

Final Conference

Fast - Charging

Name Name

Brussels, 28 September 2026



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Innovation brick – Fast charging

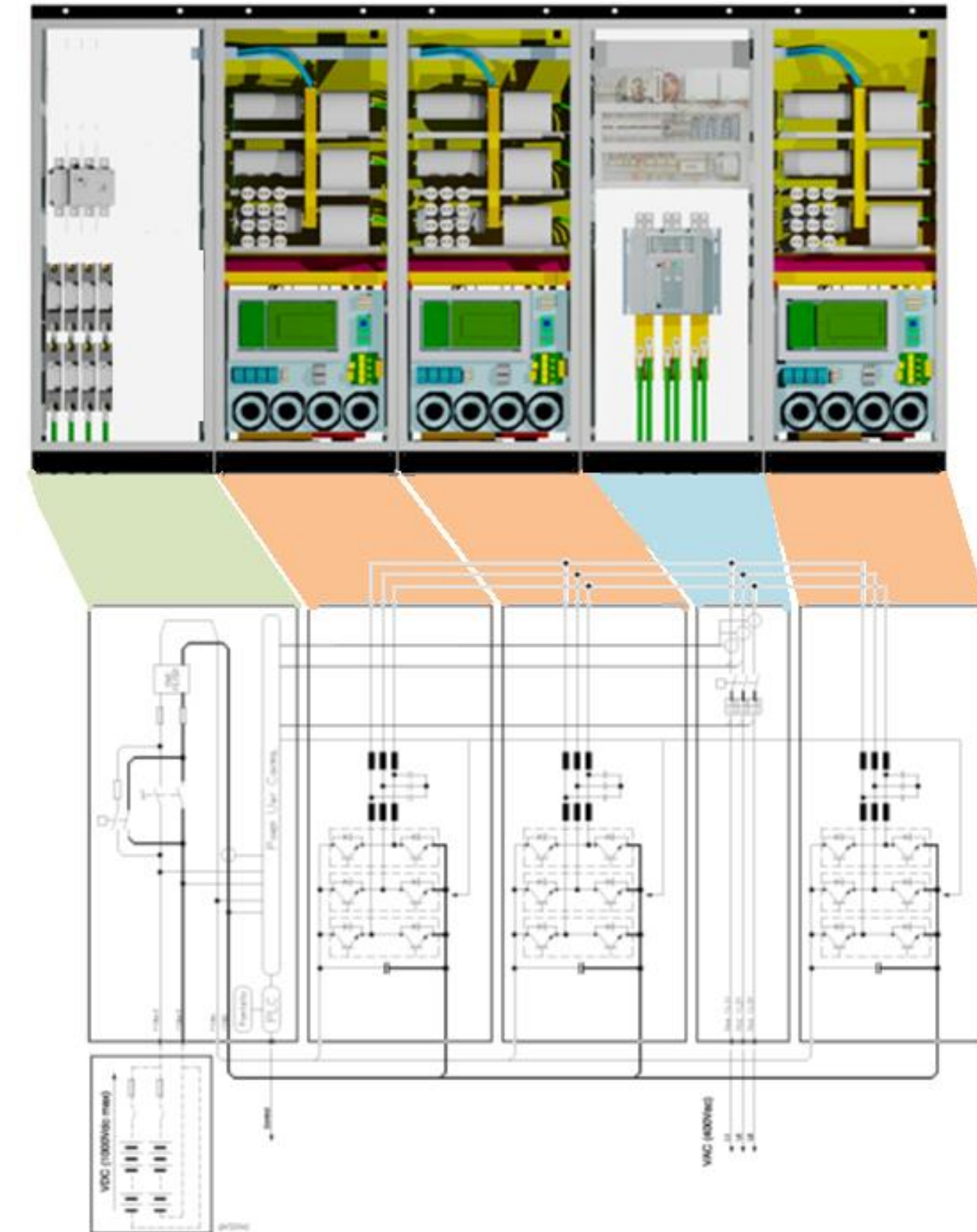




Main MCS characteristics

The main purpose during this project has been to design and develop a megawatt charging infrastructure (MCS) compliant with the following features

- A centralised power converter (AC/DC) up to 1MVA to minimize the footprint of the solution.
- Multiple outputs for Charging multiple vehicles at the same time to give scalability and modularity to the producto.
- The maximum power per output 350kW.
- **High efficiency has been achived by using recent WBG power modules (SiC).**
- Interoperable communication both between EV and EVSE (ISO15118-20) and EVSE and backend (OCPP 1.6 and OCPP 2.0)
- Internal Dynamic Load Management (DLM) to regulate optimally the output current depending on the consumption done by the EV.

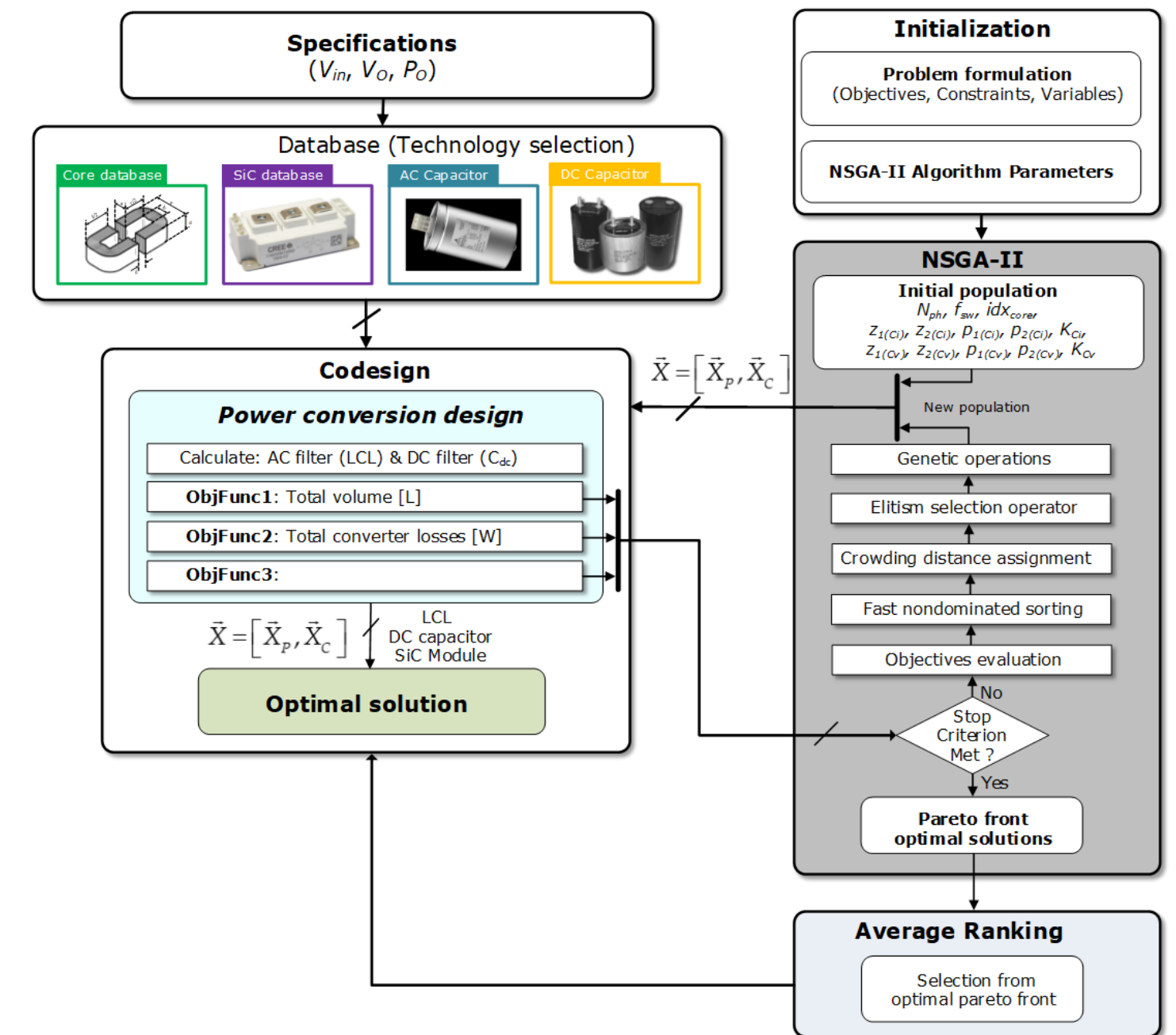




Design Optimization Framework

The optimization technique is based on a dynamic simulation model of the off-board charger. In this realistic approach, the complete system is modelled in simulation with respect to the datasheet:

- Accurate MATLAB dynamic simulation model design for converter.
- Datasheet based parameterization in dynamic simulation for half-bridge power module.
- Power loss modelling in simulation (switching loss + conduction loss).
- Thermal modelling of half-bridge module.
- Loss modelling of passive filters.
- Complete efficiency of converter estimation.
- Select maximum operating switching frequency for achieving maximum efficiency of a complete system.
- Select improved passive filter component for reducing the ripple magnitude.

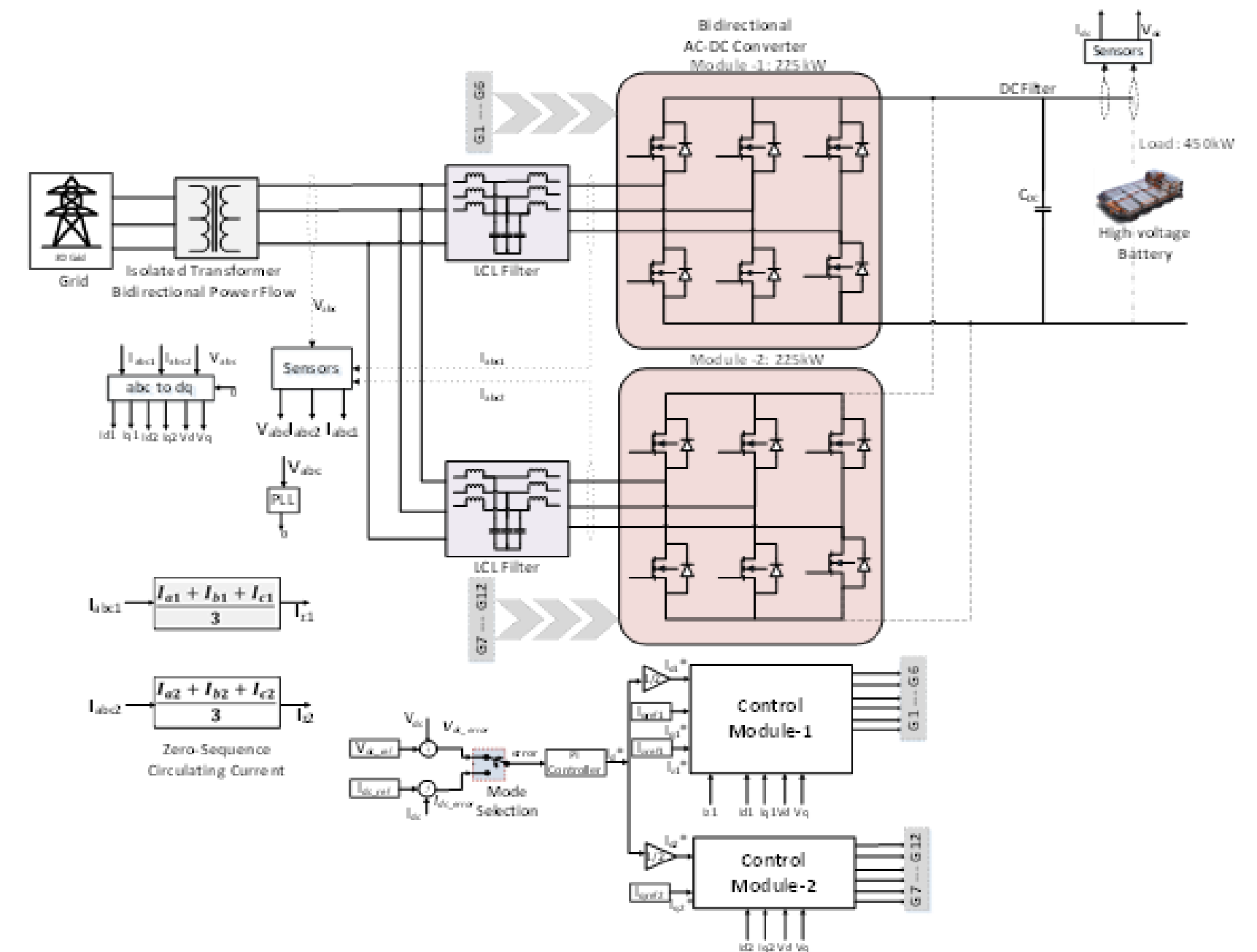




Power Converter Topology

A three-phase active front-end (AFE) rectifier tackles the total harmonics distortion (THD) issue by improving the quality of three-phase sinusoidal grid current with unity power factor and efficiency, along with a variable DC output voltage. The AFE three-phase three-leg boost rectifier as shown in Figure 8 is the best option for an off-board charger design and development among all three-phase AC-DC conversion techniques: a diode rectifier, an active buck/boost rectifier and a Vienna rectifier. From the design point of view, it is necessary to consider several elements in the development of the AC-DC AFE converter: high efficiency, high power factor, reliability, cost-effectiveness, small system size and weight, and distortion-free operation with limited grid impact.

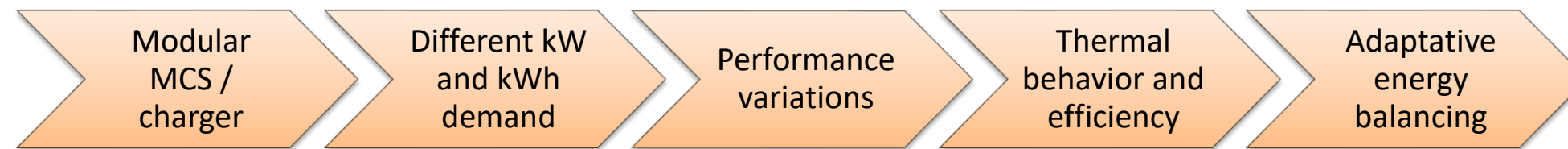
Parameter	Symbol	Min. Value	Nom. Value	Max. Value
Input voltage (RMS)	V_{ac}	--	400	--
Line frequency (Hz)	f_{line}	48	50	52
Power factor	$\cos\Phi$	0.98	0.99	1.00
Power rating (kW)	P_o	--	--	450
DC-link voltage (V)	V_{dc}	600	800	1000
DC current (A)	I_{dc}	450	564	750
Max. Junction Temperature SiC (°C)	T_j	-40	--	125



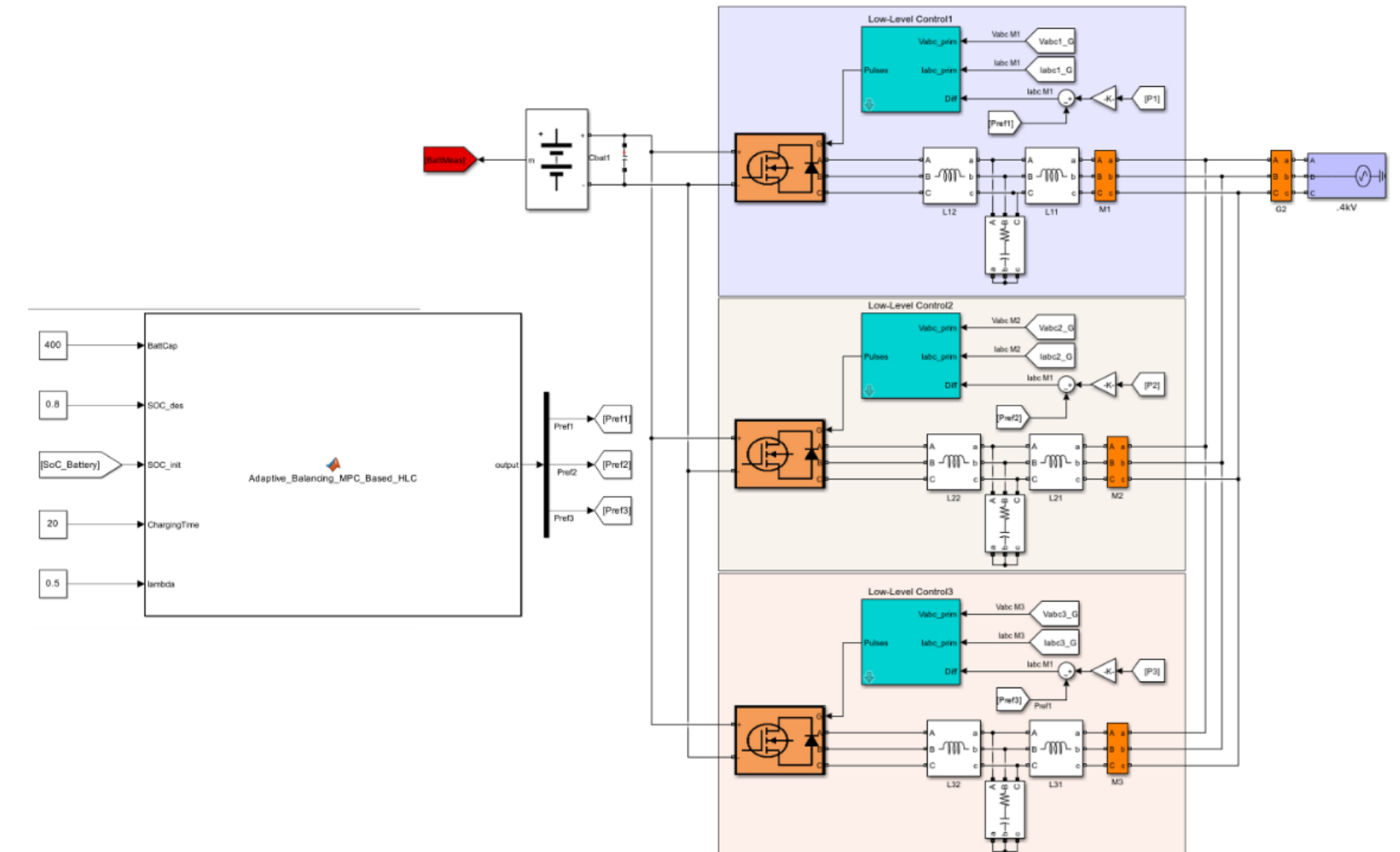


Model Predictive Control

The megawatt charging station (MCS) utilizes modular converters to efficiently manage high power levels. These converters are made up of multiple parallel modules to evenly distribute load and energy.



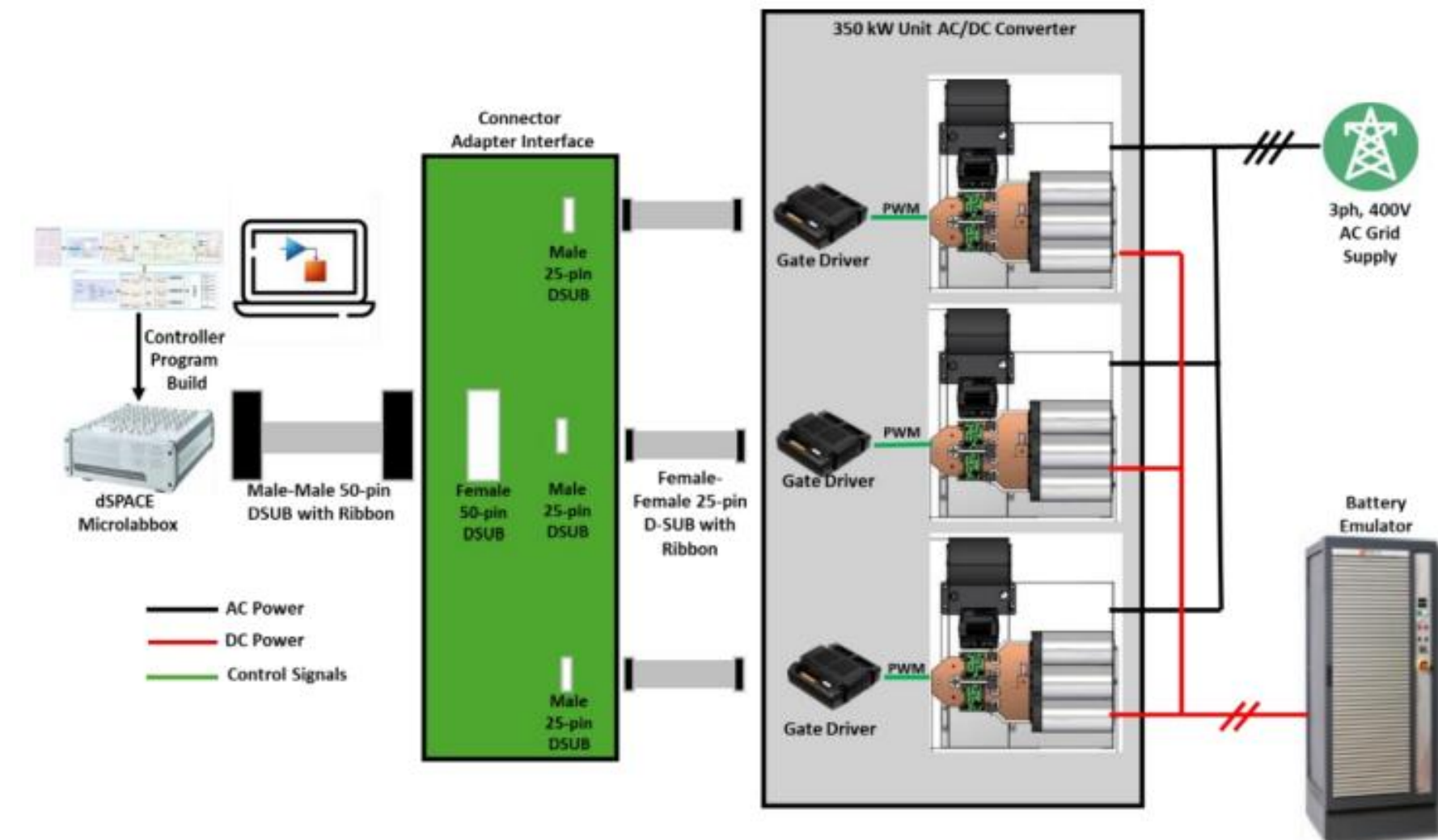
MPC is an advanced and powerful control strategy that can be used to balance energy in modular converters. It is effective in managing the complex dynamics of modular converters used in charging stations. MPC has unique capabilities, such as handling multivariable objectives and constraints and forecasting future system states. Efficiency is one of the main objectives of MPC to ensure economic benefits.





HW in the Loop testing

Hardware-in-the-Loop (HIL) testing for the development of control software for a megawatt charging converter, selecting the right real-time controller module is crucial for ensuring the effectiveness and accuracy of the testing process. The real-time controller serves as the interface between the simulation models and the physical hardware, enabling the testing of control algorithms under realistic conditions before full deployment. The key factors to consider when choosing a real-time controller module for HIL testing are performance, compatibility, flexibility, and scalability. The right choice will help in achieving the desired outcomes of accurate, stable, and efficient power delivery through the converter, particularly during demanding megawatt charging events.





Digital twin modelling

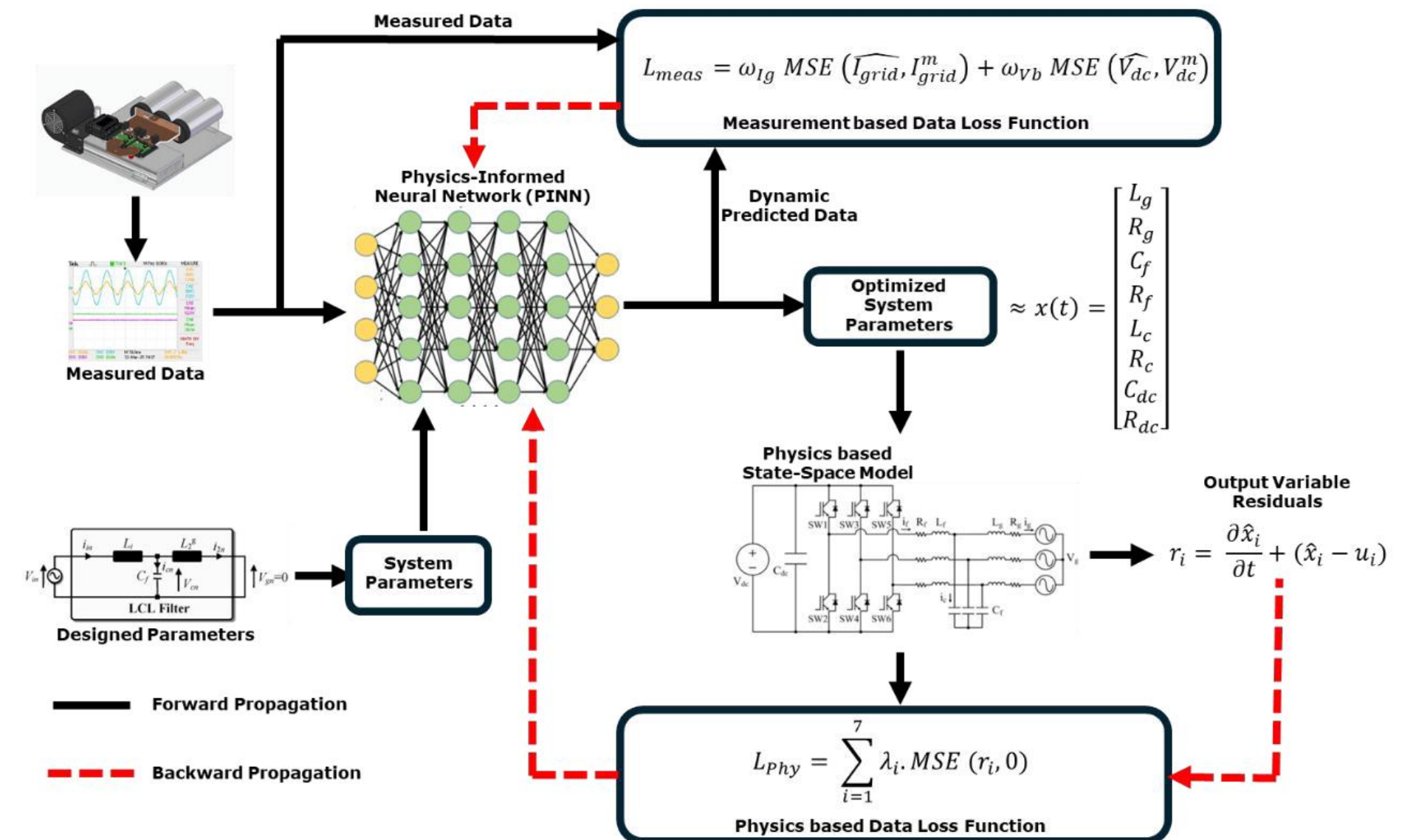
The digital twin aims to model the internal states and output behavior of this system based solely on measurable electrical quantities available in a real-world test setup.

The proposed digital twin modeling methodology includes three main phases:

Training Phase: A Physics-Informed Neural Network (PINN) is trained using only experimental measurements as supervision and physical laws as constraint enforcement. The objective is for the model to capture the physical behavior of the system from real-world input-output data.

Digital Twin Definition: Once the training is successfully completed and validated, the resulting PINN is considered a digital replica (digital twin) of the actual power conversion system. This digital twin reflects both learned behaviors and physical laws.

Simulation Evaluation: The digital twin is then tested using simulation derived inputs ($U = [v_{gd} \ v_{gq} \ v_{cd} \ v_{cq}]^T$ from the Simulink model) to predict the corresponding outputs $Y = [i_{gd} \ i_{gq} \ v_{cdf} \ v_{cfq} \ i_{cd} \ i_{cq} \ v_{dc}]^T$. These predictions are compared with the outputs from the same simulation to assess how the real converter would have behaved under identical conditions.

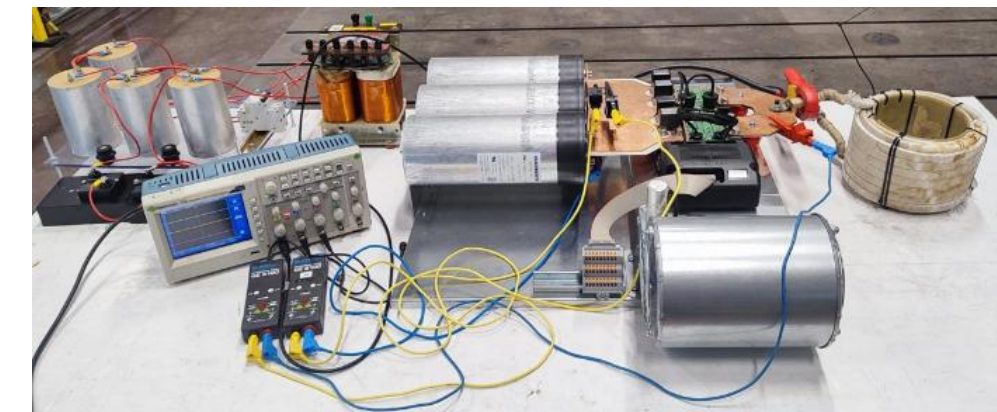
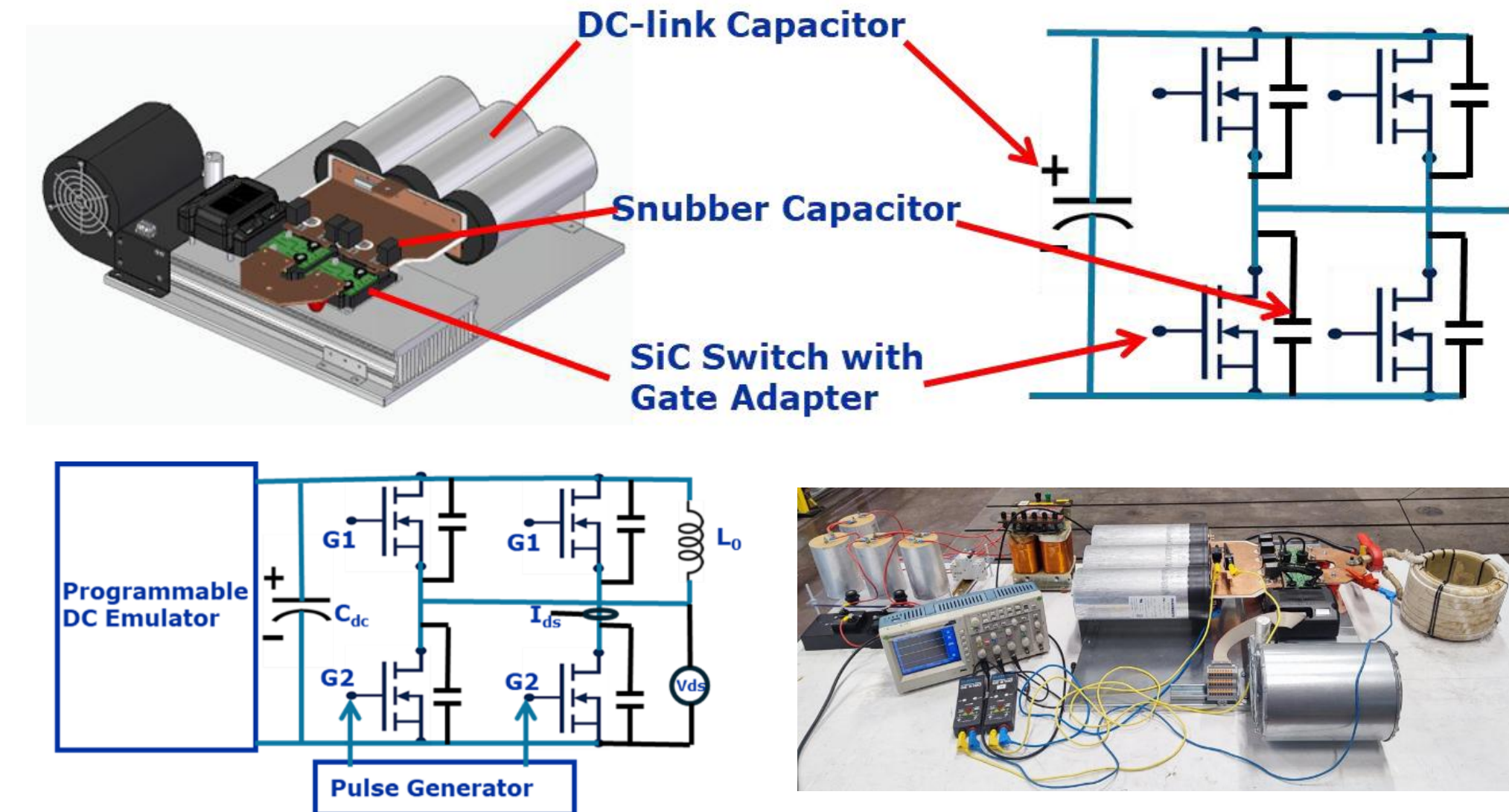
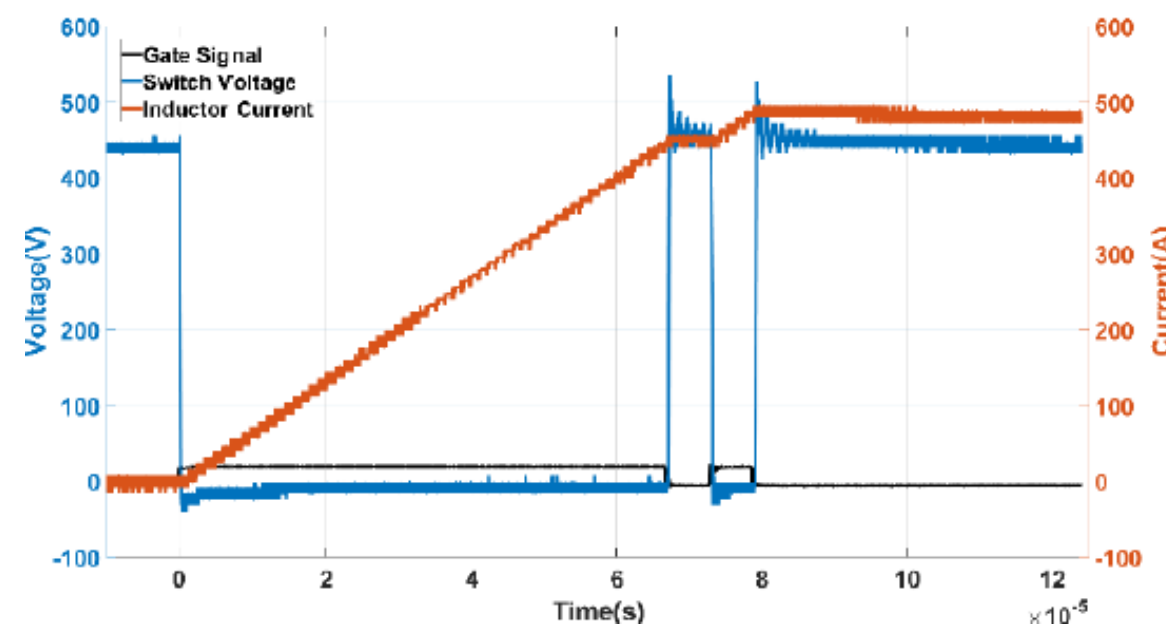




HW testing

Tests were made that provided key insights into voltage and current waveforms, switching losses, and dynamic characteristics critical for optimizing power converter design. The results served as a baseline for further system-level integration and reliability assessments of SiC-based modules in high-power applications.

To assess performance across various operating points, the DC link voltage was varied over five discrete levels: 100 V, 200 V, 300 V, 400 V, and 450 V. Simultaneously, the inductor current was increased from 100 A to 450 A, reflecting realistic current levels that the module may experience under actual charging conditions.





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