EV Fast Chargers & Microgrids

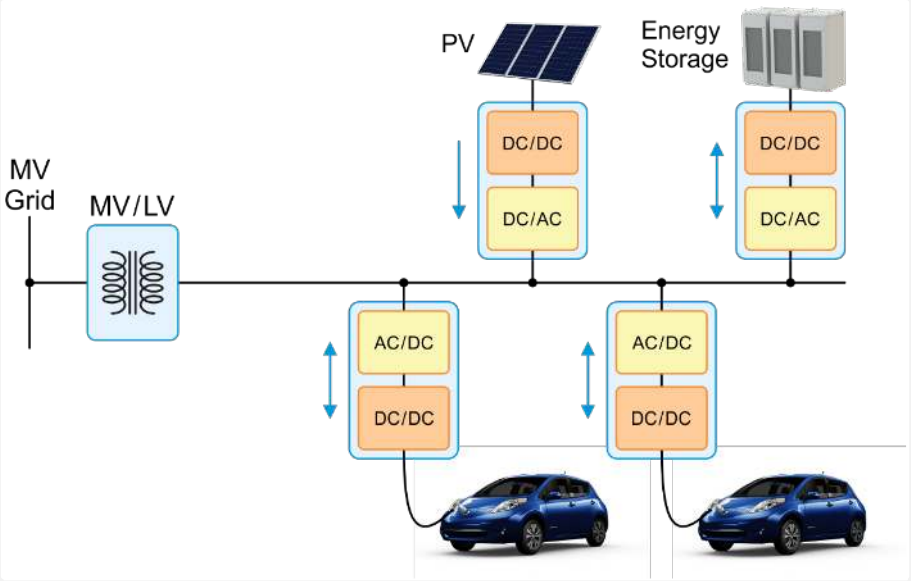
Srdjan Lukic
Professor, Electrical and Computer Engineering
North Carolina State University
Deputy Director, FREEDM Center

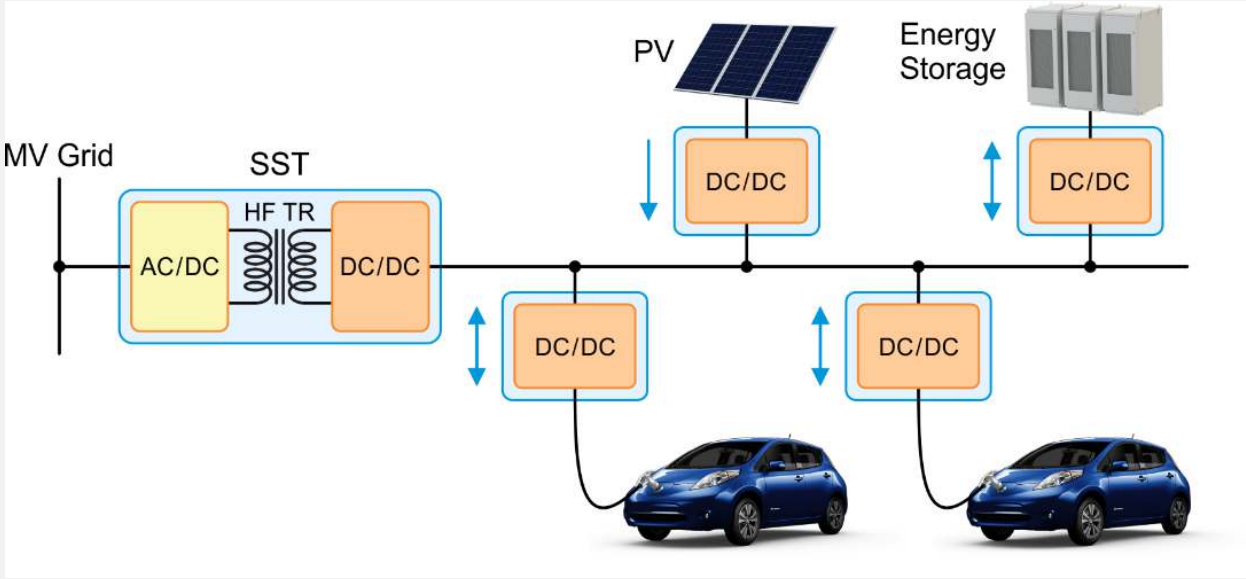
NC STATE UNIVERSITY

FREEDM SYSTEMS CENTER

MV SSTs: an enabling technology for XFC stations

- Recent increased interest in extreme EV fast charging
- Co-locating multiple chargers in the 50kW-350kW power range allows for shared infrastructure and lower per-stall cost
- Power distribution among chargers can be AC or DC, with DC having a set of potential advantages.





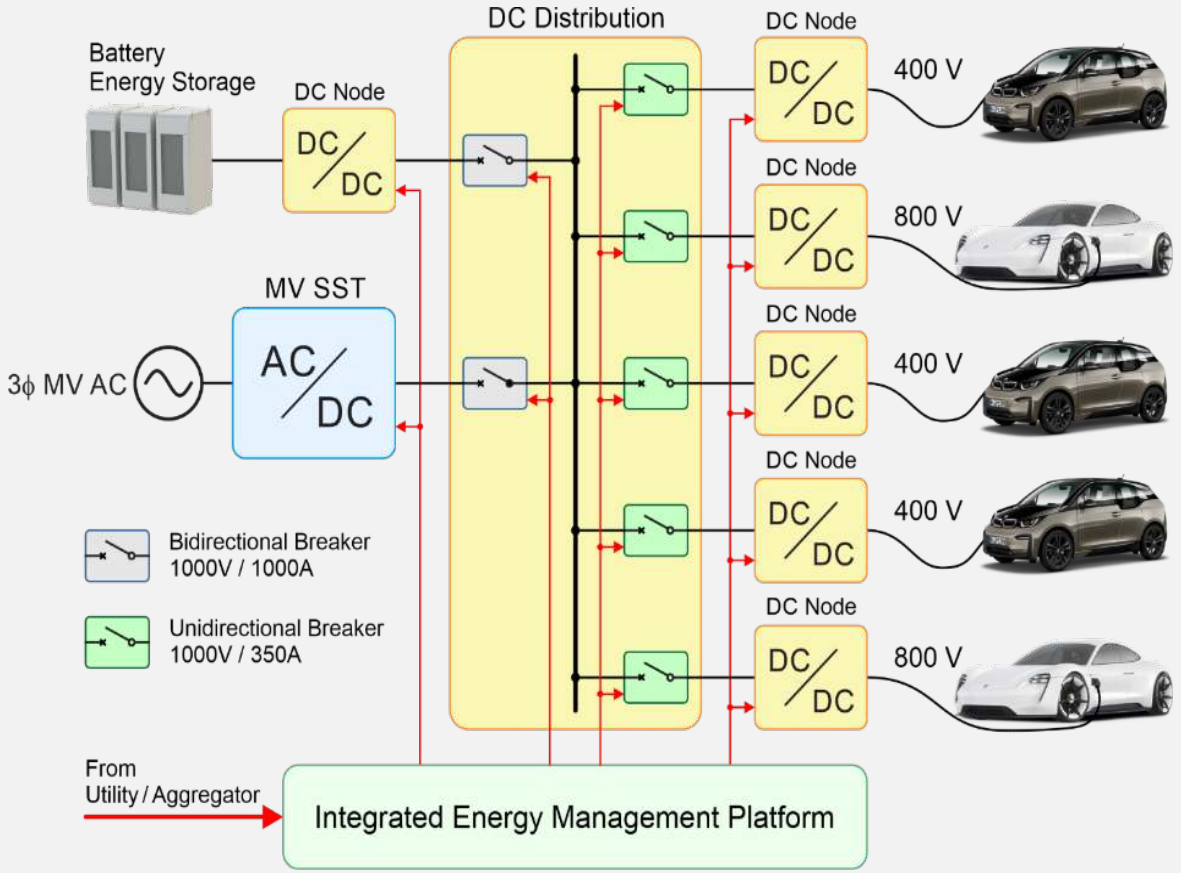
SOA vs. MV SST-based XFC station

Power:	**720 kW**	**40% more power**	**1,000 kW**
Volume:	**12,910 L**	**2x volume reduction**	**6,000 L**
Mass:	**13,000 lb.**	**3x mass reduction**	**4,000 lb.**
Efficiency:	**92%**	**2x loss reduction**	**96%**
Concrete pad:	**177 sq. ft.**	**2.5x footprint reduction**	**75 sq. ft.**

Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection ($2.7M; DOE; 2018-2022)

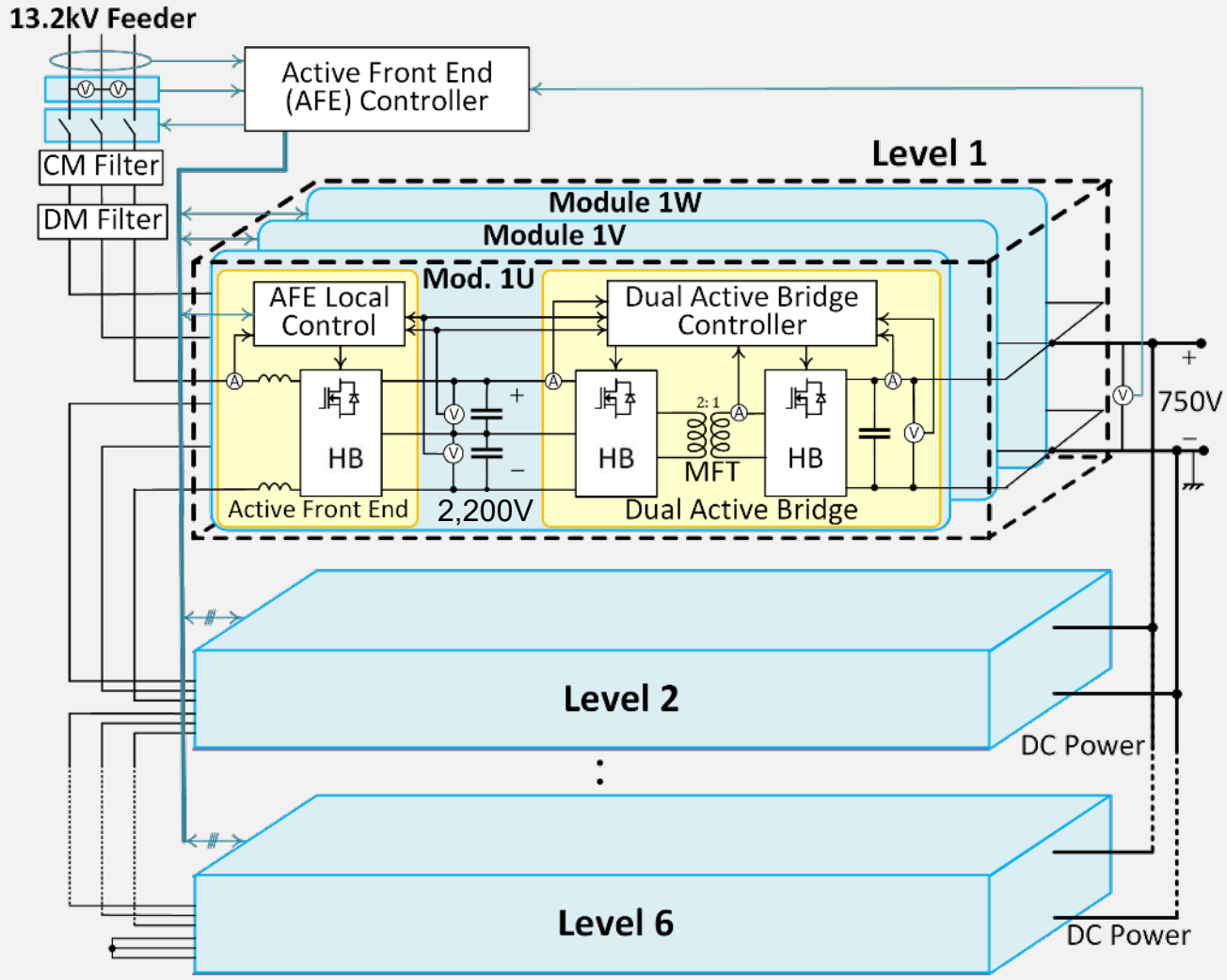
Develop & deploy a 1 MW XFC station:

- Shared bi-directional Solid State Transformer (SST) connecting directly to the medium voltage (MV) distribution system
- DC distribution network with solid-state DC protection
- Energy management platform
- Head-ends for local isolation and DC/DC conversion



SST Design

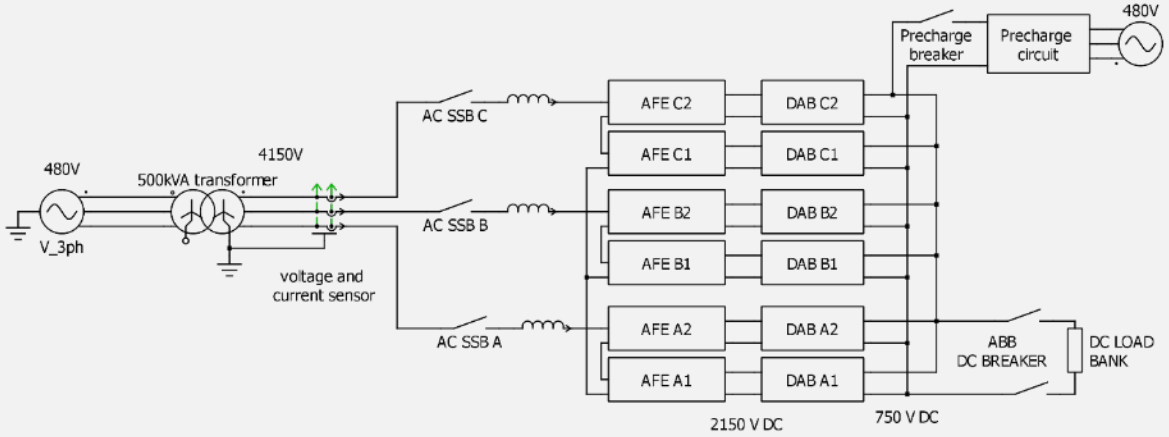
- The SST connects to three-phase 13.2kV$_{LL}$ input and delivers 750V DC
- Each level is made up of three modules processing three-phase power on the input and delivering DC power at the output
- SST dimensions approximately 3,000L & 2,000kg

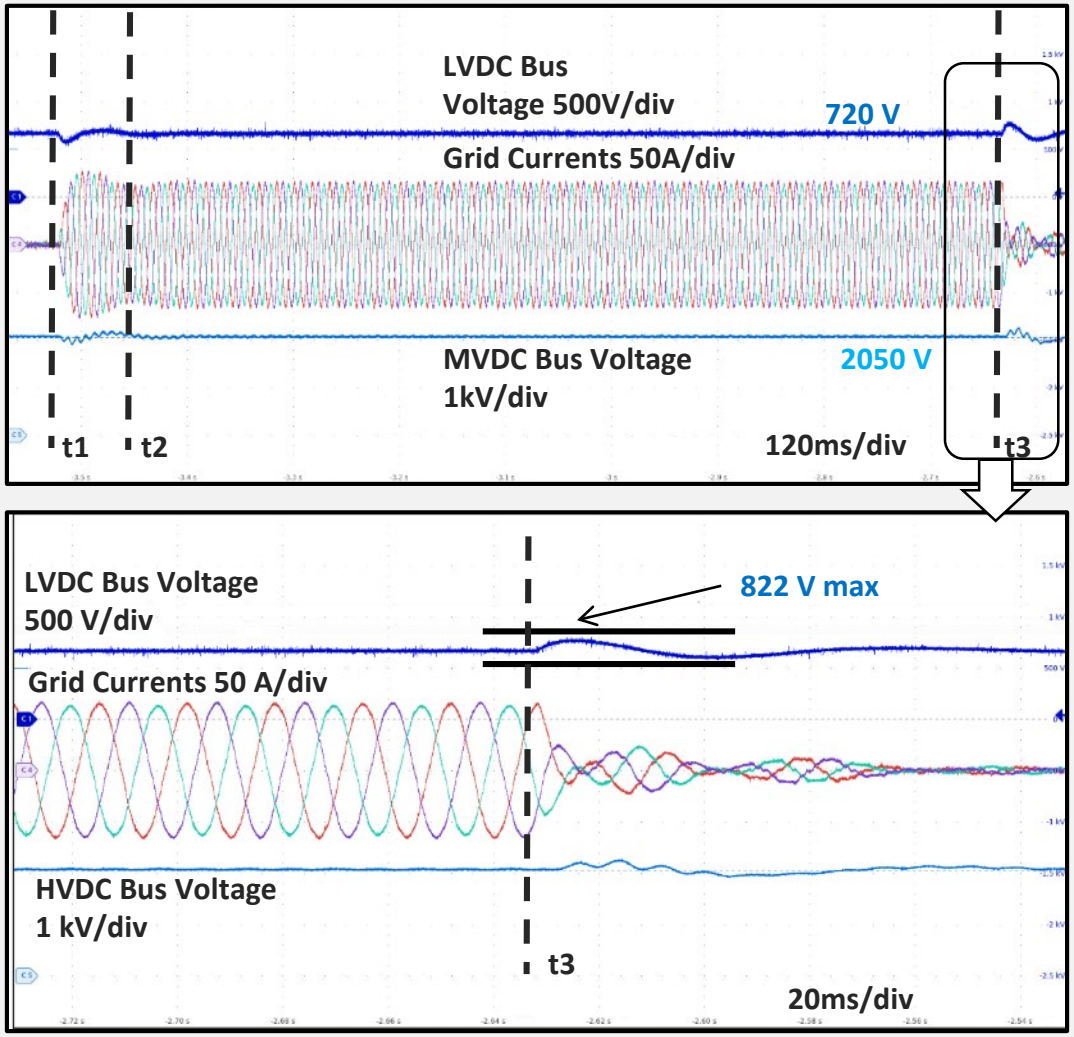


SST Performance

500kVA prototype with solid state breaker test results:

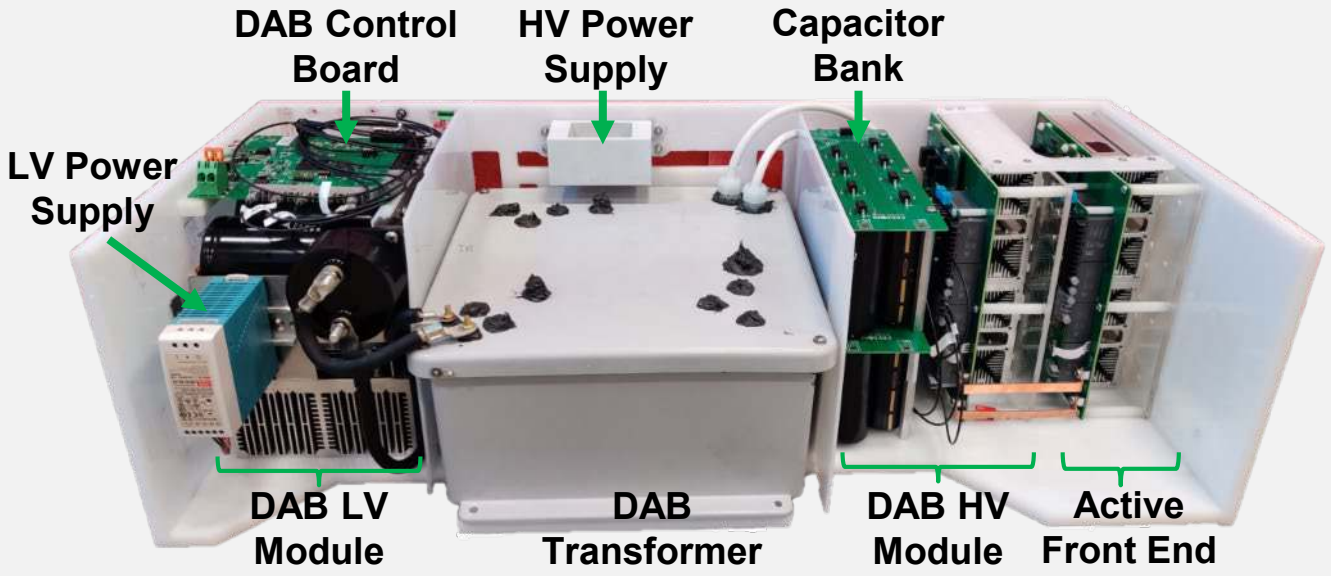
- **t0:** Each module pre-charges their HVDC Bus to rated voltage (not shown)
- **t1:** ABB DC SSB close command sent; 315 kW load connect
- **t2:** LVDC voltage settles (90% nominal); settling time 75 ms
- **t3: ABB DC SSB open command sent; 315 kW loss of load**



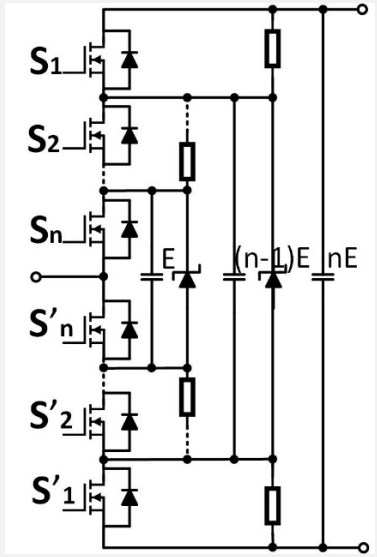


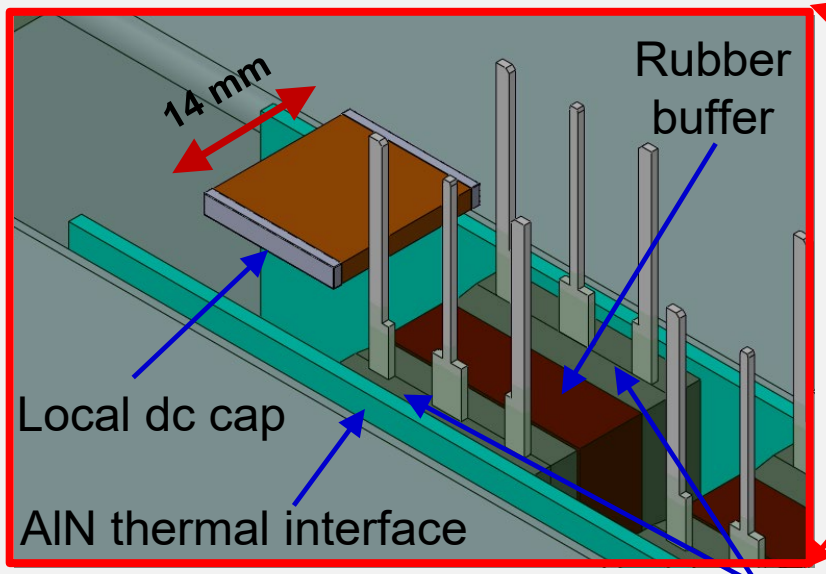
SST Prototype

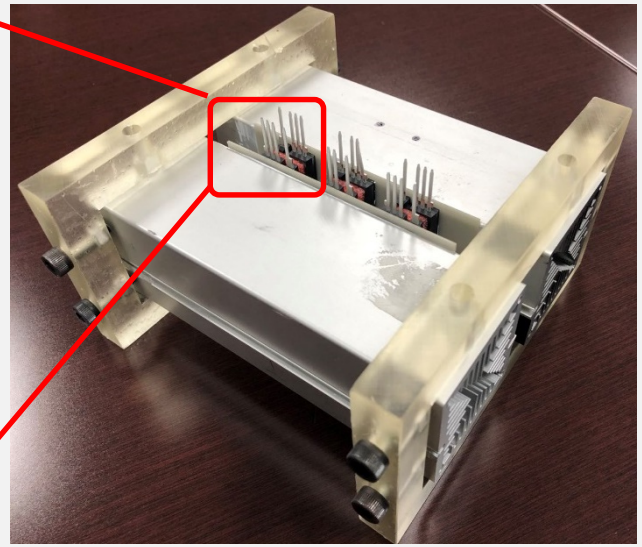
- Prototype under construction at the FREEDM lab
- First phase tested at rated voltage



AFE Design







1.2 kV SiC MOSFETs

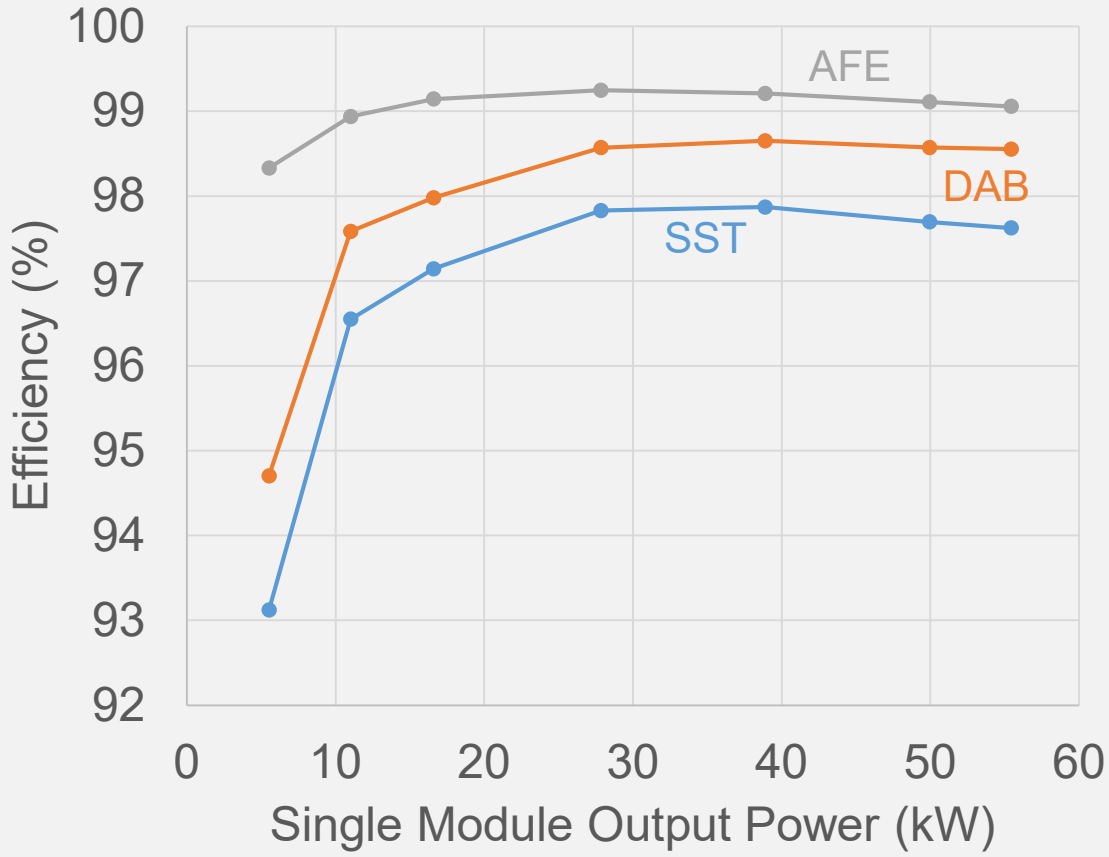
- Low cost TO-247 SiC MOSFETs
- Integrated cooling
- Optimized rubber buffer assembly
- Aluminum Nitride (AlN) thermal interface
- Minimum loop inductance

AFE Module	
Topology	Multilevel flying capacitor converter
f_{sw}	5 kHz
Device	C3M0016120D (16 mΩ / 1200V)
Flying Cap	68 nF

Dakai Wang and Wensong Yu, "Series Connection of SiC MOSFETs with Hybrid Active and Passive Clamping for Solid State Transformer Applications," presented at *2019 IEEE 7th Workshop on Wide Bandgap Power Devices and Applications (WiPDA)*, Raleigh, NC, October 2019.

SST Efficiency

- SST efficiency exceeds 96% target at loads above 20%
- Efficiency penalty due to cost optimized transformer design with relatively high core and winding losses



AFE - Active Front End

DAB - Dual Active Bridge isolated DC/DC converter

SST – Solid State Transformer (DAB+AFE)

System Integration

NY Power Authority

Mechanical Breaker & Metering

MV AC Breaker

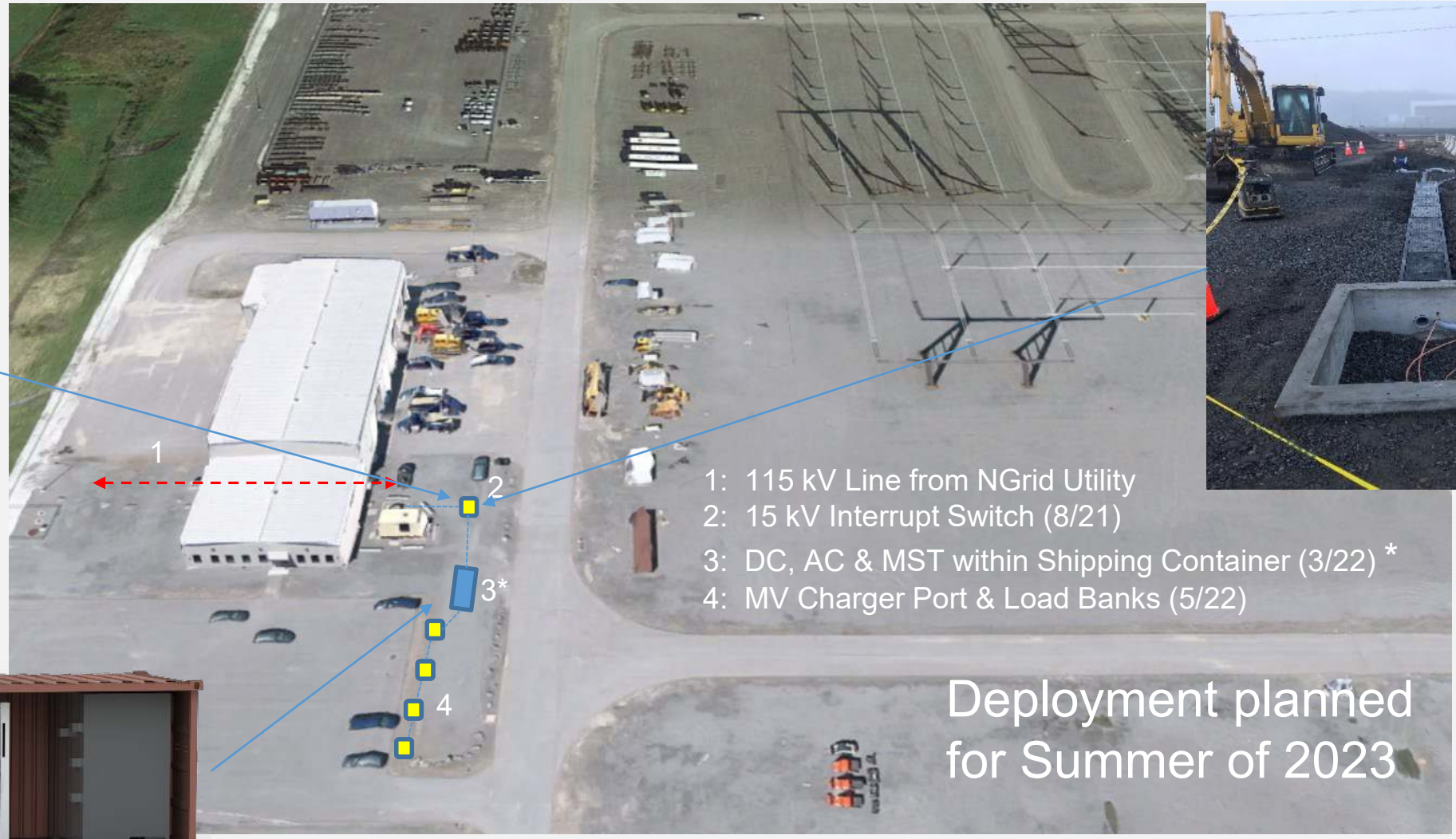
NC STATE UNIVERSITY

SST

ABB

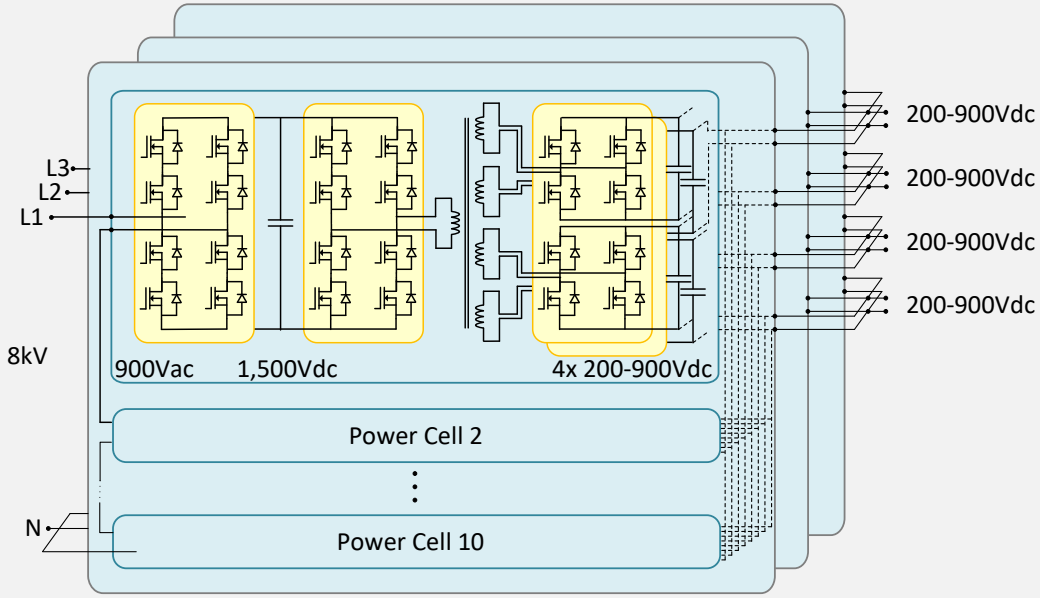
DC Breaker

Site Layout (Marcy, NY)



Ultra-low Cost, All-SiC Modular Power Converters for DC Fast Charging Equipment Connected Directly to Medium Voltage Distribution System ($3.9M; DOE; 2022-2026)

- New DOE Project focusing on reducing system cost
- SST provides independent, galvanically isolated ports
- Technology Goals:
  - 3x reduction in system volume; elimination of DC/DC stage
  - Reduce BOM cost by half



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