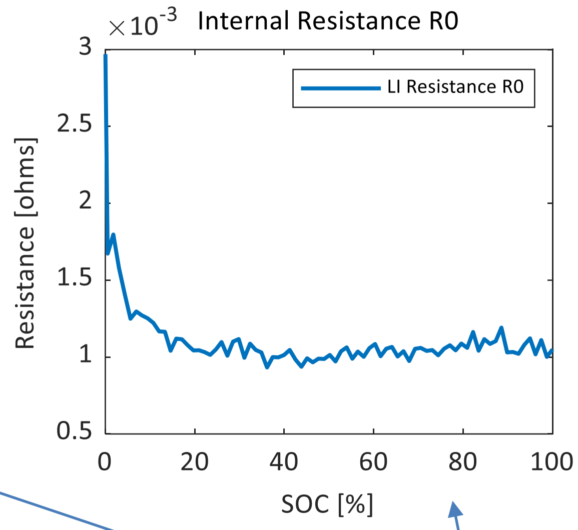
Experimental test Arrangement

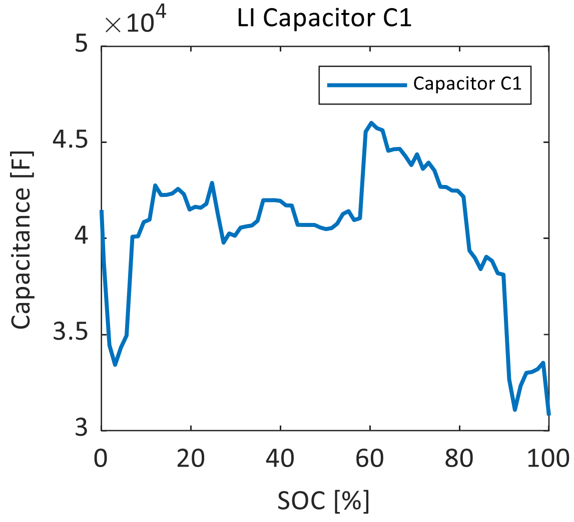
SWR3300 Battery

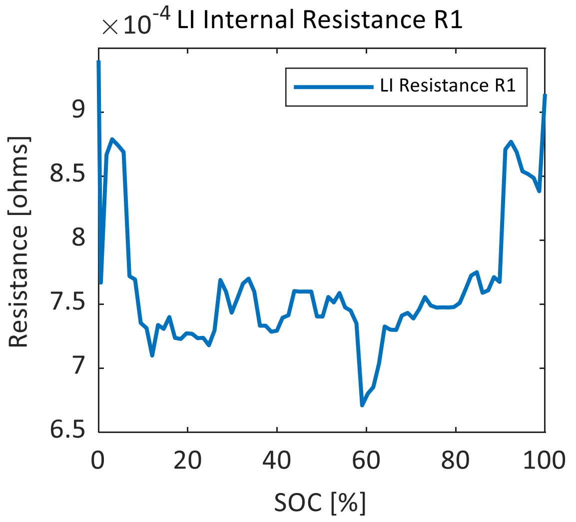
LIM50 Battery Cell

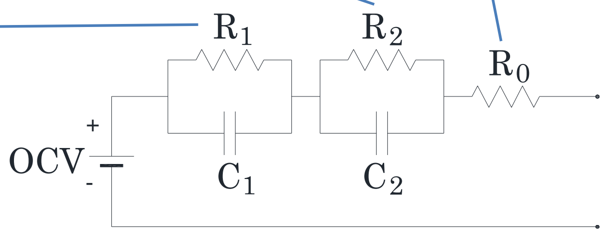
Battery Modelling – Li-ion Parameters

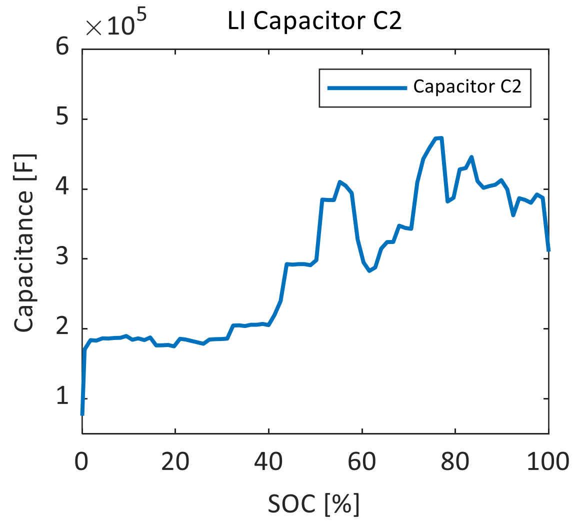












Optimisation Tools:

- BatteryEstim2RC_PTBS

Battery Modelling – Lead-acid parameters

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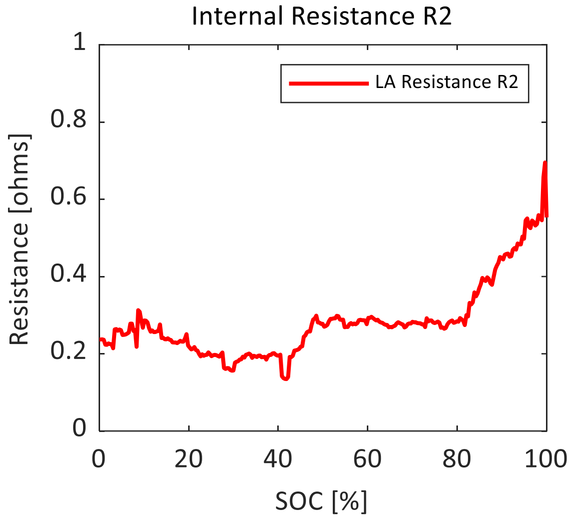

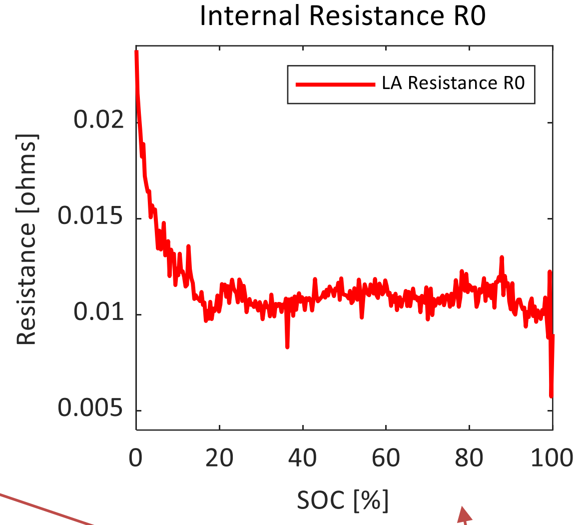

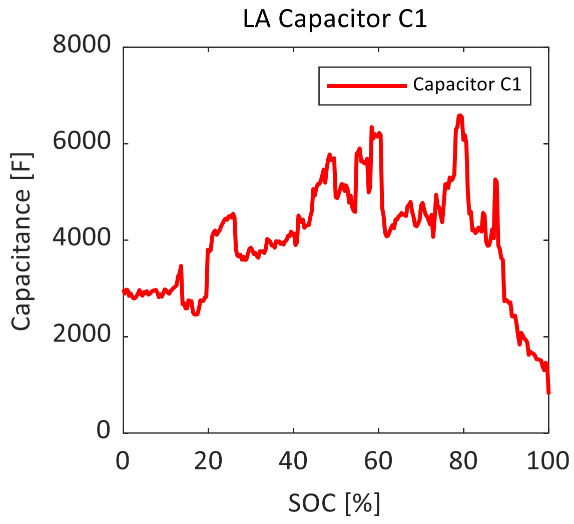

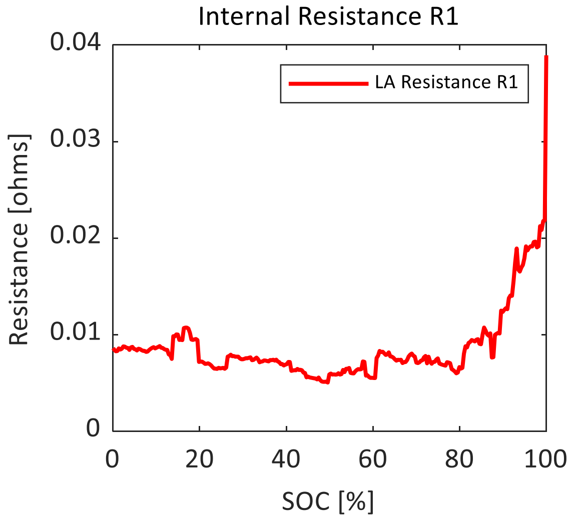

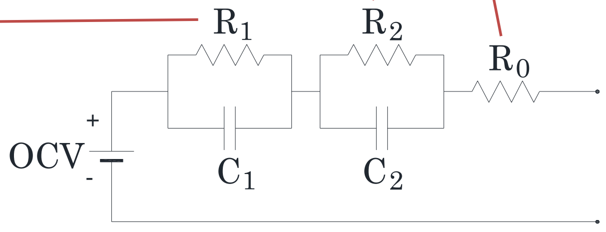

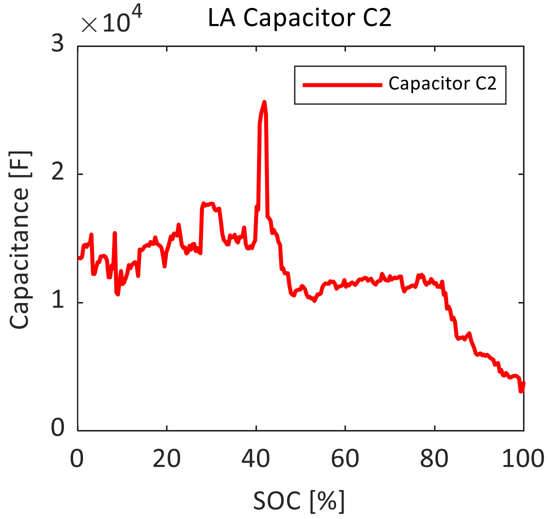

Optimisation Tools:

- BatteryEstim2RC_PTBS

MATLAB / Simulink Model Interface

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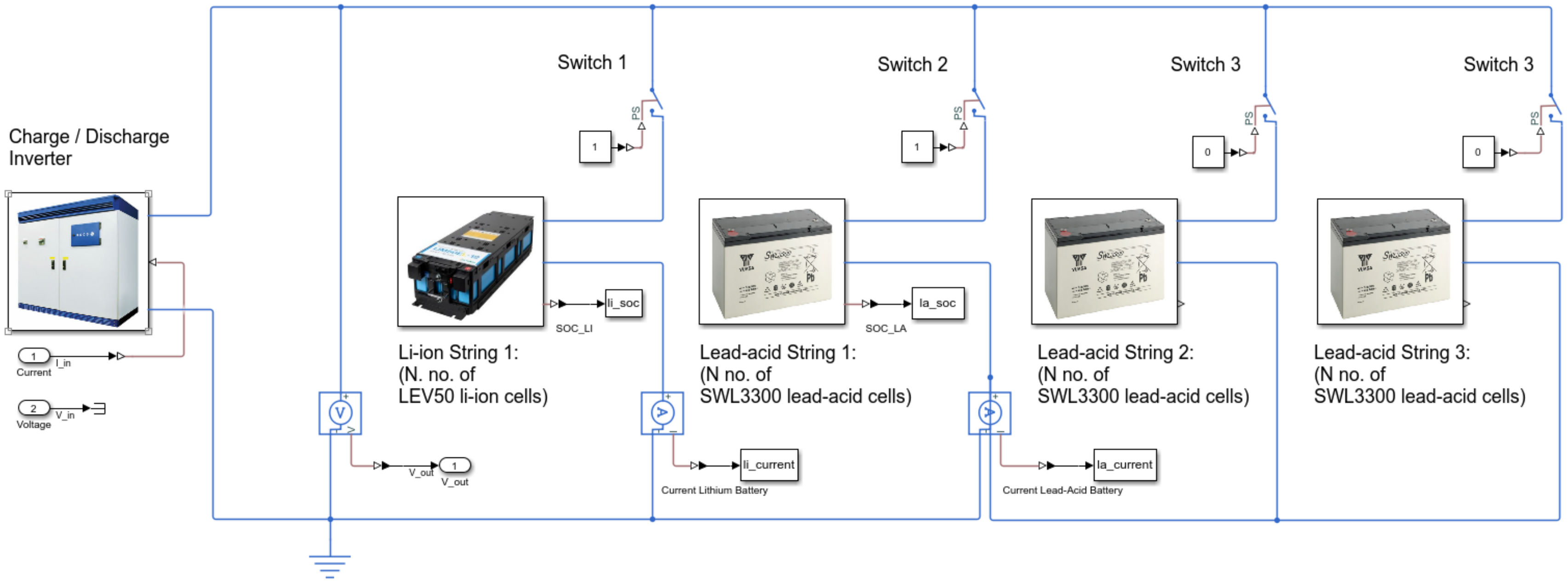
Hybrid Battery Modelling



Modelling:

- Multiple li-ion and lead-acid in series
- Multiple strings
- Calculate Power & Current Distribution
- Energy Discharged
- Dynamic Current Sharing

Modelling a Hybrid Battery System

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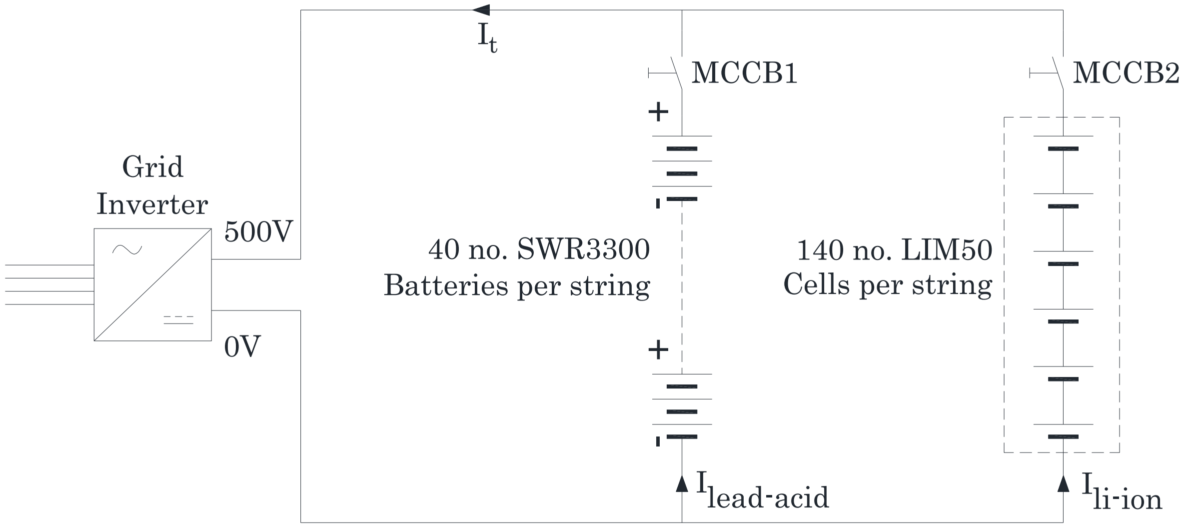
Hybrid Battery System Example:

- Hybrid Battery Storage, 500V, two strings
- Lead-acid and li-ion (SWR3300 & LIM50)
- 240 no. of lead-acid cells (40 no. batteries)
- 140 no. of li-ion cells
- Maximum / Minimum Voltage – 568 / 440 Volts
- Li-ion Cell Voltage Range – 4.06 / 3.08 Volts
- Lead-acid Voltage Range – 2.35 / 1.8 Volts



Modelled Battery Storage Schematic

SWR3300 Battery

LIM50 Battery Cell

Hybrid Battery Modelling – String Currents

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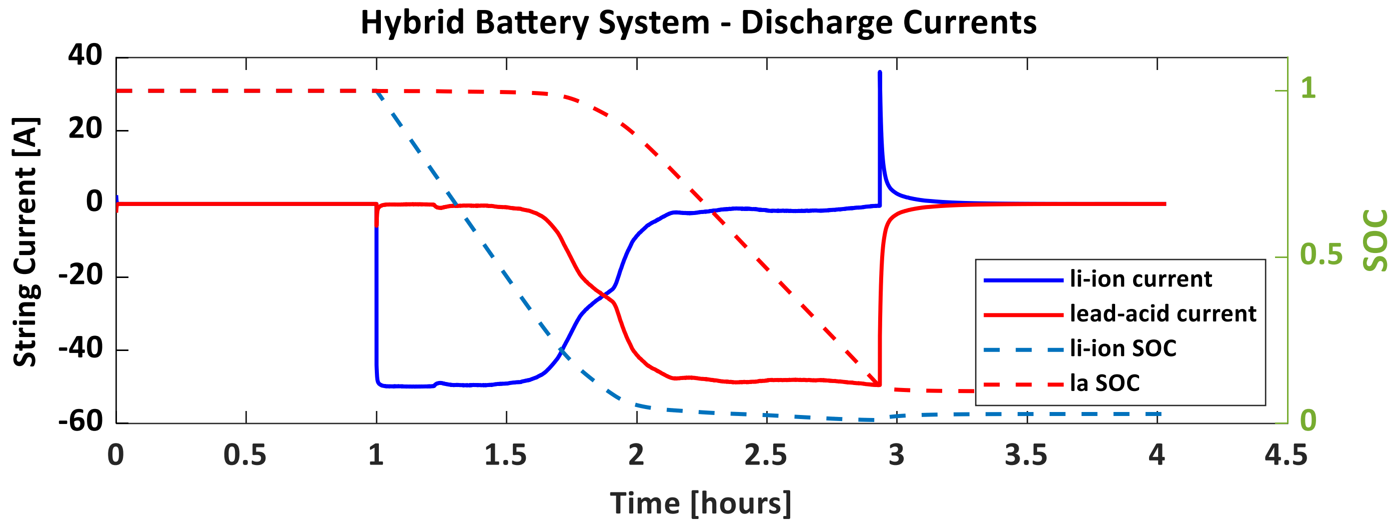
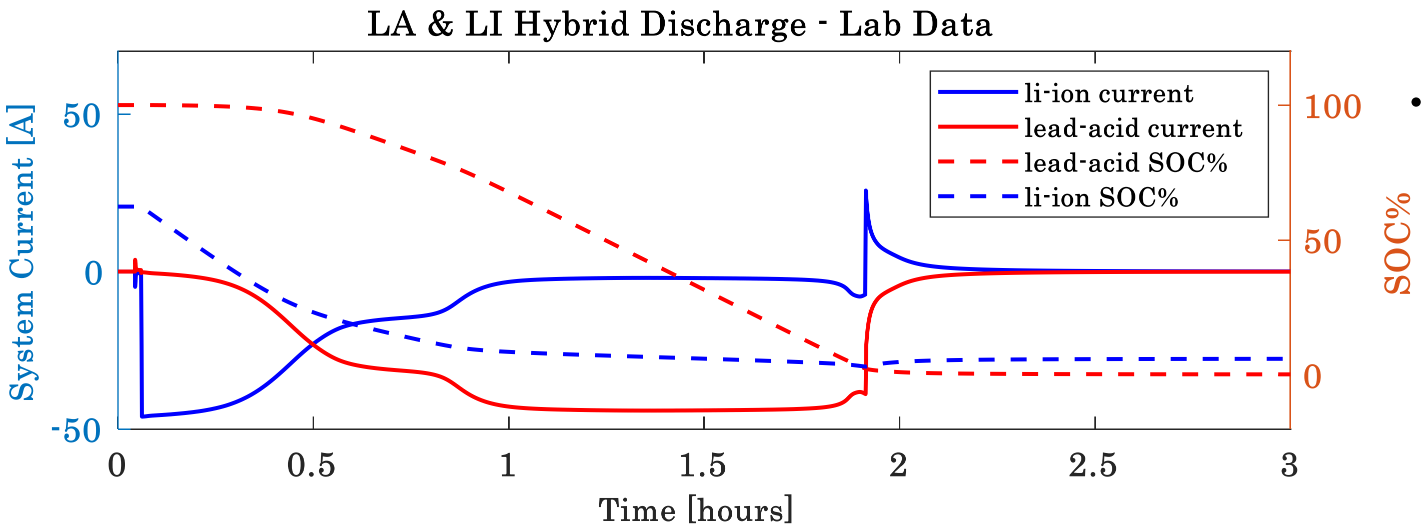


- 50A Constant Current Discharge, 90%DOD;
- Li ion reaches around 70% DOD before lead acid starts to discharge;
- Energy / charge transfer at the end of discharge process;

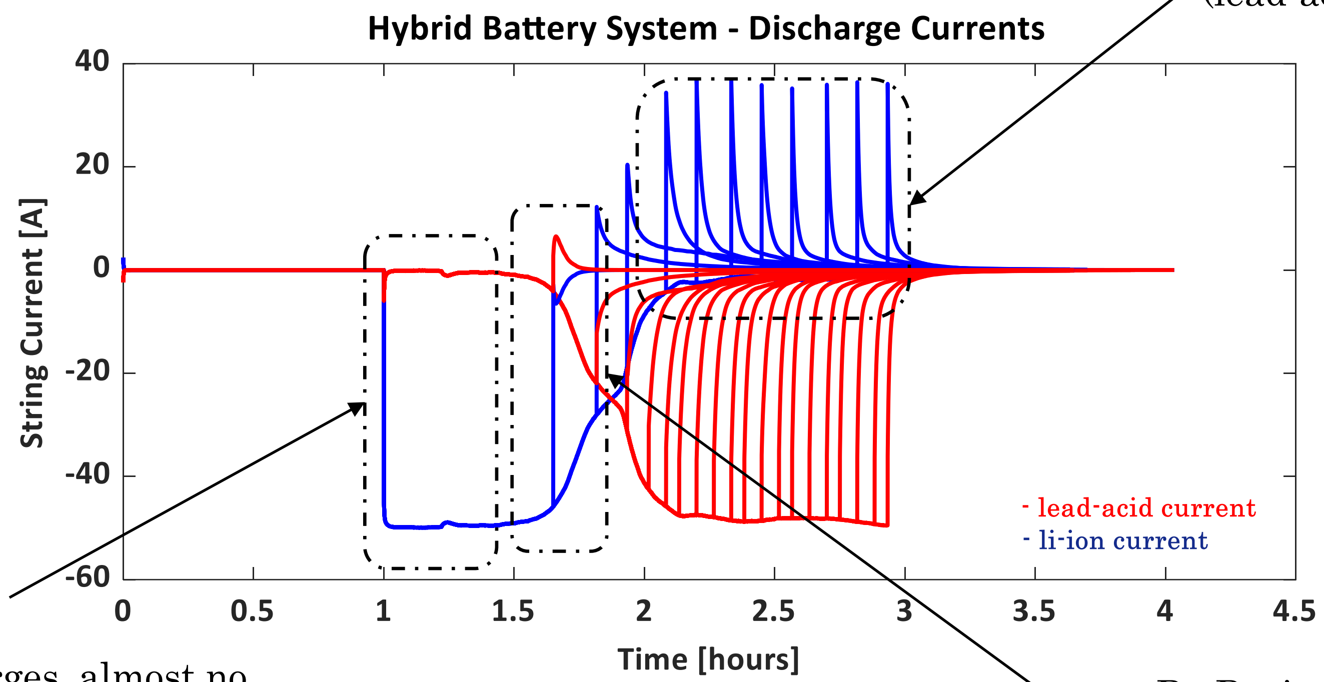


- 45A Discharge, Constant Current (experimental data)

Hybrid Battery Modelling – String Currents

- 50A Constant Current Discharge, lead-acid 90% to 0% DOD;
- Energy transfer due to circulation currents vary;

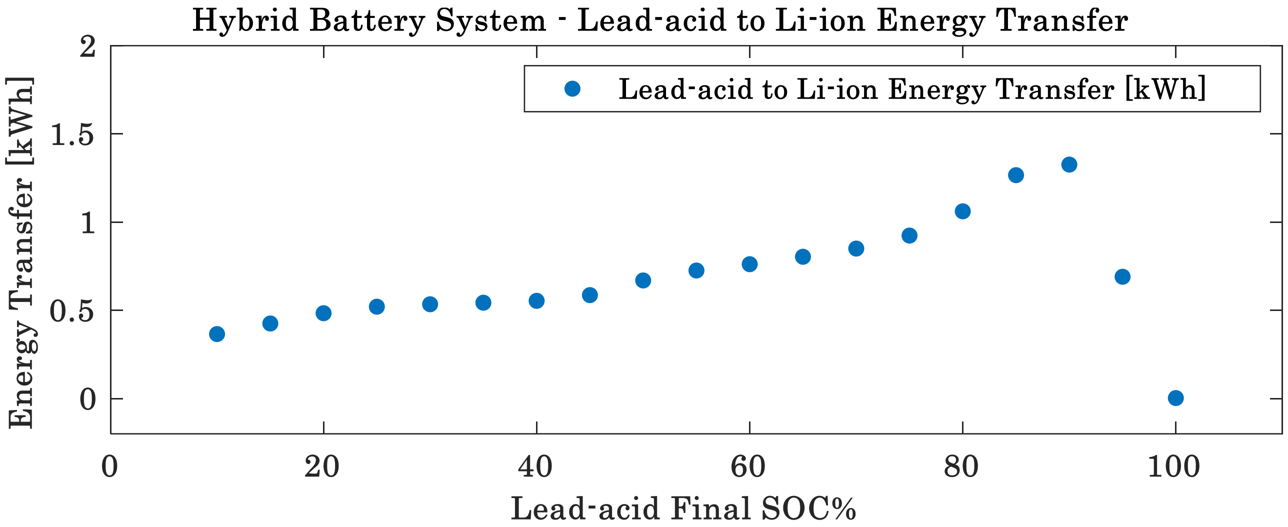
C – Region
(lead-acid charges li-ion)



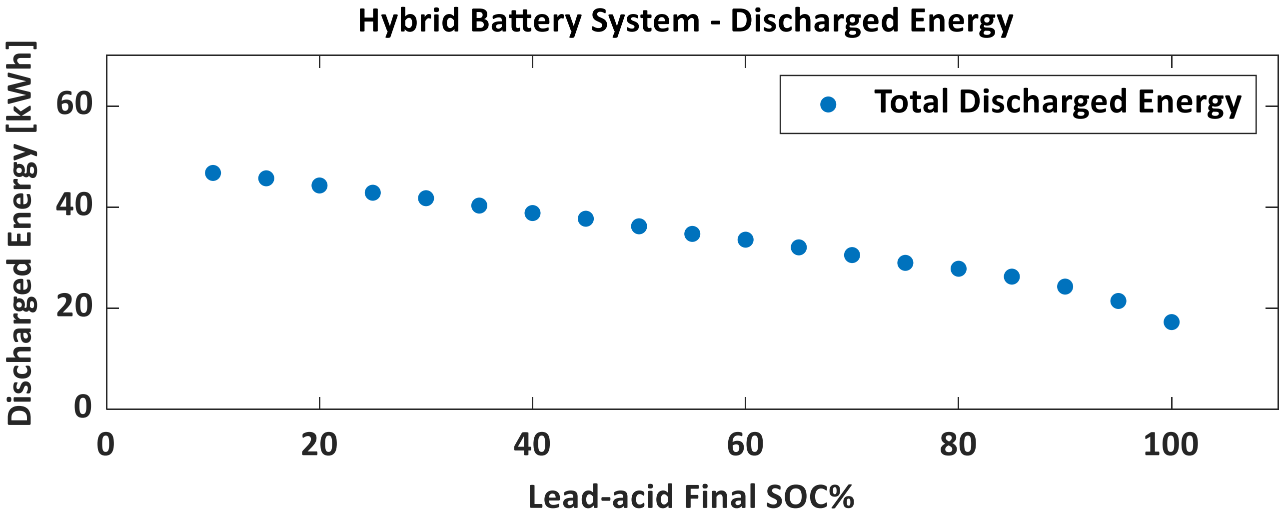
A – Region
(li-ion discharges, almost no lead-acid contribution and no circulation currents)

B - Region
(li-ion discharged almost completely, li-ion charges lead-acid)

Energy Transfer & Total Energy Discharged

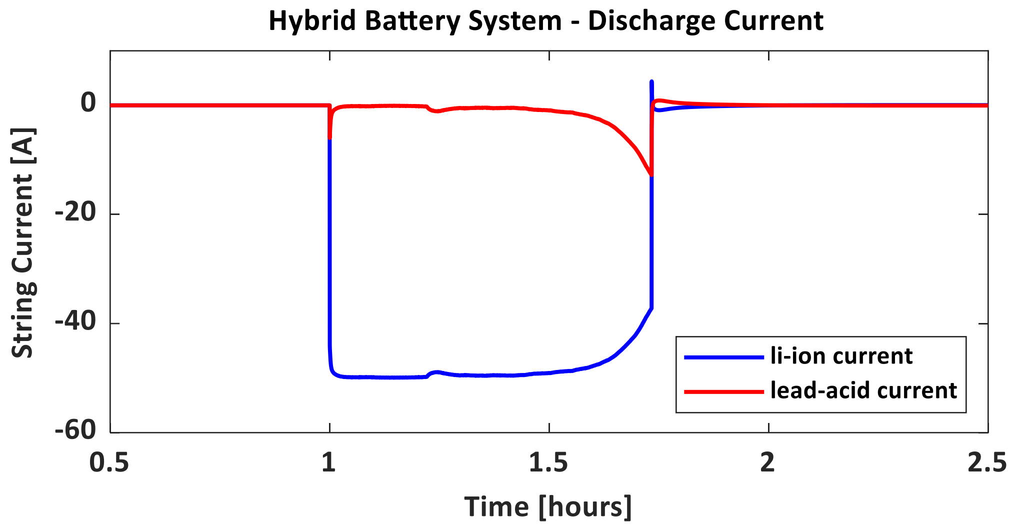


Total energy transfer from lead-acid to li-ion strings as the discharge process stops at different lead-acid SOC%.

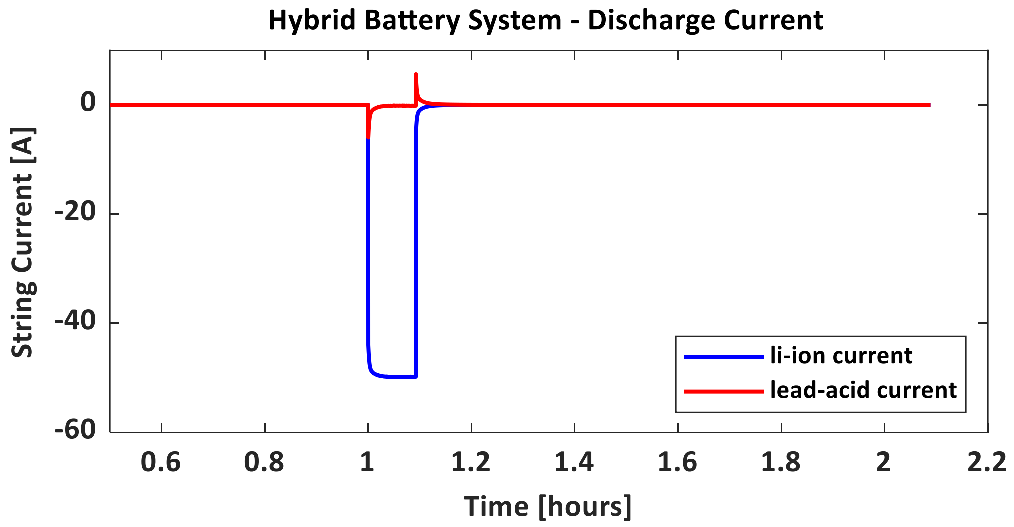


Total discharged energy by lead-acid and li-ion

Hybrid Battery Modelling – String Currents



Li-ion 80% DOD
Lead-acid 100% SOC



Li-ion 10% DOD
Lead-acid 100% SOC

Dual Chemistry Summary

- Zero carbon economy targets are driving force for growing ESS business
- Electricity storage is now indispensable to allow further penetration of Intermittent renewables especially wind and solar
- Energy storage provides multiple benefits across a range of operating periods.
- Lithium ion and lead acid can work in a complementary way to provide economical and sustainable solutions for many services from the same system.
- The Gemini Dual Chemistry package combines the maximum storage function with minimum power and control overheads.
- The modular container designs provide a consistent set of solutions ranging from full lithium to full lead acid and all combinations between.
- Research by University of Southampton is leading to tools to identify optimal solutions for multiple service provision.