FREEDM SYSTEMS CENTER

Architecture of Megawatt Charging Systems

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Personal Background

Postdoctoral Research Associate
FREEDM, NCSU
SiC converters for EVs

Senior Research Scientist
UTRC, Ireland
High power converters for hybrid propulsion of aircrafts

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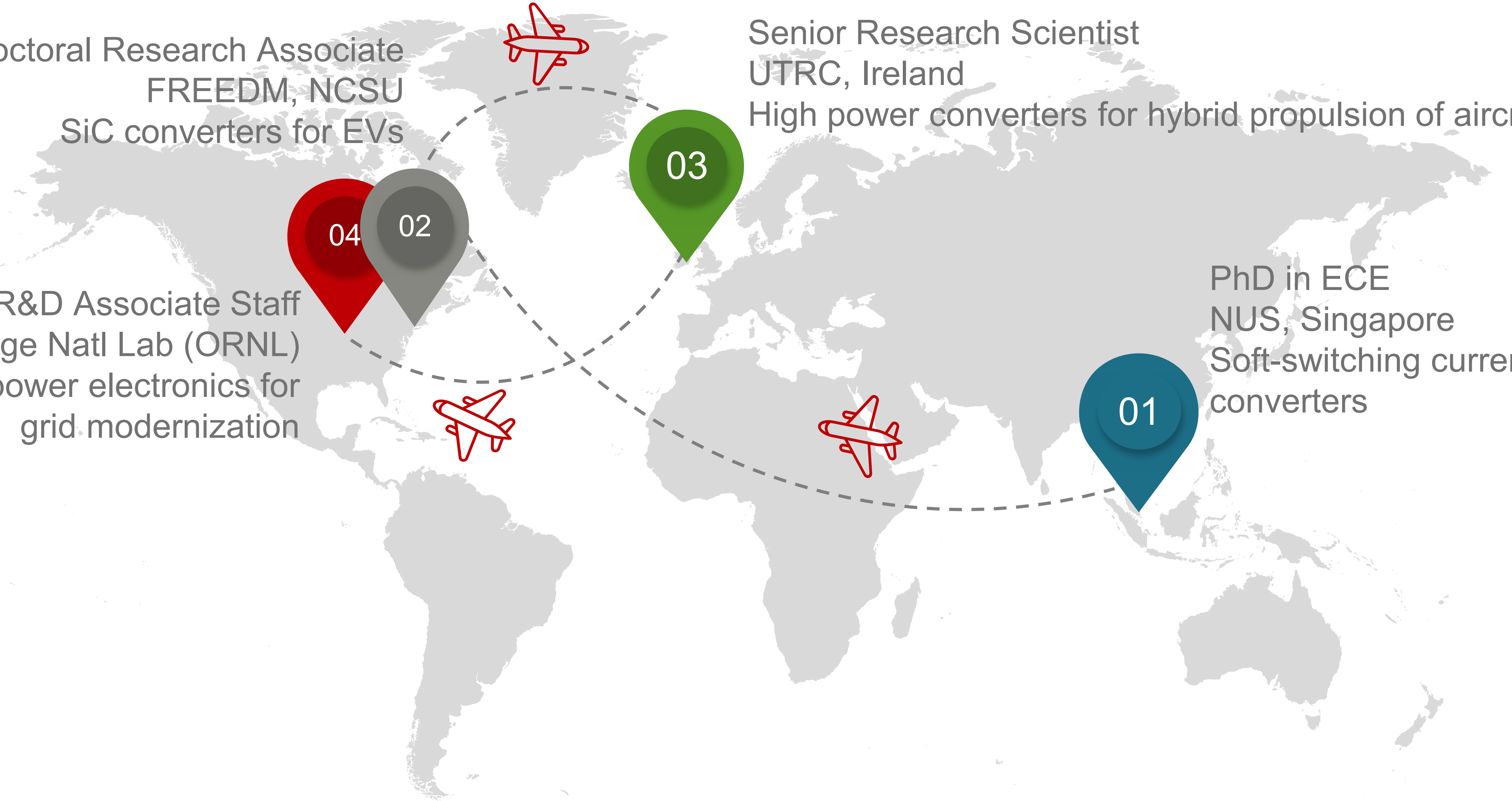
Oak Ridge Natl Lab (ORNL)
Advanced power electronics for grid modernization

PhD in ECE
NUS, Singapore
Soft-switching current-fed dc/dc converters



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Acknowledgement

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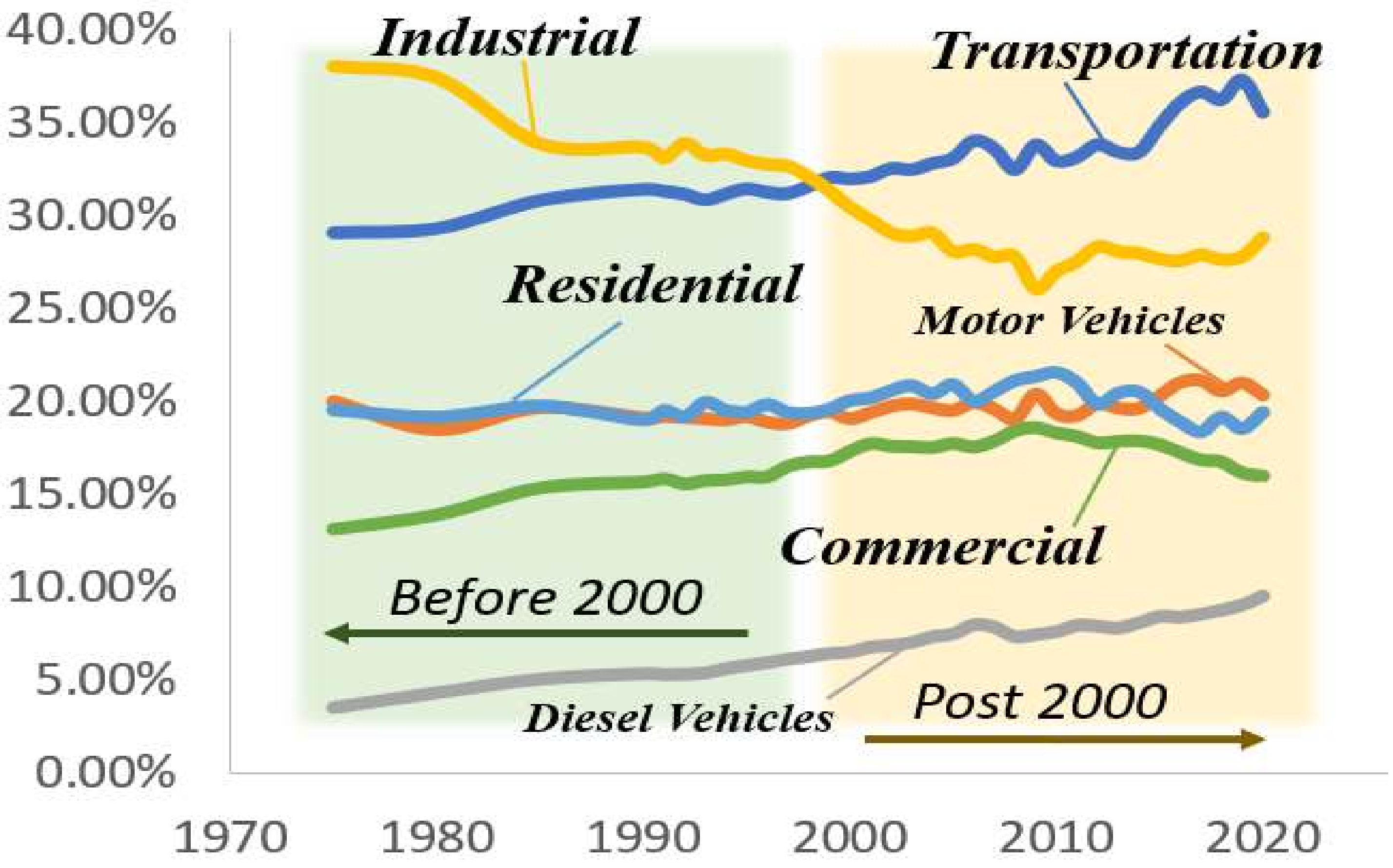
Introduction

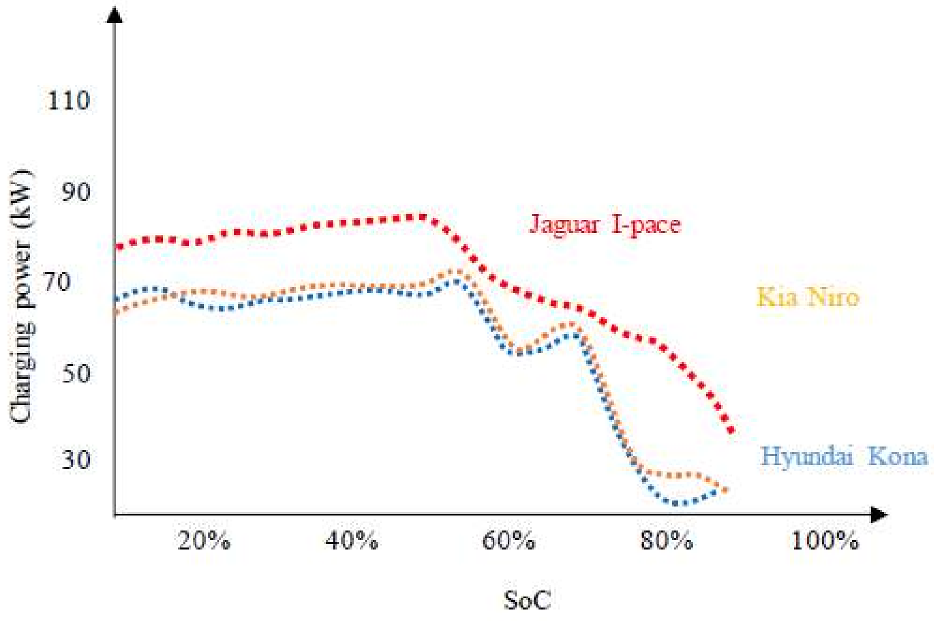
- Transportation has been the highest CO_2 producing sector in the U.S - represents as much as 36% of the total CO_2 produced
- To reduce emissions, diesel vehicle electrification (or electrification of much larger medium-duty (MD) and heavy-duty (HD) vehicles) is needed.
- Greater energy storage capacity requirements and multipliers higher in power and torque for towing will be necessary.



Charging Profiles of Vehicles

- Charging time requirement: The time taken to charge the vehicle to 80 % SOC should be under 30 minutes to accelerate EV penetration

- Max allowable SOC: 80 % ~ 90 % SOC is preferred to extend the battery life



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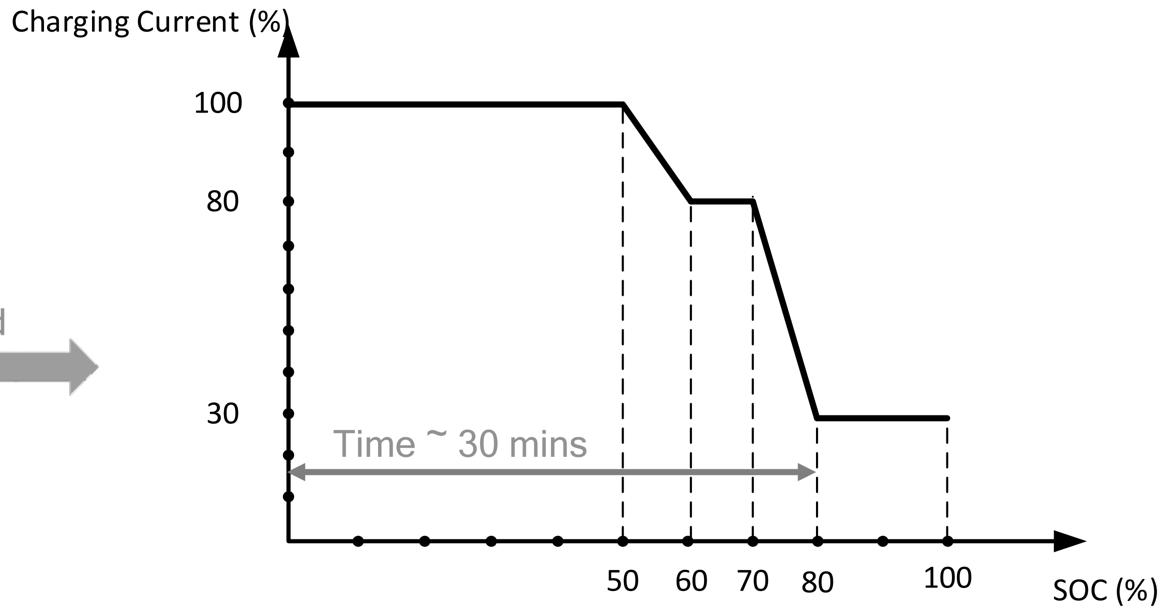
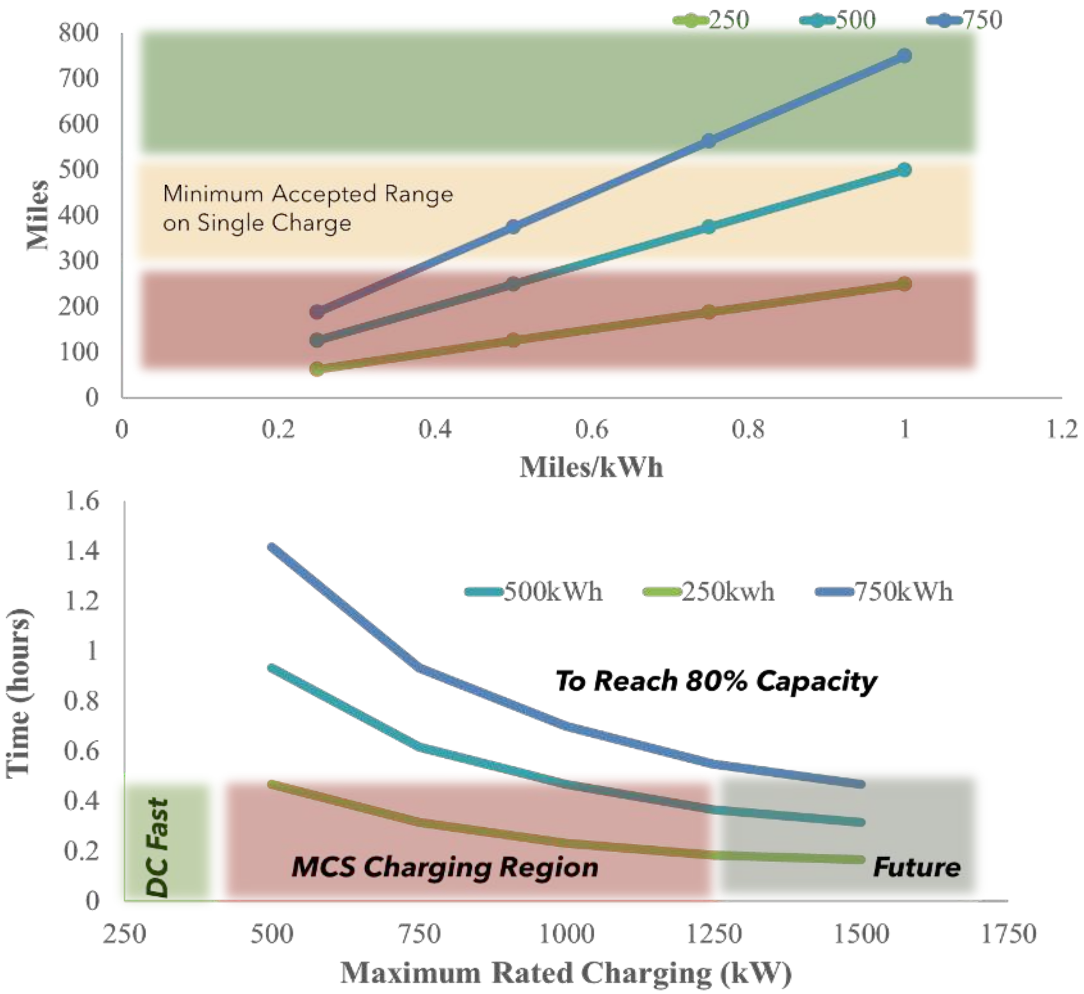


Allowable SOC: 80 ~ 90 % for battery life

Need for Megawatt Charging Systems



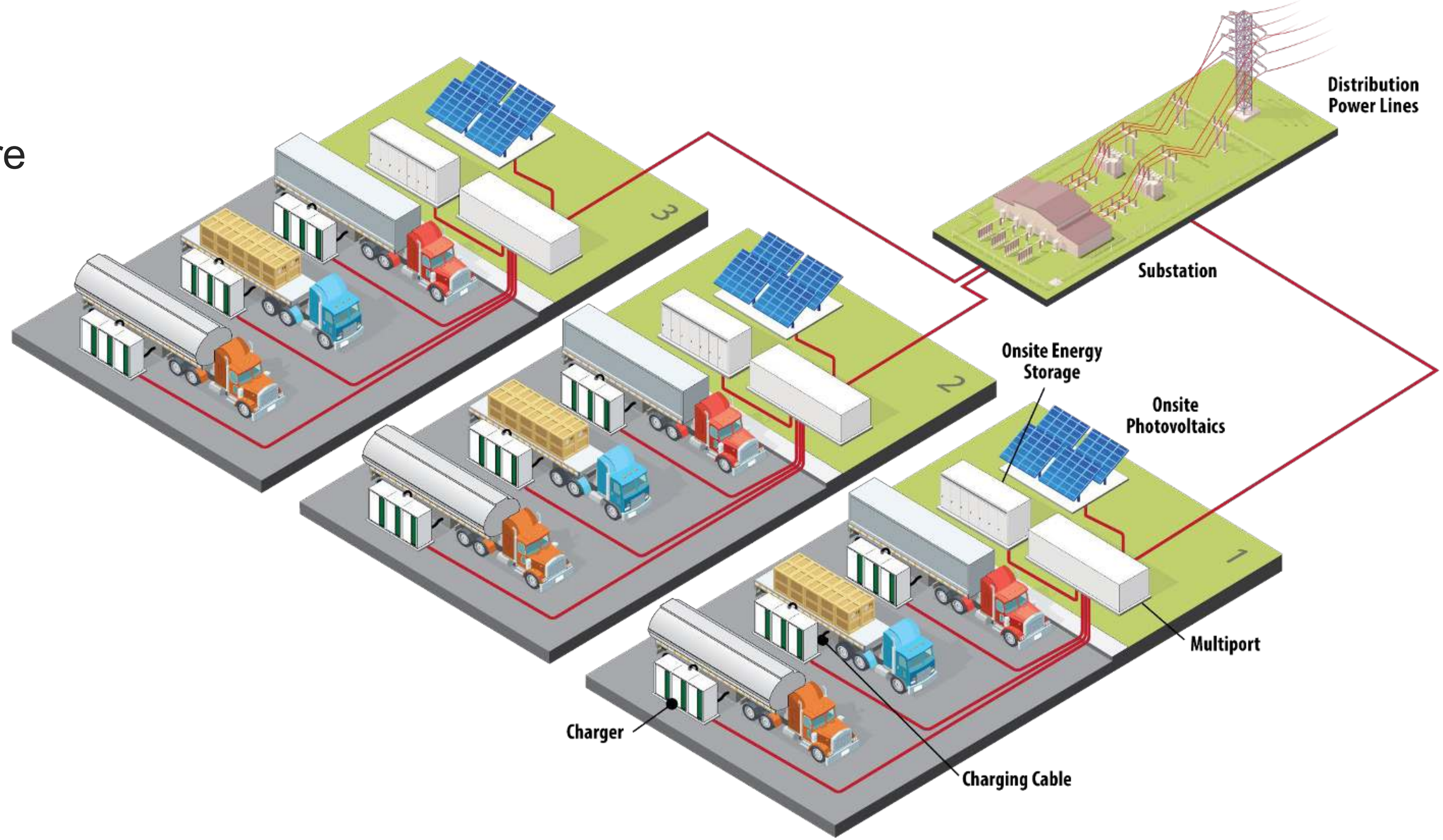
- Mile/kWh reported for Tesla Semi is ~0.5/kWh
- MD and HD-EV battery capacity should range from **500 ~ 750 kWh** to get a driving range of **300 ~ 500 miles** approximately
- This translates to MCS charging range to charge the vehicle to 80 % SOC in under 30 minutes
- For a 500 kWh battery, the charging power ~ 1.2 MW

Megawatt Charging System (MCS)

MCS: 10 ~ 15 MW charging infrastructure for charging heavy, medium or light duty vehicles

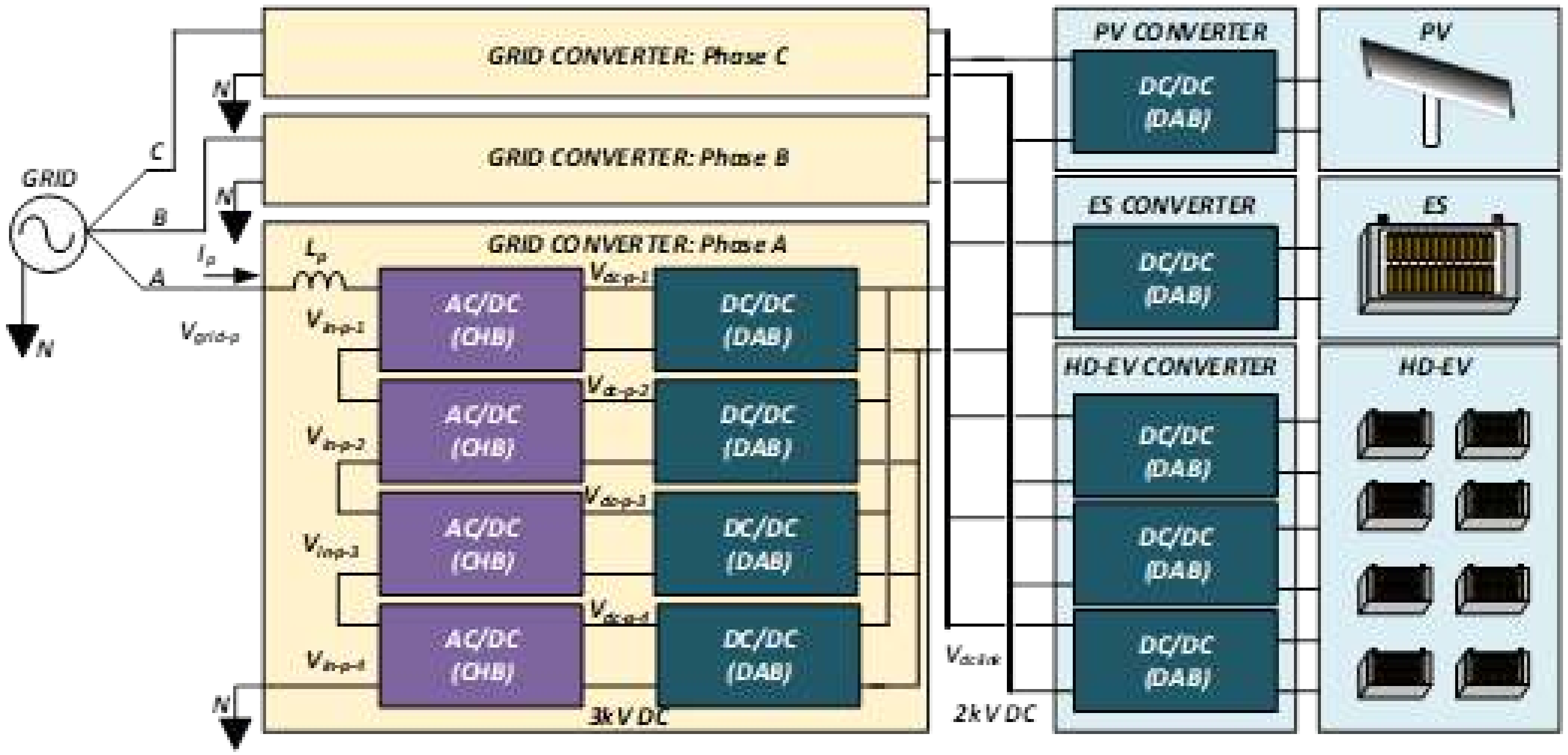
- A wholistic architecture with controls, communication & optimization

- Single point of connection to the grid and is separately metered.



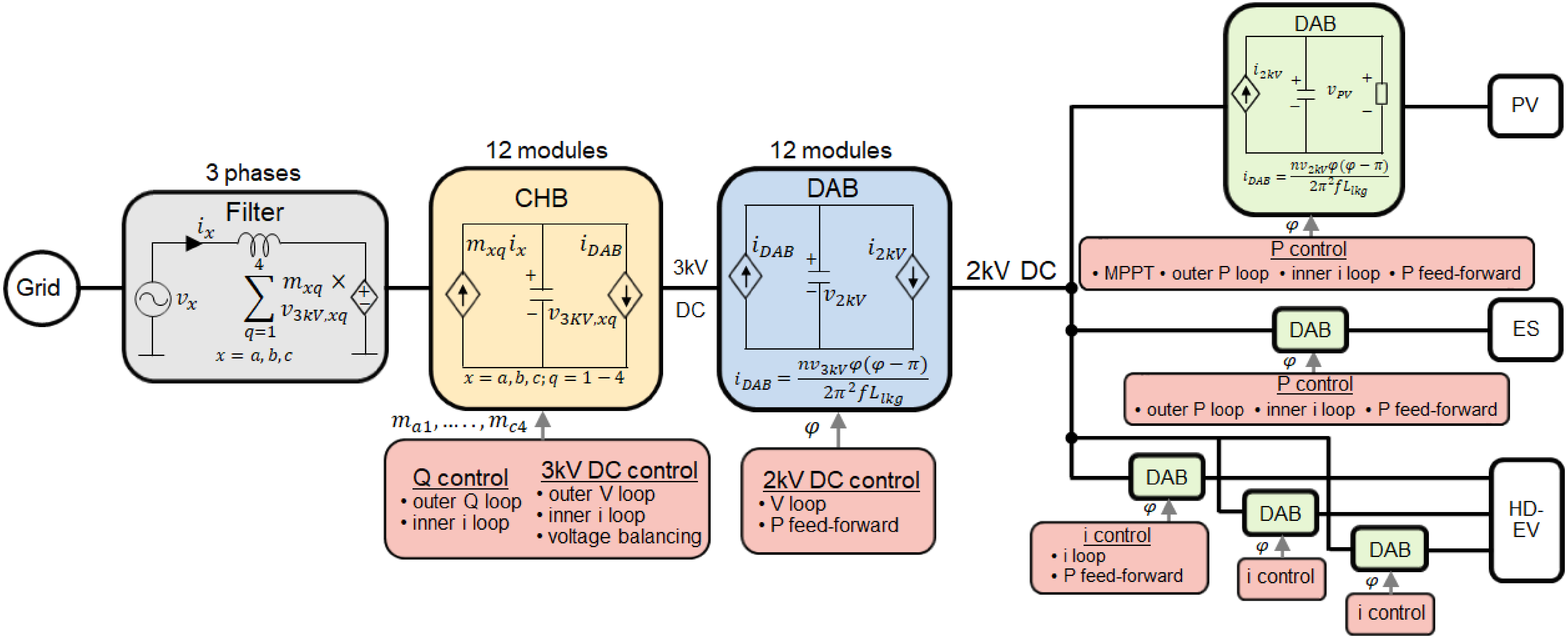
Multiport in MCS - Architecture

- Capable of charging 3 HD-EVs at 1.2 MW each
- Can have a single MW charging port or 3 – XFC ports

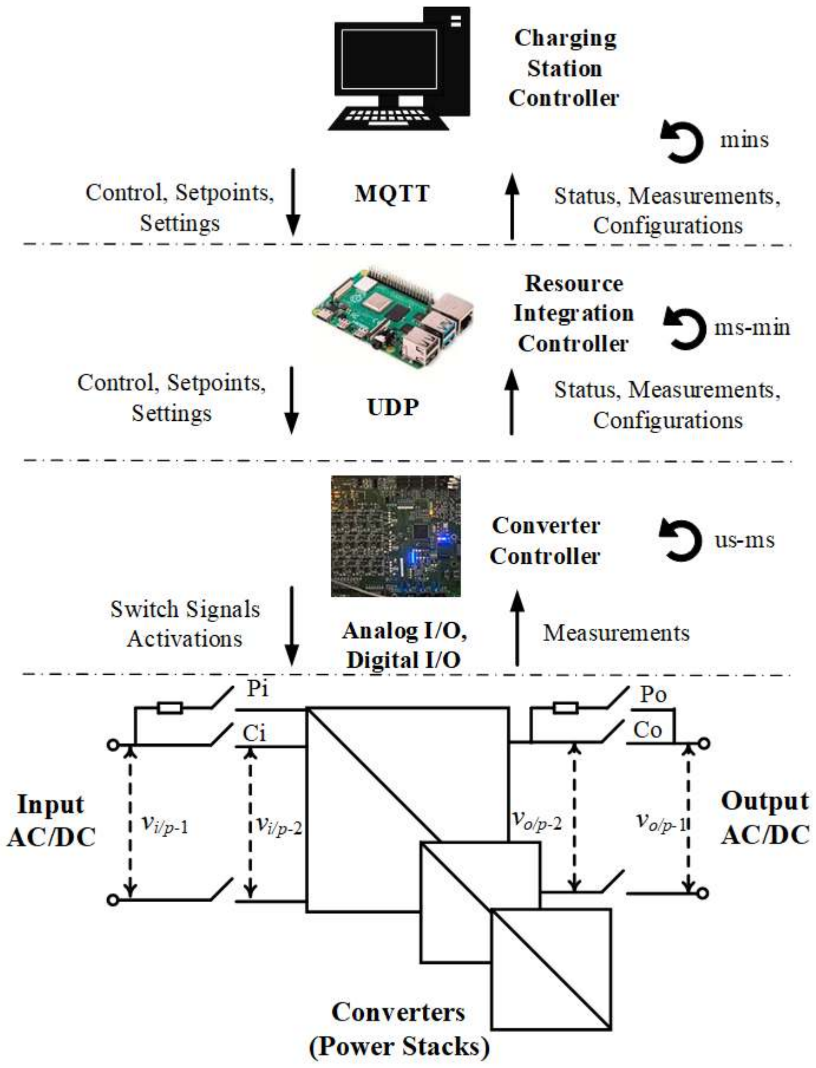


Interfacing converter	Configuration & Power rating	Control Functionalities
Grid-side interface	3.6 MW	Vdc regulation, Q control & voltage balancing control
EV interface	3x400 kW	Charging current control
ESS interface	400 kW	P control
PV interface	400 kW	Maximum Power Point Tracking (MPPT)

Control & Modeling of Multiport



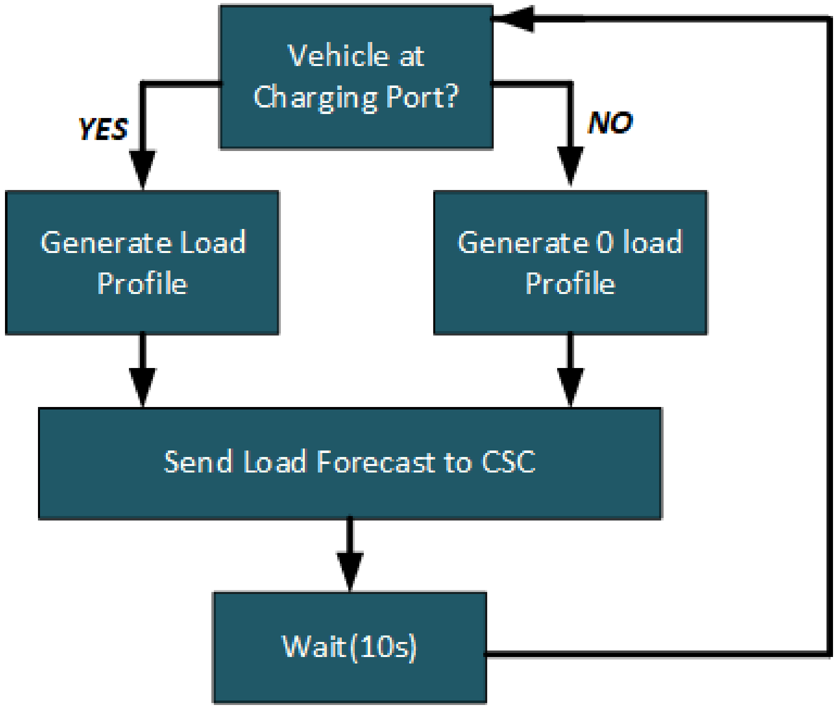
MCS – Control & Management



CSC: Station level optimization, historian & forecasts

RIC: Decision making & safety check on integration

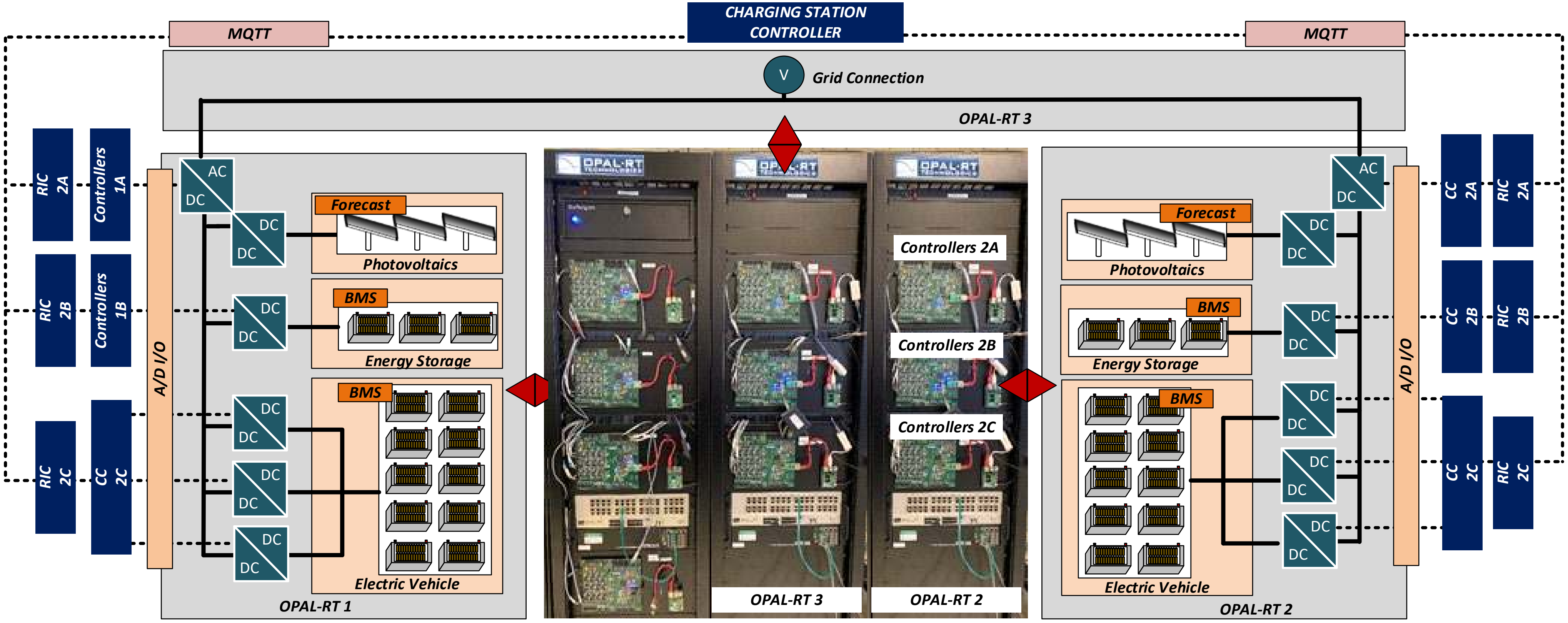
CC: Closed loop control & functions including fault detection & state machine



EV Charging model in EV Agent

Controller Hardware in Loop Testbed

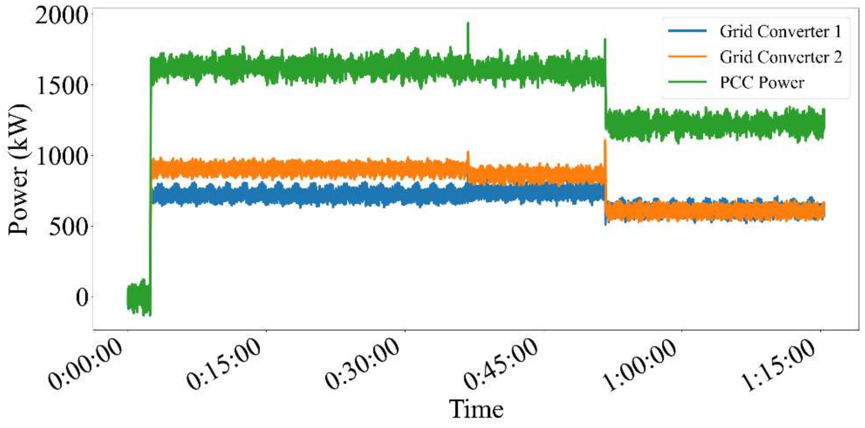
- 50+ converter models, 6 DSPs for converter controls, 6 Raspberry Pi’s for resource integration controls, 1 DELL OptiPlex as Station controller and 3 OPAL-RT simulators for grid and station modelling integrated for simulation

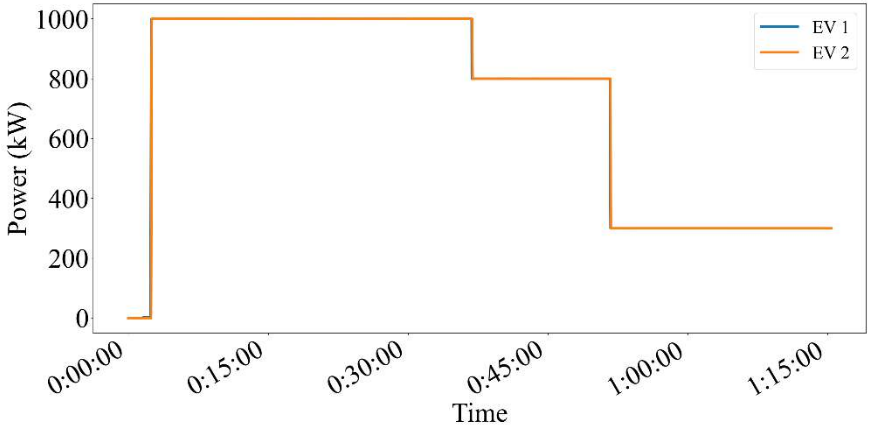


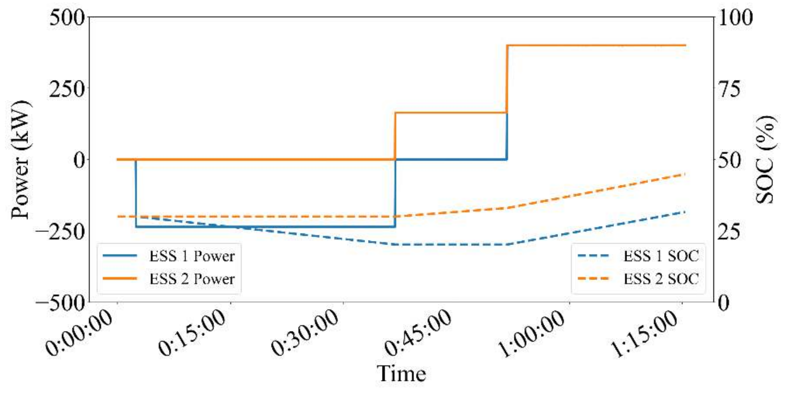
#1 – Parallel EV Charging

Use Case - 1

Two HD-EVs with SOCs less than 10% pull into the station simultaneously while the SOC of ES in both the multiports are at 30%. In this case, the grid power is limited to 1.8 MW by the CSC to handle the loading condition.



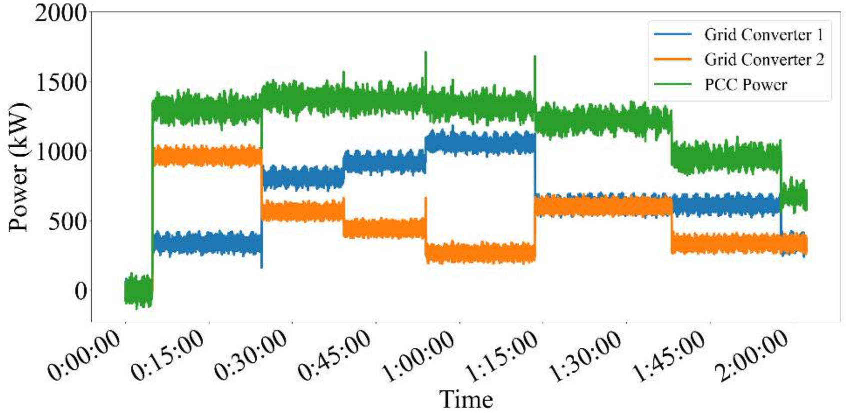


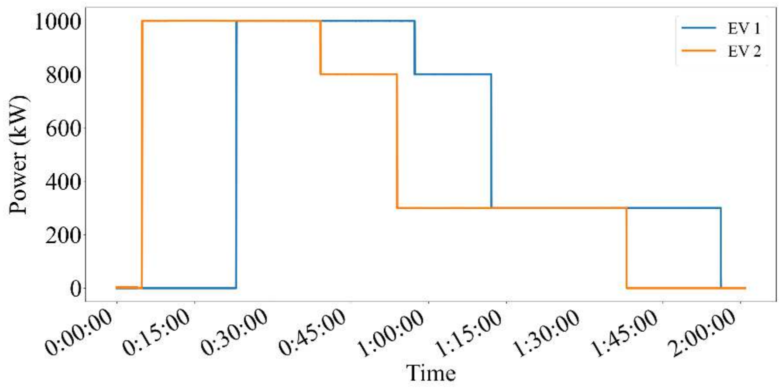


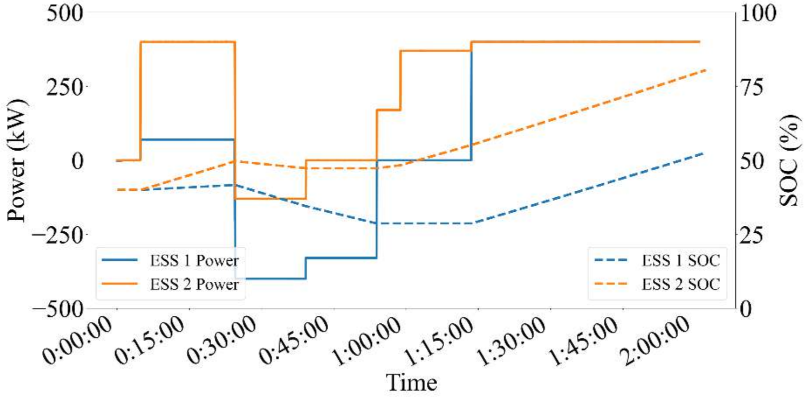
#2 – Offset EV Charging

Use Case - 2

Two HD-EVs with less than 10% SOCs pull into the station at different time intervals, and the ES of the two multiports are at 40 % SOC. In this case, the grid power is limited to 1.5 MW by the CSC to handle the loading condition.







Summary & Future Work

- MCS architecture with a station level optimization considering 3-multiports was presented.

- The station is an integration of several systems, and the integration has been established through a complex software layer that incorporates hierarchical controls, intelligence, and communication for effective coordination.

- Station architecture has been validated using controller hardware in loop testbed.

- The architecture can support the charging of light, medium and heavy-duty vehicles simultaneously. Future work will discuss this philosophy and study the grid impacts

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Thank You ☺