GigHz
A Global Engineering partner

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Battery Module Design
for
5kW Home BESS

Scope : Battery Module Design - Electrical

Application : Home UPS

Designing a battery module for a 5kW home Battery Energy Storage System (BESS) involves several critical considerations to ensure efficiency, safety, and longevity. For a 5kW system, the rated power capacity and energy storage capacity must align with the energy requirements, considering factors like peak energy usage and backup power needs.

Electrical Design - Challenges

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The client requested to develop an electrical design for battery module with the capacity of 5kW design with low cost. They also need the design with a scalable module-based approach, allowing for future expansion or capacity adjustments without major system overhauls.

Challenges

- Current Distribution and Balancing
- Voltage Monitoring and Cell Balancing
- Overcurrent Protection
- Isolation and Grounding
- EMI/EMC Compliance
- Packaging and Space Constraints
- Cost Optimization

Simulation - Challenges

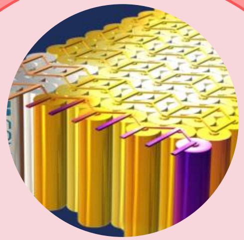
- Modeling Accuracy
- Computational Complexity
- Material Characterization
- Meshing and Resolution
- Multi-Physics Interactions

Electrical Design - SoW

Requirement Analysis

Cell Selection

Electrical Design



Battery Module Simulation

Result

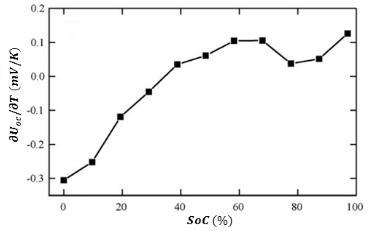
Requirement Analysis

- Requirement Analysis in battery module design is a crucial first step to ensure that the battery system meets the technical, performance, and safety needs of the intended application.
- This stage involves gathering and analyzing all necessary requirements to define the battery module's specifications.
- Collaborating with clients is key to understanding the project's specific needs and constraints.

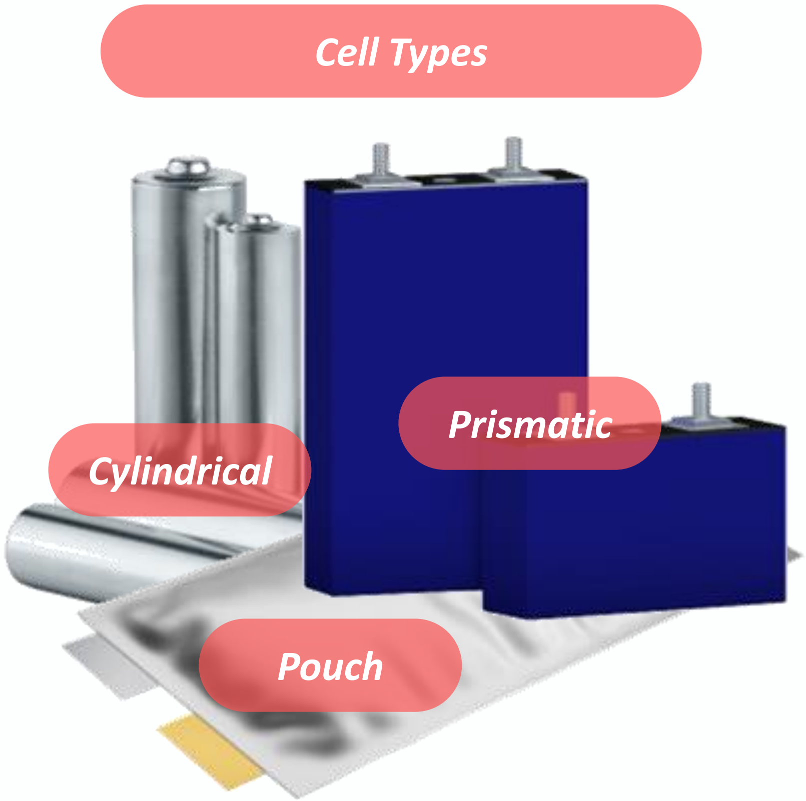
Electrical Parameters:				
Pack Details -Electrical				
Energy	5	kWh		
Charging Power	1	kW		
Discharging Power	5	kW		
Cell Details - Electrical				
Part No	PF173-280A			
Form Factor	Pouch			
Capacity	280	Ah		
Max Voltage (100% SoC)	3.65	V		
Nominal Voltage	3.2	V		
Min Voltage (0% SoC)	2.5	V		
Open Circuit voltage at reference temperature		Graph		
Ohmic overpotential at 1C				
Dimentionless charge exchange current				
Cell Details - Mechanical			Tolerance	
Thickness	71.5	mm	0.5	mm
Width	174.4	mm	0.5	mm
Shoulder height	204.3	mm	0.5	mm
Total height	207.2	mm	0.5	mm
Weight	5.4	kg	0.2	kg
Radius		mm		
Max Temp	35	C		
Min Temp	10	C		
Absolute Max Temp	55	C		
Absolute Min Temp	-10	C		
Humidity	≤75	%		
Cell Details - Thermal				
Through layer thermal conductivity	2	W/m·K		
In layer thermal conductivity	30	W/m·K		
Heat capacity	4000	J/K		
Density	2000	kg/m3		
Temperature derivative of Open Circuit Voltage	--->	Graph		
Module Details - Electrical				
Voltage	36	V		
Current	280	A		
Connector Details - Power, Communication	In Doc			
Cable Details - Power, Signals	In Doc			
Module Details - Mechanical				
Level of Detail	In Doc			
3D model of CMU	In Doc			
3D model of BMU	In Doc			
Cell Holder Material	In Doc			
Cell Spacer Material	In Doc			
Current Collector Material	In Doc			
Enclosure Material	In Doc			
Fan Part No	In Doc			
Module Details - Thermal				
Max Temp	0	C		
Min Temp	50	C		
Charge / Discharge cycle - Fixed time / Random load	In Doc			
EMI				
Certification				
Others				
Cell balancing	Passive			
Wire and Connectors details	In Doc			
Power for Fan	CMU			

Parameters and Details

- Defining Use Case (Application): Identify the specific application of the battery pack (e.g., automotive, renewable energy storage, consumer electronics, UPS, peak load shaving). It will be very helpful to arrive all conditions and objectives.
- Derive Design Objectives:
  - Grid Connection: [On/Off grid with frequency]
  - Capacity: [e.g., 50 kWh for Energy Storage Systems]
  - Charging Power: [e.g., 30kW and what charges it?]
  - Discharging Power or time: [e.g., 50kW for 1hr]
  - Voltage Range: [Nominal and maximum voltage values]
  - Current Rating: [Minimum, Nominal and Maximum values]
  - Cycle Life: [Number of charge-discharge cycles]
  - Form factor: [for Enclosure]
  - Space & Weight constraint:
  - Thermal Management: To maintain safe operating temperature limits
  - Safety Features: Overcurrent, overvoltage, and thermal runaway protection
  - Regulatory Compliance: Adherence to industry standards such as CISPR 25, ISO 26262, and UN38.3
  - Additional features: like IP rating
- System Load Profile / Electricity consumption profile: There could be daily, weekly, or seasonal patterns.
- Environmental Conditions:
  - Operating temperature: [Minimum, Nominal and Maximum values]
  - Humidity:
  - mechanical shock/vibration requirements:



Cell Selection



- *Cell Chemistry:* LFP cells were selected for their inherent safety, high cycle life, and stable thermal characteristics
- *Mechanical Properties:* select based on Space & Weight constraint along with thermal properties
  - Form Factor: Prismatic
  - Dimension
  - Weight
  - Tolerance
  - Regulatory Compliance
- *Electrical Characteristics:*
  - Voltage : 3.2V
  - Current : 280A @ 1C
  - Capacity :280Ah
  - C-Rate : 10 Max.
  - SoC and SoH
- *Cycle Life and Safety:* Balance cycle life, safety features, and cell costs..
- Based on the above condition and requirement the cell is selected.

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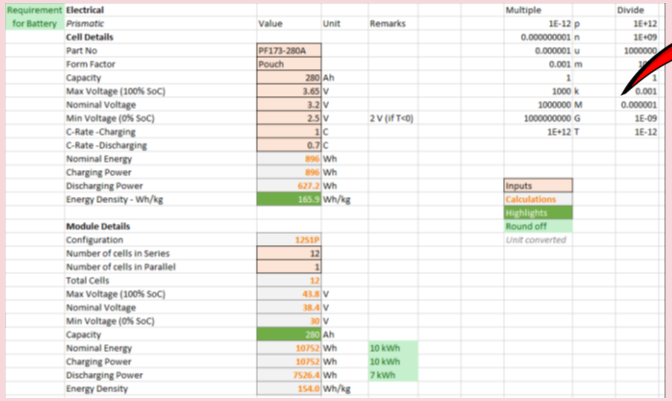
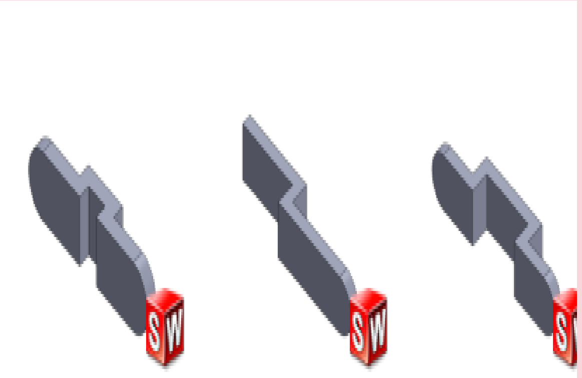
Electrical Design

Cell Configuration

Define series-parallel configuration to achieve desired voltage and capacity.



Requirement for Battery	Electrical				Multiple		Divide
	Prismatic	Value	Unit	Remarks	1E-12	p	1E+12
	Cell Details				0.000000001	n	1E+09
	Part No	PF173-280A			0.000001	u	1000000
	Form Factor	Pouch			0.001	m	[illegible]
	Capacity	280	Ah		1		1
	Max Voltage (100% SoC)	3.65	V		1000	k	0.001
	Nominal Voltage	3.2	V		1000000	M	0.000001
	Min Voltage (0% SoC)	2.5	V	2 V (if T<0)	1000000000	G	1E-09
	C-Rate -Charging	1	C		1E+12	T	1E-12
	C-Rate -Discharging	0.7	C				
	Nominal Energy	896	Wh				
	Charging Power	896	Wh				
	Discharging Power	627.2	Wh		Inputs		
	Energy Density - Wh/kg	165.9	Wh/kg		Calculations		
					Highlights		
	Module Details				Round off		
	Configuration	12S1P			*Unit converted*		
	Number of cells in Series	12					
	Number of cells in Parallel	1					
	Total Cells	12					
	Max Voltage (100% SoC)	43.8	V				
	Nominal Voltage	38.4	V				
	Min Voltage (0% SoC)	30	V				
	Capacity	280	Ah				
	Nominal Energy	10752	Wh	10 kWh			
	Charging Power	10752	Wh	10 kWh			
	Discharging Power	7526.4	Wh	7 kWh			
	Energy Density	154.0	Wh/kg				

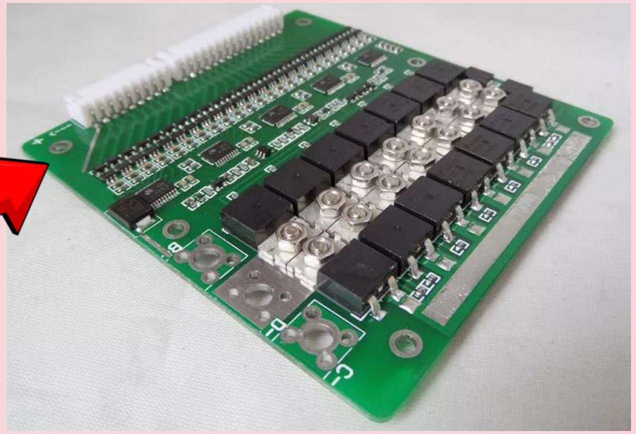


Wiring Harnesses and Connectors

The busbar design was optimized to handle up to 280A current without significant ohmic losses.

Cell Balancing

Provided by client for electrical design



Electrical Design

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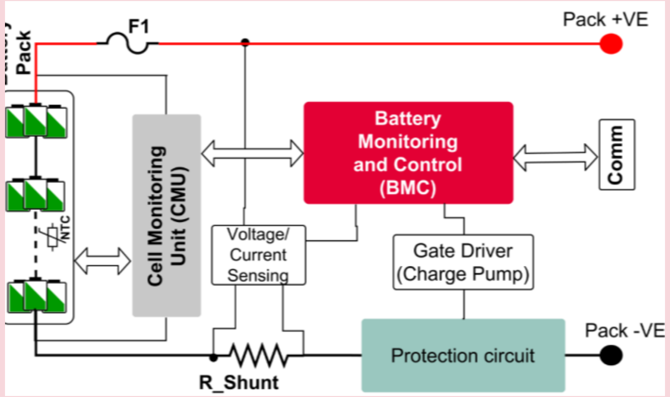
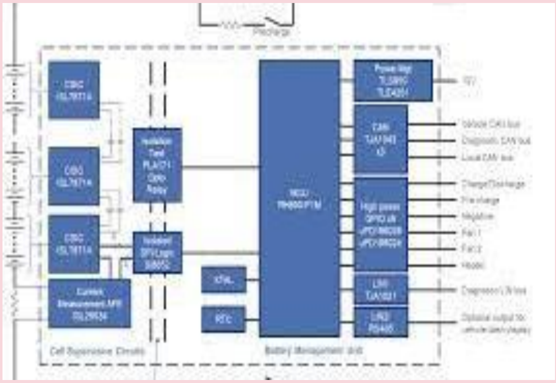
Protection Circuit

Add reverse polarity protection, Relay, fuse, and overcurrent protection.





BMS

Provided by client for this design

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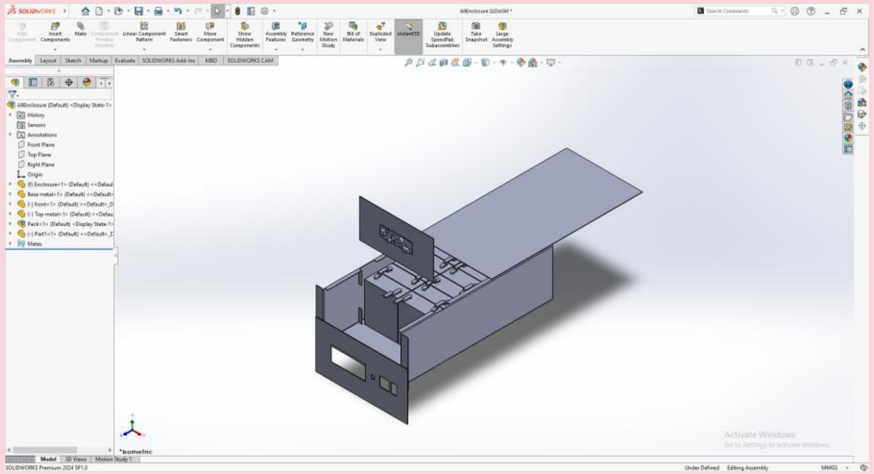
Battery Module Simulation

Geometry Creation

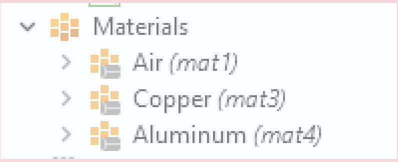
The model was developed with removing components with negligible or no effects on the simulation.



Assign Material

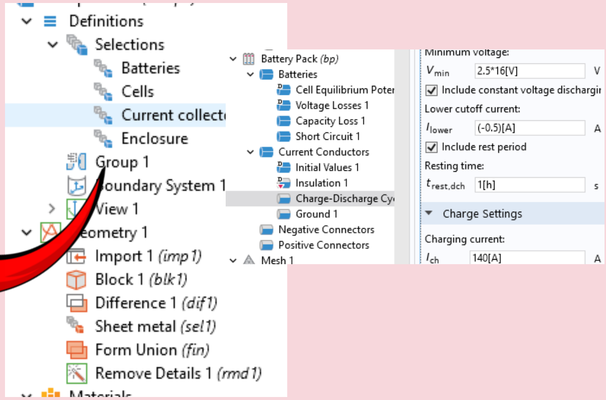
Cu for current collector

Al for enclosure

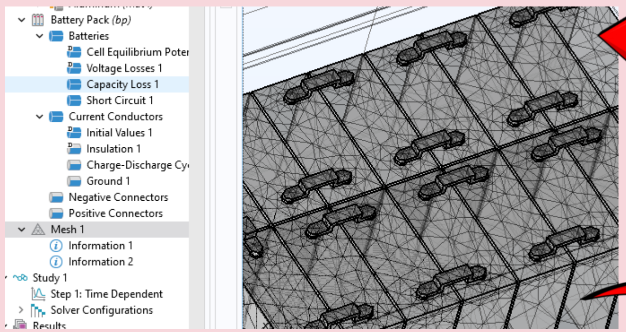


Defining Boundary condition

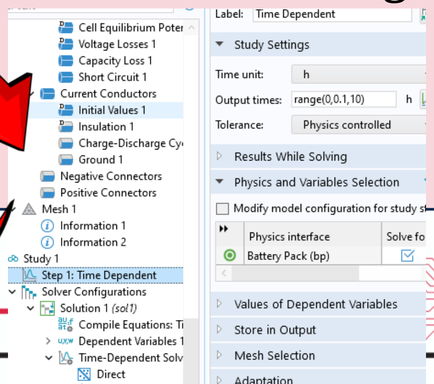
In COMSOL Boundary were created



Assign Mesh



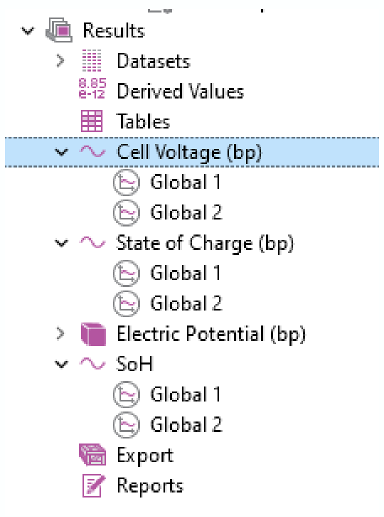
Simulation Setting

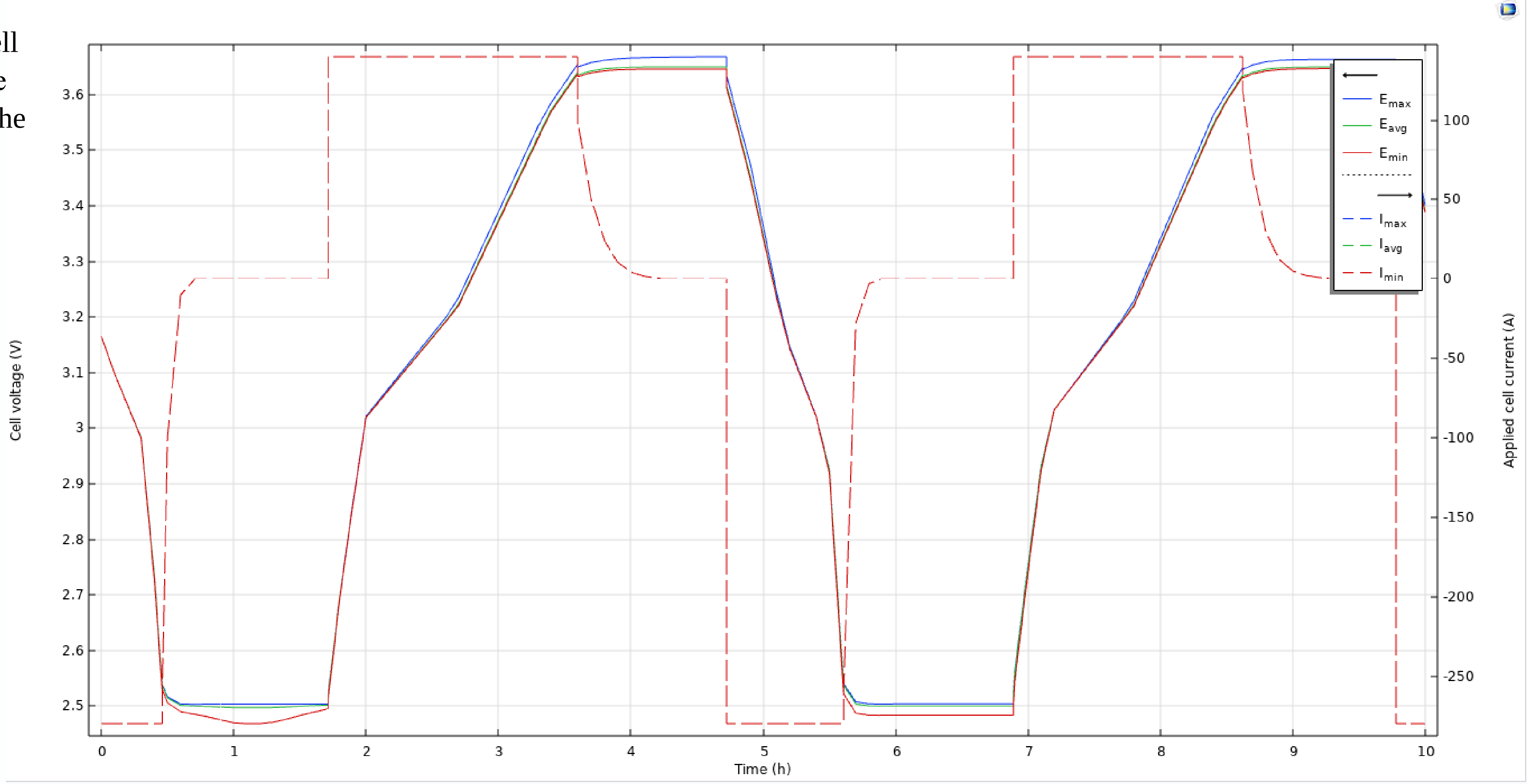


Run the Simulation

Cell Voltage – Simulation Result

Based on the simulation, the cell voltage doesn't vary much. The charge discharge cycle shows the batteries are in good condition.

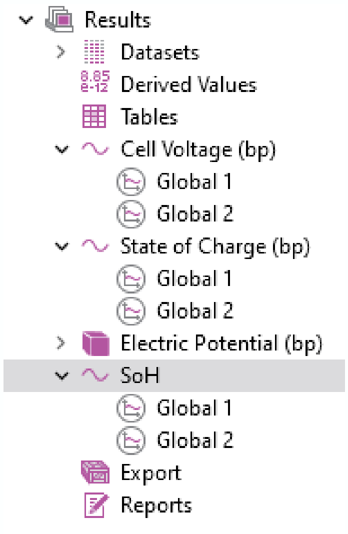




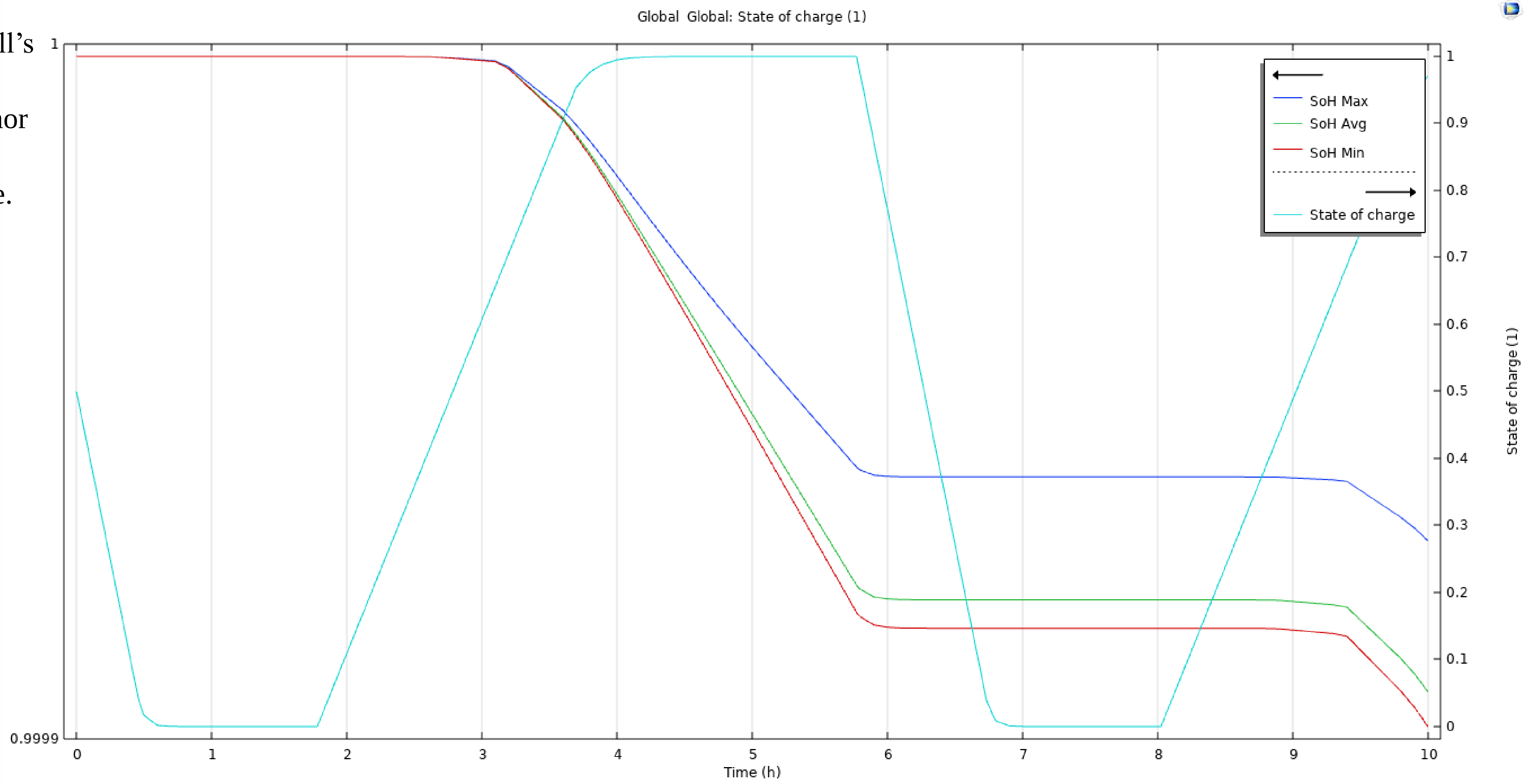
Cell Voltage & Current

Simulation Result

Based on the simulation, the cell's min, max, avg state of health (SoH) the result have some minor variation between cells after multiple charge-discharge cycle.



From all, we completed a cost effective 5kW battery module electrical design.



SoH

Customer Testimonial

We are delighted to share a testimonial from a satisfied client highlighting the success of our Battery Module Electrical Design project. The team exceeded expectations by delivering a high-quality, reliable battery module design tailored to our specific requirements. Their expertise in electrical design ensured optimal performance, all while keeping the project within budget. The project was completed within a challenging timeframe without compromising on accuracy or quality. We highly recommend their exceptional service, attention to detail, and cost-effective solutions for battery module design.

Conclusion

Our commitment to excellence and technical expertise was evident in the successful delivery of customized Battery Module Electrical Design solutions that met industry standards.

We meticulously designed and simulated the battery module to ensure optimal performance, efficiency, and safety, significantly reducing the need for costly post-production testing.

Our focus remains on providing top-tier electrical design services, demonstrating our unmatched proficiency and dedication to delivering exceptional results while maintaining the highest levels of reliability and innovation.