Extreme Fast Charging: Challenges and Potential

Jonathan Kimball

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Overview

High-Level Goals

Grid Support Functions

Power Conversion Topologies and Control

Summary and Next Steps

Project Goals

Extreme Fast Charging of Electric Vehicles

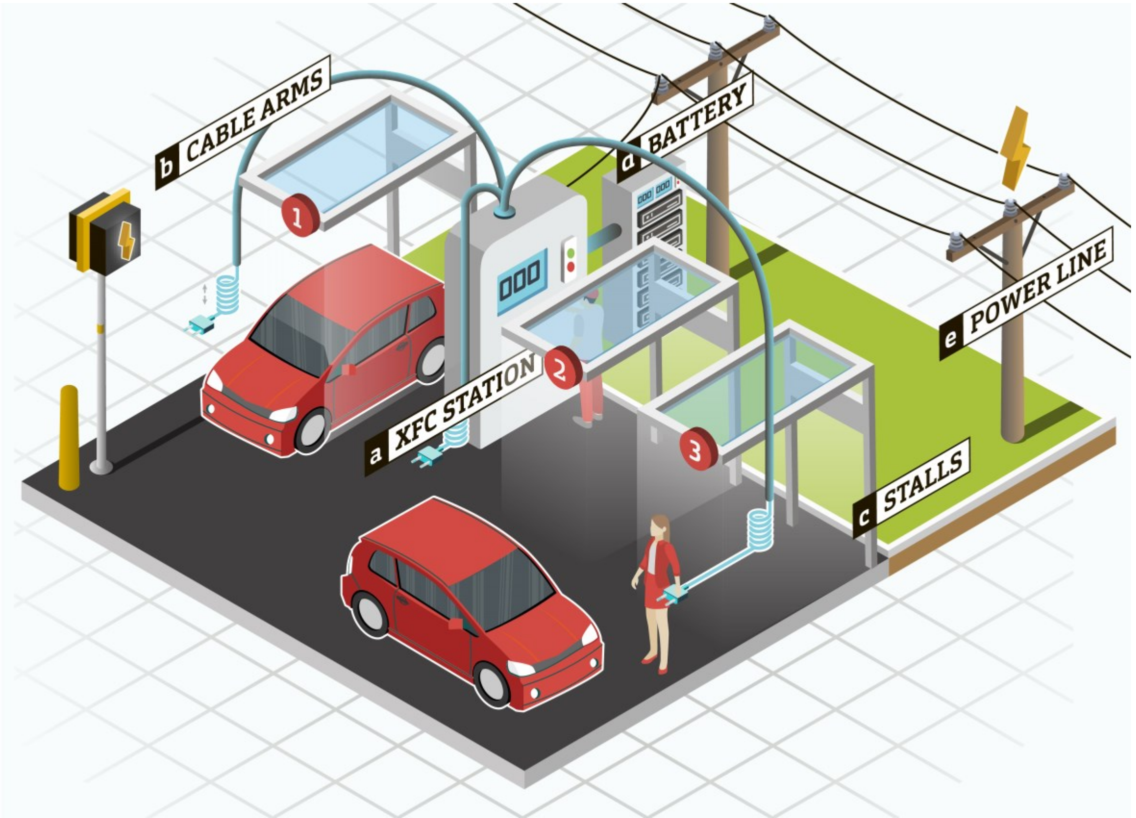
Achieve bulk charge in a time similar to refueling conventional vehicles

Peak Power Demand of 350 kW per charge port

Provide Grid Support Functions

Connect Directly to Medium-Voltage Feeder

Mitigate Battery Wear-out



Grid-Side Challenges

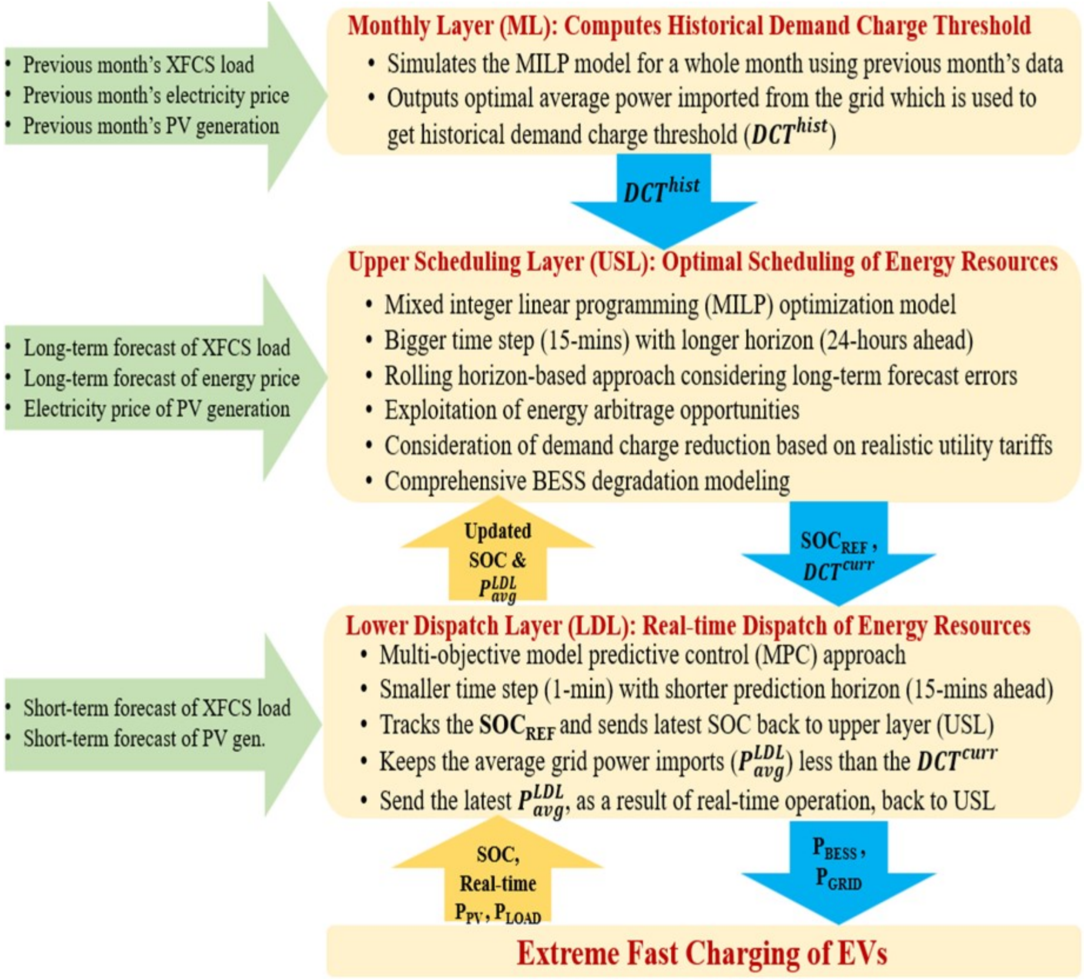
Intermittent nature and large-scale XFCS demand → increased daily demand peaks, feeder overloading, increased power losses, and power quality issues in host power grids

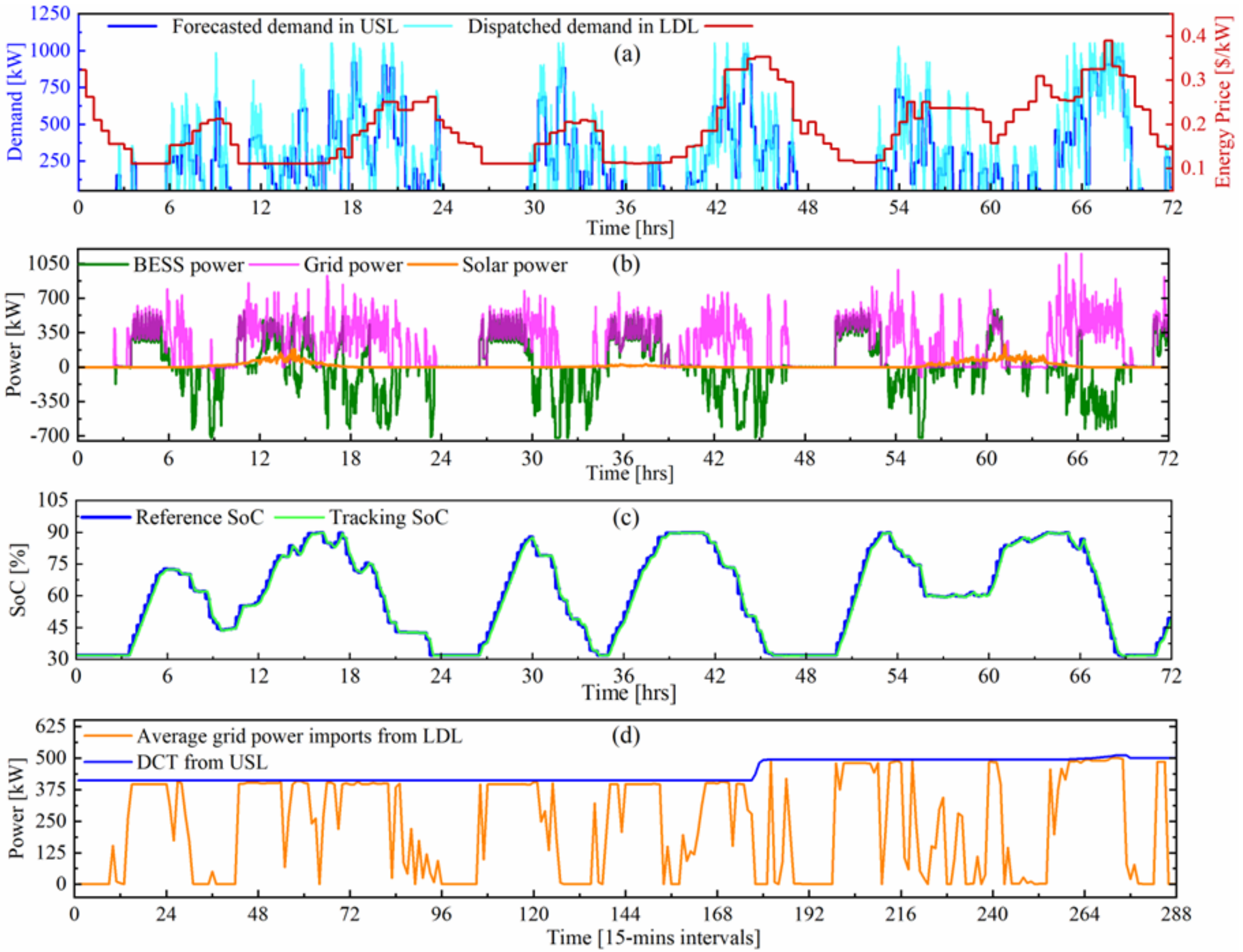
Overall operational cost minimization

- energy arbitrage
- reduction of demand charges cost
- feeding excess generation from PV to grid

Multi-Level Energy Management Framework

Timescales from milliseconds to months





Active and Reactive Power Management

Q-compensation → to mitigate steady-state voltage violations

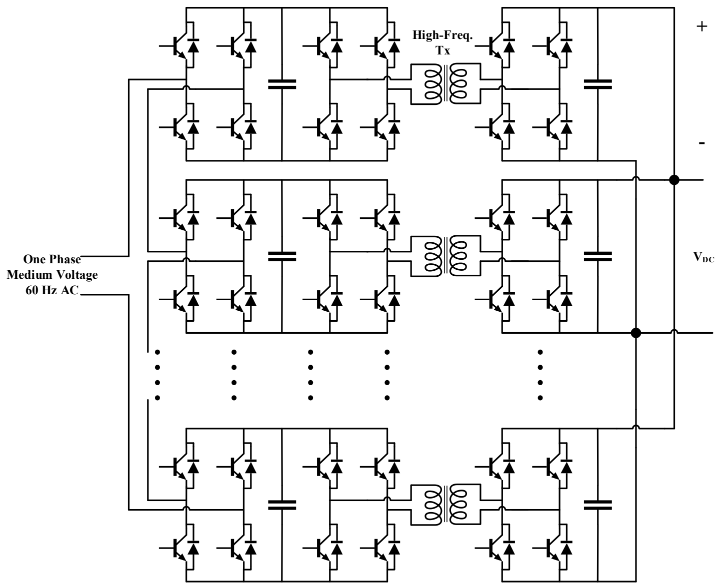
- Deadband on voltage; enable outside of bounds, disable on change of sign of Q

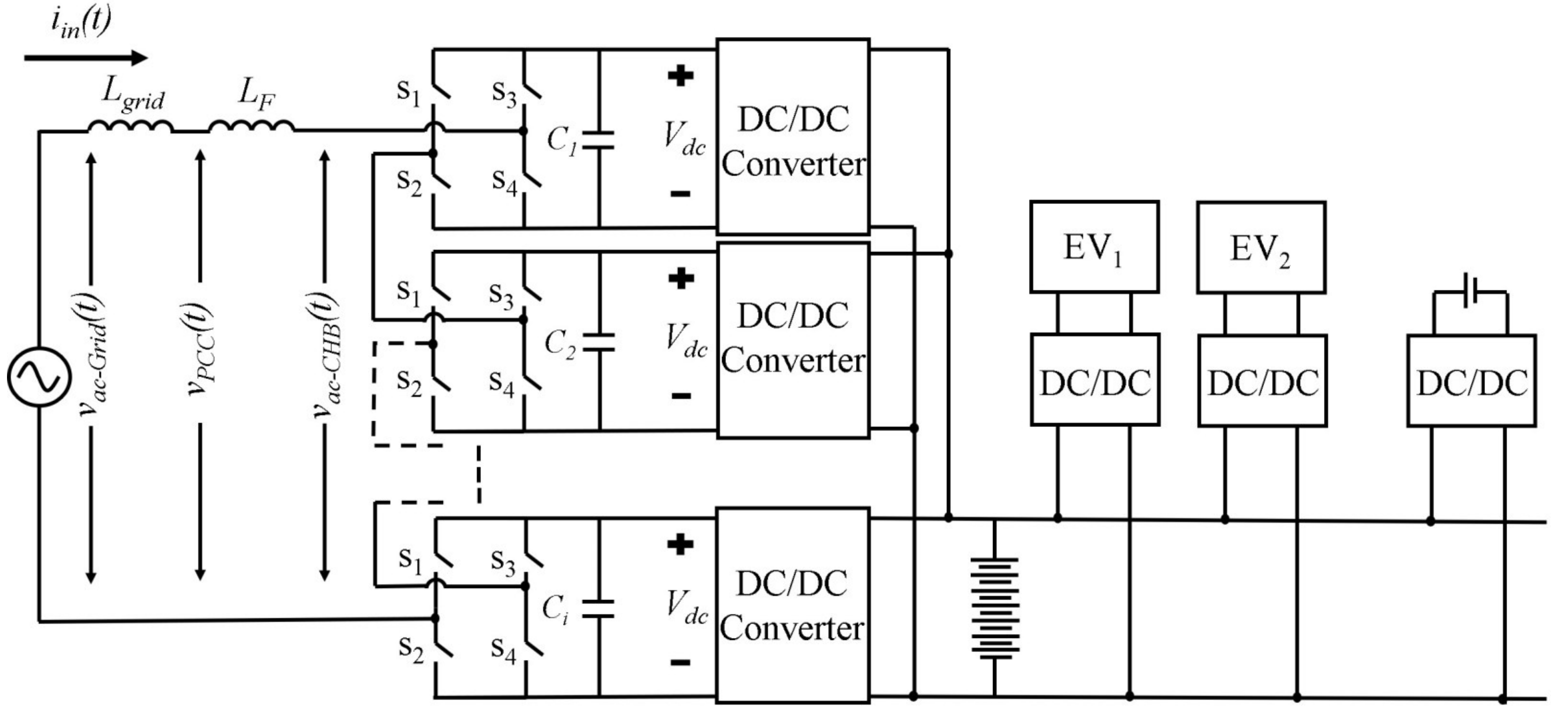
Power converter limits affect the active power imports from the grid → ESS may function as a load-sharing device to provide supplemental power to satisfy EV demand

Power buffering of the ESS → to buffer the power swings and mitigate the dynamic impact on the grid's power quality

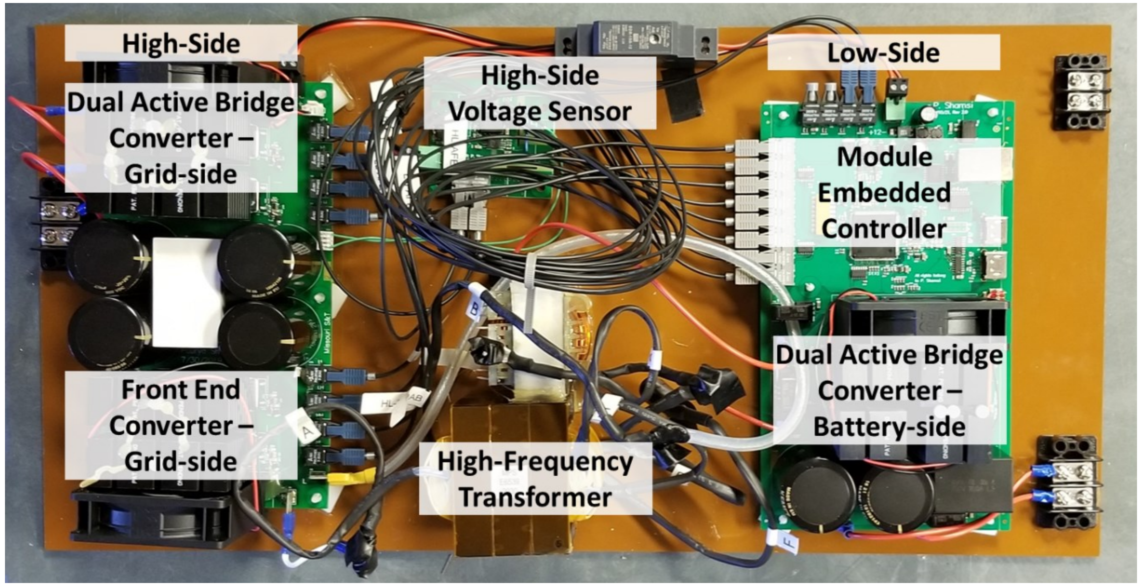
Power Conversion

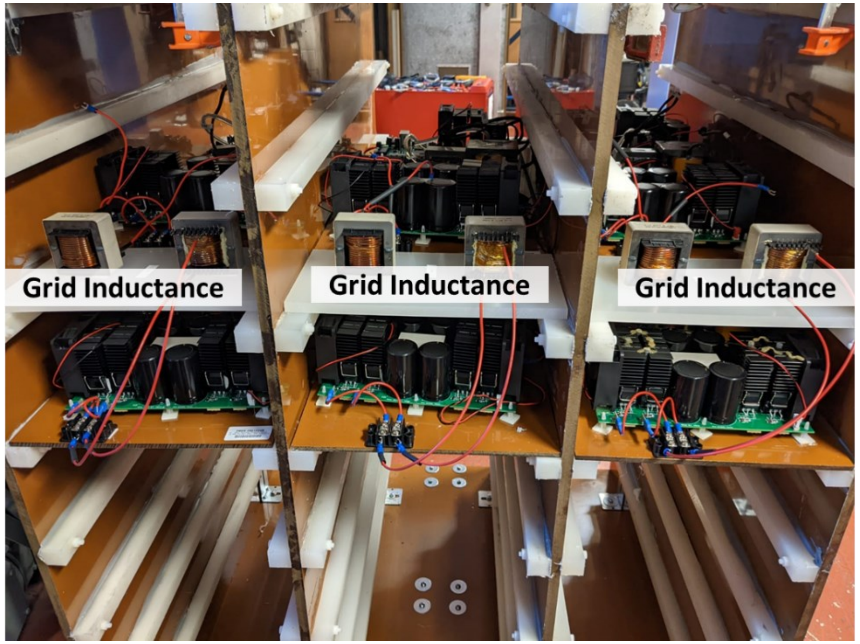
Goal: Connection to medium-voltage feeder (12.47 kV 3Φ)





Low-Voltage Prototype





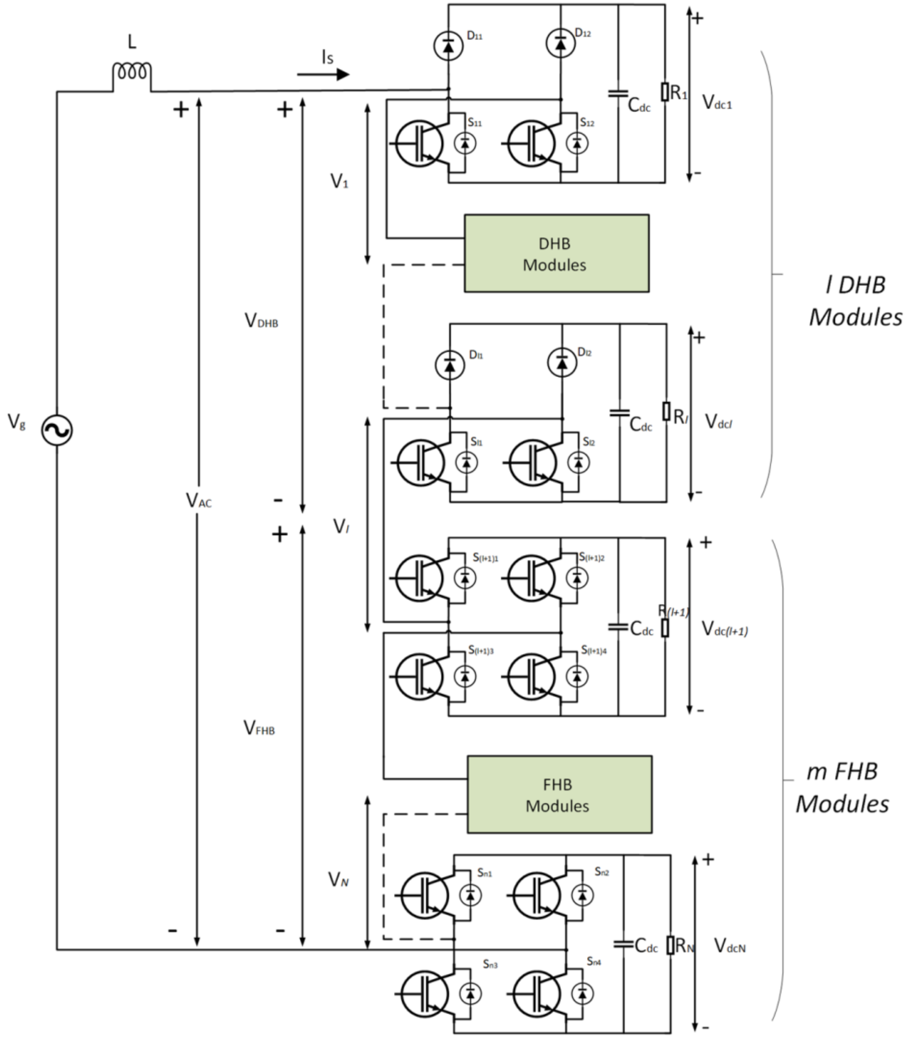
AFE Topology Option: Cascaded Bridgeless Multilevel Rectifier

Replace some full H-bridges with diode H-bridges

Fewer gate drivers and signals, so easier control

Limited range of Q; P > 0

Limits grid services that can be provided



DC-DC Topology Option: LLC

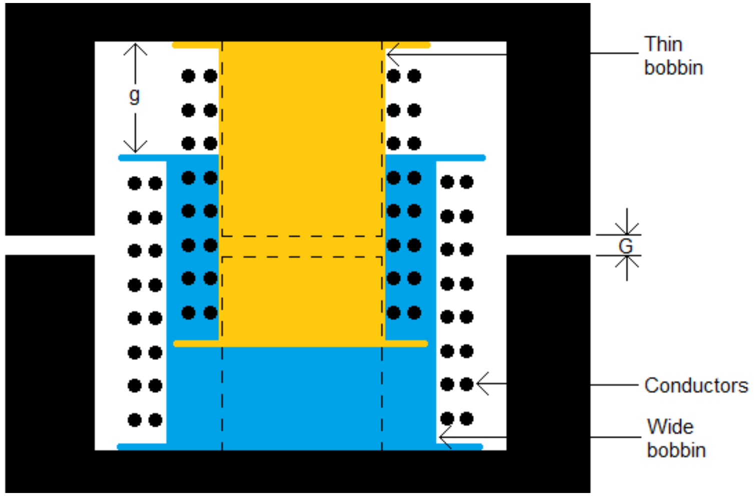
Or CLLLC for bidirectional power flow

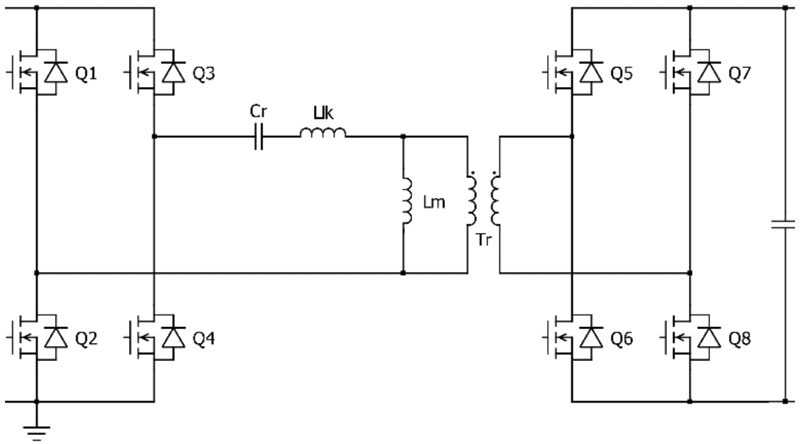
Resonant converters are controlled by frequency

Gain determined by inductances

Propose novel variable transformer to vary magnetizing & leakage

Introduce new hybrid 2D model for leakage inductance; also useful for any transformer where windings do not fill the window

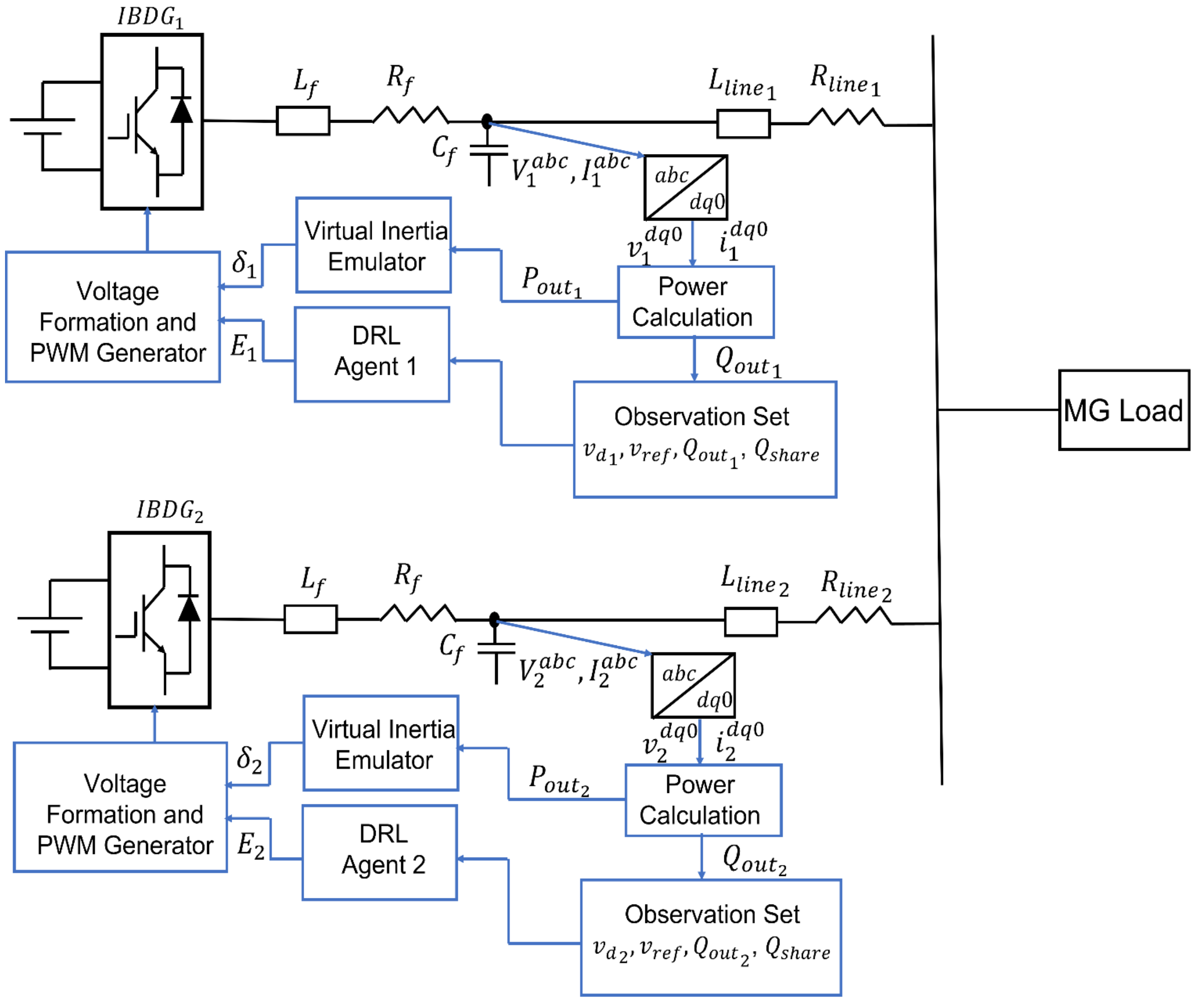




Virtual Synchronous Generator

Emulate exciter, inertia of a rotating generator

Use reinforcement learning to achieve accurate voltage regulation, frequency regulation, active power sharing, and reactive power sharing



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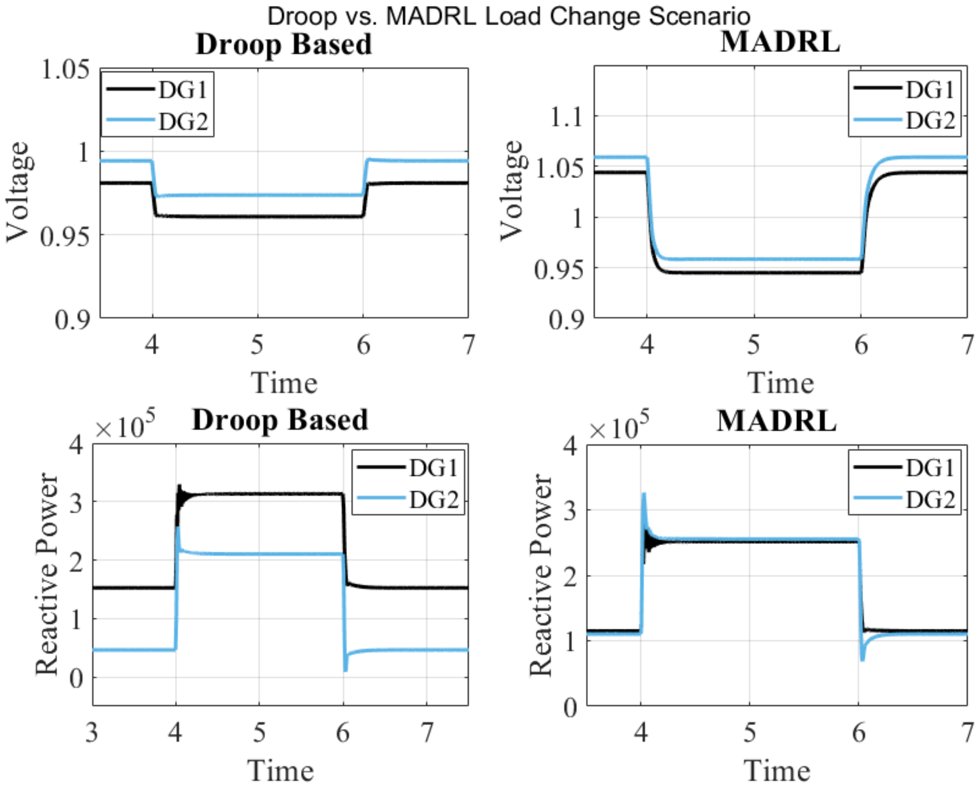
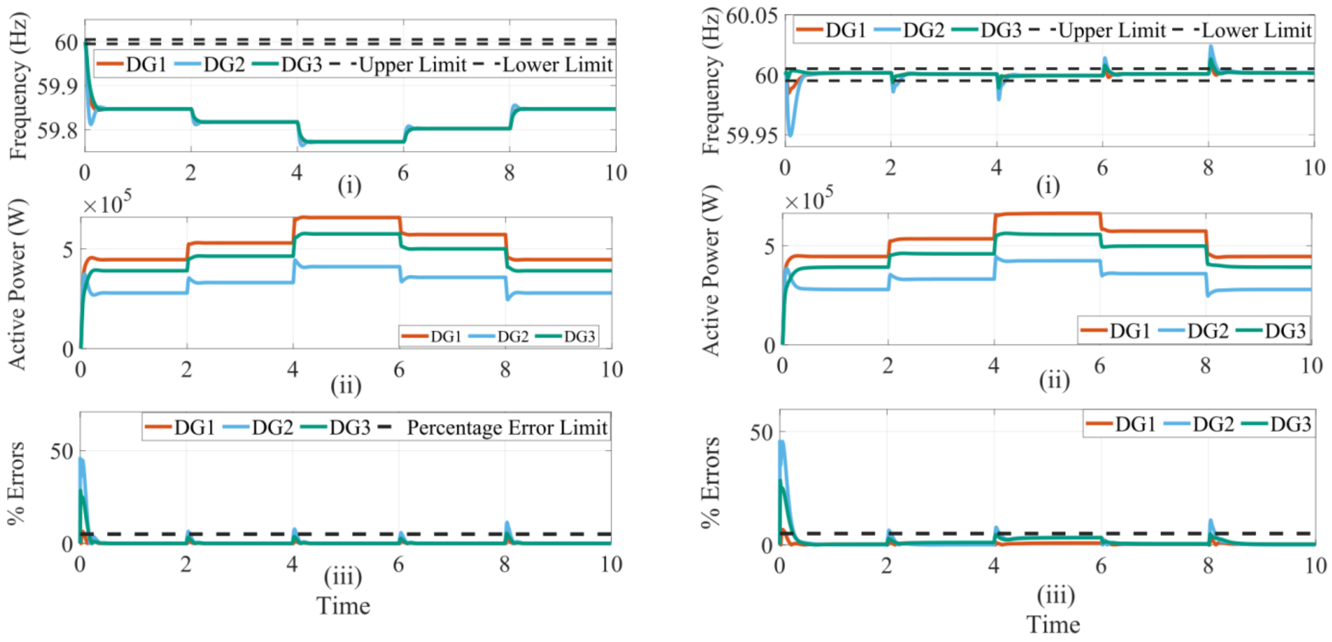
Example Results

Voltage Regulation and Reactive Power Sharing



Frequency Regulation and Active Power Sharing



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Summary and Next Steps

Effective integration requires a multi-timescale approach, from milliseconds to months

A variety of topologies provide a range of capabilities

- Cascaded H-bridge plus DAB is the most promising
- Medium-voltage challenges remain

Deep reinforcement learning can enhance coordination among multiple large power converters on the grid

- More work is needed to scale up

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