EV Fast Chargers & Microgrids

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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

<table>
<thead>
<tr>
<th>Feature</th>
<th>SOA</th>
<th>MV SST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>720 kW</td>
<td>1,000 kW</td>
</tr>
<tr>
<td>Volume</td>
<td>12,910 L</td>
<td>6,000 L</td>
</tr>
<tr>
<td>Mass</td>
<td>13,000 lb.</td>
<td>4,000 lb.</td>
</tr>
<tr>
<td>Efficiency</td>
<td>92%</td>
<td>96%</td>
</tr>
<tr>
<td>Concrete pad</td>
<td>177 sq. ft.</td>
<td>75 sq. ft.</td>
</tr>
</tbody>
</table>

- 40% more power
- 2x volume reduction
- 3x mass reduction
- 2x loss reduction
- 2.5x footprint reduction

Schneider QED-2
750 kVA

Tesla Urban Supercharger
5 x 144 kW

MV Breaker & Metering
1MW SST
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

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

### AFE Module

<table>
<thead>
<tr>
<th>Topology</th>
<th>Multilevel flying capacitor converter</th>
</tr>
</thead>
<tbody>
<tr>
<td>f&lt;sub&gt;sw&lt;/sub&gt;</td>
<td>5 kHz</td>
</tr>
<tr>
<td>Device</td>
<td>C3M0016120D (16 mΩ / 1200V)</td>
</tr>
<tr>
<td>Flying Cap</td>
<td>68 nF</td>
</tr>
</tbody>
</table>
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

- Mechanical Breaker & Metering
- MV AC Breaker
- SST
- DC Breaker
Site Layout (Marcy, NY)

1: 115 kV Line from NGrid Utility
2: 15 kV Interrupt Switch (8/21)
3: DC, AC & MST within Shipping Container (3/22) *
4: MV Charger Port & Load Banks (5/22)

Deployment planned for Summer of 2023
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