Ultra-low Cost, All-SiC Modular Power Converters for DC Fast Charging Equipment Connected Directly to Medium Voltage Distribution System

Srdjan Lukic, Principal Investigator (NCSU)

Team Members: Iqbal Husain (NCSU); Wensong Yu (NCSU); Kenneth Dulaney (NCSU); Richard Sapienza (NCSU); Lisa Poger (NCSU); Heather Brutz (NCSU); Dan Isaksson (Danfoss); Stefan Schröder (Danfoss); Marko Laitinen (Danfoss); Joseph Rowny Jr. (NCSU); Alan Ettlinger (NYPA); John Markowitz (NYPA); Gregory Pedrick (NYPA); Patrick G. Stephens (GoTriangle); Aleksandar Vukojevic (ComEd)

Award No: DE-EE0009871
Agenda

- Project Overview
- Team Members, Relevant Experience and Key Responsibilities
- Review of Statement of Project Objectives
- Technology Description
- Project Management
- Technology Transfer Plan
- Risk Mitigation
Overview

Timeline
• Project Start Date: April 2022
• Project End Date: April 2026
• Percent Complete: 2%

Barriers
• Development of a low cost oil-free EVSE connecting to utility at medium voltage
• System siting, integration and deployment

Budget
• Total Project Funding
  • DOE Share: $ 3,858,646
  • Contractor Share: $ 1,468,674
• Spending to Date (Q1 2022)
  • DOE Share: $ 0
  • Contractor Share: $ 0

Partners
• NCSU/FREEDM - Lead
• NCSU/NCCTEC
• Danfoss
• New York Power Authority (NYPA)
• Commonwealth Edison
• GoTriangle
Objectives and Relevance

Objectives

- Reduce the cost of SST-based EVSE by at least 50% compared to the baseline system through topology, electrical, and mechanical cost-cutting innovations that reduce BOM costs and improve reliability
- Identify best insertion points for the technology by analyzing the total cost of ownership of SST-based EVSE

Project Impact:

- Demonstrate all-SiC ultra-low cost, light, and compact SST-based EVSE
- Total cost of ownership analysis will guide future roadmapping and development of SST-based EVSEs

Key Deliverables:

- All-SiC SST-based EVSEs operational in the field
- Total cost of ownership analysis
Objectives and Relevance

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Key Deliverables:
• All-SiC SST-based EVSEs operational in the field
• Total cost of ownership analysis
Approach

Technology Goals:

• Integration of galvanic isolation between EVSE charging ports within the SST for cost reduction
• Reduce BOM cost by half
• 3x reduction in system volume
• Maintain SST peak efficiency above 98%

SST is built up of identical Power Cells with 900Vac input and 4x independent 200-900V outputs system stacks 10 power cells in series to connect to 15kV class distribution system
Team Introductions

NC STATE UNIVERSITY

NC CLEAN ENERGY TECHNOLOGY CENTER

NEW YORK STATE OF OPPORTUNITY NY Power Authority

FREEDM SYSTEMS CENTER

GO Triangle

comed AN EXELON COMPANY
Team Introductions

- Project role: Lead Institution
- Prior Experience in SST Development: Leads on DE-EE0008450*
  - Shared bi-directional Solid State Transformer (SST) connecting directly to the medium voltage (MV) distribution system
  - DC distribution network with solid-state DC protection

*Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection
Team Introductions

• Project role: Leading Total cost of Ownership (TCO) Analysis
• Prior Experience
  • Analysis of fleet compositions to create TCO models including recommendations for EVSE infrastructure installations
  • Created the 50 States of Electric Vehicles publications which track policy developments across utilities and state governments as well as rate design changes that pertain to electric vehicles.
  • Staff maintains the DSIRE* database which includes information on incentives provided by utilities that may affect the cost of installing EVSE infrastructure which includes data about EV charging rates offered by investor-owned utilities.

* Database of State Incentives for Renewables & Efficiency
Team Introductions

- **Project role:** All aspects of SST Development
- **Prior Experience**
  - Danfoss is a leader in Medium Voltage Drives
  - MV Drives unit is headquartered in Durham, NC and performs all development and production tasks for the Danfoss MV Drives portfolio.
  - Danfoss is an Associate Member of the FREEDM Center.

Danfoss VACON 3000 Drive
Team Introductions

- Project role: Demonstration Partner
- Prior Experience: Partners on DE-EE0008450*
  - Provided a Demonstration Site for the demonstration of Baseline System
  - Will provide data from the site throughout this project
  - Self Permitting Entity
Team Introductions

- Project role: Demonstration Partner
- ComEd is the largest electric utility in Illinois and the sole electric provider in Chicago.
- ComEd is a unit of the Chicago-based Exelon Corporation, one of the nation's largest electric and gas utility holding companies.
- ComEd provides electric service to more than 3.8 million customers.
Team Introductions

• Project role: Demonstration Partner

• Research Triangle Regional Public Transportation Authority, provides bus service to the Research Triangle region of North Carolina in Wake, Durham, and Orange counties. The organization owns and operates a fleet of electric buses and has identified a site where the team will demonstrate the proposed technology.
## Team Introductions

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Role</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Srdjan Lukic</td>
<td>NCSU/FREEDM</td>
<td>PI</td>
<td>Professor</td>
</tr>
<tr>
<td>Wensaoing Yu</td>
<td>NCSU/FREEDM</td>
<td>SST Development</td>
<td>Professor</td>
</tr>
<tr>
<td>Iqbal Husain</td>
<td>NCSU/FREEDM</td>
<td>SST Development</td>
<td>Professor</td>
</tr>
<tr>
<td>Ken Dulaney</td>
<td>NCSU/FREEDM</td>
<td>Tech Transfer</td>
<td>Insutrdy Director</td>
</tr>
<tr>
<td>Heather Brutz</td>
<td>NCSU/NCCETC</td>
<td>Lead/Cost Analysis</td>
<td>Clean Transportation Finance and Operations Manager</td>
</tr>
<tr>
<td>Lisa Poger</td>
<td>NCSU/NCCETC</td>
<td>Cost Analysis Team</td>
<td>Senior Clean Transportation Specialist</td>
</tr>
<tr>
<td>Brian Lips</td>
<td>NCSU/NCCETC</td>
<td>Cost Analysis Team</td>
<td></td>
</tr>
<tr>
<td>Richard Sapienza</td>
<td>NCSU/NCCETC</td>
<td>Cost Analysis Team</td>
<td>Director, Clean Transportation Program</td>
</tr>
<tr>
<td>Autumn Proudlove</td>
<td>NCSU/NCCETC</td>
<td>Cost Analysis Team</td>
<td>Senior Policy Program Director</td>
</tr>
<tr>
<td>Isaksson Dan</td>
<td>Danfoss</td>
<td>Lead/SST Development</td>
<td>Head of Medium Voltage Drives,</td>
</tr>
<tr>
<td>Stefan Schroeder</td>
<td>Danfoss</td>
<td>SST Development</td>
<td>Chief-Engineer for MV Drives</td>
</tr>
<tr>
<td>Marko Laitinen</td>
<td>Danfoss</td>
<td>SST Development</td>
<td>HW Development manager</td>
</tr>
<tr>
<td>Joseph Rowny Jr.</td>
<td>Danfoss</td>
<td>SST Development</td>
<td>Engineering Manager</td>
</tr>
<tr>
<td>Alan Ettlinger</td>
<td>NYPA</td>
<td>Lead/ Demo Partner</td>
<td>Director, Research, Tech Dev and Innovation</td>
</tr>
<tr>
<td>Greg Pedrick</td>
<td>NYPA</td>
<td>Demo Partner</td>
<td>Senior RTD&amp;I Engineer I,</td>
</tr>
<tr>
<td>Aleksandar Vukojevic</td>
<td>ComEd</td>
<td>Lead/ Demo Partner</td>
<td>Senior Manager, Smart Grid</td>
</tr>
<tr>
<td>Dino Lelic</td>
<td>ComEd</td>
<td>Demo Partner</td>
<td>Distribution Planning, Smart Grid &amp; Innovation</td>
</tr>
<tr>
<td>Patrick Stephens</td>
<td>GoTriangle</td>
<td>Lead/ Demo Partner</td>
<td>Director</td>
</tr>
<tr>
<td>Vinson Hines</td>
<td>GoTriangle</td>
<td>Demo Partner</td>
<td>Asst director at GT</td>
</tr>
<tr>
<td>Brian McLean</td>
<td>GoTriangle</td>
<td>Demo Partner</td>
<td>Maintenance Manager</td>
</tr>
</tbody>
</table>
DOE Team

- Adrienne Riggi, Program Manager
- Fernando Salcedo, Program Manager
- Steven Boyd, Program Manager
- Lee Slezk, Program Manager
- Andrew Meintz
- Shane Buchanan, Contract Specialist
Timeline

Development
- Cost Analysis, Cost of Ownership Targets & Initial Prototyping
  - BP1
  - 4/22 - 4/23

Optimization
- System Optimization & Finalized Power Cell Design
  - BP2
  - 4/23 - 4/24

Integration
- System Packaging, Reliability & Standards Testing
  - BP3
  - 4/24 - 4/25

Deployment
- Demonstration
  - BP4
  - 4/25 - 4/26

BP: Budget Period
# Project Summary

1. **Cost Analysis, BOM, Cost of Ownership Targets and Initial Prototyping**
2. **System Optimization and Finalized Power Cell Design**
3. **System Packaging, Reliability, and Standards Testing**
4. **System Demonstration**
## Go/No-Go Milestones

<table>
<thead>
<tr>
<th>Title</th>
<th>Budget Period</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCO Report defines cost/performance targets</td>
<td>Budget Period 1</td>
<td>SST-based EVSE cost analysis showing ≥50% cost reduction over the baseline system; TCO analysis specifying cost/performance targets and optimal product insertion points into the marketplace complete</td>
</tr>
<tr>
<td>Power cell meets performance targets</td>
<td>Budget Period 2</td>
<td>Power cell meets performance targets, including meeting the EMI limits, efficiency target of &gt;98%, bidirectional power flow, and black-start capability. SST BOM meets cost targets</td>
</tr>
<tr>
<td>SST-based EVSE meets performance targets</td>
<td>Budget Period 3</td>
<td>SST-based EVSE meets performance targets, including EMI limits and efficiency target of &gt;98%; demonstration sites identified.</td>
</tr>
</tbody>
</table>
BP1

Cost Analysis, BOM, Cost of Ownership Targets and Initial Prototyping: The Recipient will design the low-cost power cell that stacks to make up the SST-based EVSE, determine the cost targets for each power cell subsystem, and iterate the power cell design until the cost targets are met. The Recipient will also investigate the system reliability and set redundancy targets to meet reliability goals. The Recipient will conduct a total cost of ownership analysis, with input from industry stakeholders and project demonstration partners. An initial prototype of the transformer, the power cell, system level mechanical assembly, and system level control firmware will be developed, and the Diversity, Equity, and Inclusion Plan will be launched.

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SST simulation and analysis</td>
<td>Technical</td>
<td>Demonstrate efficiency, meeting the target of ≥98%; BOM target costs ≤$90,000</td>
</tr>
<tr>
<td>for modularity and system</td>
<td>Technical</td>
<td>Sub-system cost targets validated to meet the BOM cost ≤$90,000</td>
</tr>
<tr>
<td>scalability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bill of materials (BOM) cost</td>
<td>Technical</td>
<td>Quantify TCO and identify use cases where the MV solution outperforms the LV solution</td>
</tr>
<tr>
<td>analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCO analysis</td>
<td>Technical</td>
<td></td>
</tr>
<tr>
<td>Outreach initiatives</td>
<td>Diversity</td>
<td>Launch SRIU and SBP programs</td>
</tr>
<tr>
<td>TCO Report</td>
<td>Go/No Go</td>
<td>SST-based EVSE cost analysis showing ≥50% cost reduction over the baseline system; TCO analysis specifying cost/performance targets and optimal product insertion points into the marketplace complete</td>
</tr>
</tbody>
</table>
**BP2**

**System Optimization and Finalized Power Cell Design:** The Recipient will finalize the design of the low-cost power cell that stacks to make up the SST-based EVSE and meet cost and performance targets, including testing benchmarks. The Recipient will develop and finalize the design of the power cell, the system-level mechanical design, and the system firmware as well as demonstrate a power cell charging an electric vehicle or vehicle emulator. The Recipient will finalize the total cost of ownership analysis, with input from industry stakeholders and project demonstration partners.

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power cell design and evaluation</td>
<td>Technical</td>
<td>Final design of power cell meets cost of ≤$3,900, efficiency &gt;98%, and power density of ≥3kW/L</td>
</tr>
<tr>
<td>Transformer Testing</td>
<td>Technical</td>
<td>Transformer passes IEEE C57.12.01TM standard tests and meets cost targets</td>
</tr>
<tr>
<td>Power Cell testing</td>
<td>Technical</td>
<td>Power cell meets performance targets, including EMI limits, efficiency of &gt;98%, and power density target ≥3kW/L</td>
</tr>
<tr>
<td>Outreach initiatives</td>
<td>Diversity</td>
<td>Administer SRIU and SBP programs</td>
</tr>
<tr>
<td>Go/No Go Decision</td>
<td>Go/No Go</td>
<td>Power cell meets performance targets, including meeting the EMI limits, efficiency target of &gt;98%, bidirectional power flow, and black-start capability. SST BOM meets cost targets</td>
</tr>
</tbody>
</table>
System Packaging, Reliability, and Standards Testing: The Recipient will finalize the design of the SST-based EVSE and packaging the power cells. The SST-based EVSE will be tested against all relevant standards and sites for system demonstrations will be identified.

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2 System level mechanical design</td>
<td>Technical</td>
<td>Final SST racked, tested, and meeting performance targets (cost ≤$90,000, efficiency &gt;98%, and power density ≥3kW/L.)</td>
</tr>
<tr>
<td>4.4 EVSE dispenser communication and control development</td>
<td>Technical</td>
<td>Demonstration of complete SST charging an electric vehicle or vehicle emulator; system passes all safety tests and is ready for deployment</td>
</tr>
<tr>
<td>5.1 Outreach initiatives</td>
<td>Diversity</td>
<td>Administer SRIU and SBP programs</td>
</tr>
<tr>
<td>5.2 Design of the EVSE of the future</td>
<td>Diversity</td>
<td>Thematic focus of SRIU and SBP programs</td>
</tr>
<tr>
<td>Go/No Go Decision</td>
<td>Go/No Go</td>
<td>SST-based EVSE meets performance targets, including EMI limits and efficiency target of &gt;98%; demonstration sites identified.</td>
</tr>
</tbody>
</table>
Demonstration: The Recipient will test the unit against a test plan generated from the review of the standards.

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>System commissioning and testing</td>
<td>Technical</td>
<td>Ship, install, test, and commission EVSE system at partner sites</td>
</tr>
<tr>
<td>Outreach initiatives</td>
<td>Diversity</td>
<td>Administer SRIU and SBP programs</td>
</tr>
<tr>
<td>Design of the EVSE of the future</td>
<td>Diversity</td>
<td>Thematic focus of SRIU and SBP programs</td>
</tr>
<tr>
<td>Operational in Field and tested</td>
<td>Technical</td>
<td>SST-based EVSEs operational in the field</td>
</tr>
</tbody>
</table>
### Budget Period 1: Cost Analysis, BOM, Cost of Ownership Targets and Initial Prototyping

![Image of task and phase plan]

#### Task Description
- **Task 1:** Project Management
  - 1.1: Project Kickoff Meeting
  - 1.2: PMP Development
- **Task 2:** System Design to Meet Total Cost of Ownership Targets
  - 2.1: SST Simulation and Analysis for Modularity and Scalability
  - 2.2: BOM Cost
  - 2.3: Reliability Analysis
  - 2.4: Total Cost of Ownership Analysis
  - M2.1: TCO Report showing 50% cost reduction vs baseline
- **Task 3:** System Design
  - 3.1: Power Cell Design and Evaluation
  - 3.2: System Level Mechanical Design
  - 3.3: Medium Frequency Transformer Design
  - 3.4: Firmware Development and Testing
  - 3.5: Design for Safety and Applicable Standard
  - M3.1: Power Cell Meets Performance Targets
- **Task 4:** System Performance Evaluation
  - 4.1: Transformer Testing
  - 4.2: Power Cell Testing
  - 4.3: SST Performance Evaluation
  - 4.4: EVSE Communication and Control
  - M4.1: System Meets Performance Targets
- **Task 5:** Outreach Initiatives
  - 5.1: Summer Research Internships
  - 5.2: Design of EVSE of the Future

#### Phase Plan
- **Phase 1: Year 1 to Year 4**
- **Phase 2: Year 1 to Year 4**
Baseline EVSE Design

Result of DE-EE0008450*:

- 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

*Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection
Baseline EVSE Design

Proof of Concept: Highly Flexible Design
Not Optimized for Cost

NCSU 1MVA SST

ABB Switchgear

COTS Isolated DC/DC
Approach to Cost Reduction Over Baseline System

- Driven by Total Cost of Ownership Analysis
- Main focus: minimize the cost of SST and integrate functionality to reduce the cost of the balance of system
  - Minimize cost of DC protection (at the expense of flexibility/speed of response)
  - Minimize cost of DC nodes by providing galvanic isolation from the SST (at the expense of flexibility, but potentially with higher efficiency)
  - Minimize SST BOM by moving to lower cost TO 247 devices and using high volume components cost-optimized in other applications
  - Minimize Power Cell cost through design for manufacturing optimization
Baseline Prototype

• System made of 21 identical modules, each rated at 57kW
• Each L-N phase made of 7 modules in a single rack
• SST dimensions 1x1.5x2m (3,000L)
• Weight is approximately 2,000kg
• Peak Efficiency 97.9%
SST Module Design

- 1MVA SST single module built and tested
- Module rated at 57kW to deliver 1MW from 18 modules (3 spares)
- Cabinet level thermal test and computational fluid dynamics (CFD) simulation validate the system cooling performance

Module thermal test with cabinet cooling, and CFD simulation to identify equivalent flow resistance
New SST Module Design

- Eliminate use of expensive SiC modules
- Adopt use of low-cost TO-247 SiC devices throughout the system
- Revert to dry-type transformer design while addressing partial discharge issues faced in earlier designs
Proposed SST Topology

- Proposed SST-based EVSE design provides 4 independent outputs delivering 200-900V at up to 350kW each.
- Sub-module design relies on H8 topology on high voltage side.
- Each power stage will use the same device/cooling construction resulting in economies of scale and simplified mechanical assembly.
## Comparison of the Proposed SST to Baseline SST

<table>
<thead>
<tr>
<th>Metric</th>
<th>Baseline</th>
<th>Proposed</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input Power/Voltage</strong></td>
<td>1MVA at 13.2kV</td>
<td>1MVA at 13.2kV</td>
<td>Short-term goal is $90,000; long-term goal is under $50,000</td>
</tr>
<tr>
<td><strong>Output Power/Voltage</strong></td>
<td>1,000kW at 750Vdc bus</td>
<td>4 x 200-900Vdc at 300kW or 2 x 400-1800Vdc at 600kW</td>
<td>New system will feature four galvanically isolated ports</td>
</tr>
<tr>
<td><strong>SST Volume</strong></td>
<td>2200L</td>
<td>400L</td>
<td>Our existing design of DC/DC stage for this application reaches 6kW/L</td>
</tr>
<tr>
<td><strong>Power Cell kW/L</strong></td>
<td>0.5kW/L</td>
<td>3kW/L</td>
<td></td>
</tr>
<tr>
<td><strong>Devices Used</strong></td>
<td>SiC TO-247 and SiC Modules</td>
<td>SiC TO-247 Exclusively</td>
<td>Leads to significant cost reduction</td>
</tr>
<tr>
<td><strong>System Efficiency</strong></td>
<td>98%</td>
<td>98%</td>
<td>No penalty at reduced cost</td>
</tr>
<tr>
<td><strong>BOM Cost for 1MVA System</strong></td>
<td>$230,000</td>
<td>&lt;$90,000</td>
<td>Short-term goal is $90,000; long-term goal is under $50,000</td>
</tr>
</tbody>
</table>
## Cost Comparison of the Proposed SST to Baseline SST

<table>
<thead>
<tr>
<th>Items</th>
<th>Baseline System Price</th>
<th>New System Price</th>
<th>Cost Reduction Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFE</td>
<td>$2,462</td>
<td>$950</td>
<td>Cost estimate based on H8 and DC/DC design</td>
</tr>
<tr>
<td>DABHV</td>
<td>$2,462</td>
<td>$950</td>
<td></td>
</tr>
<tr>
<td>DABL V</td>
<td>$3,898</td>
<td>$950</td>
<td></td>
</tr>
<tr>
<td>Sensors</td>
<td>$2,019</td>
<td>$500</td>
<td>Use fewer &amp; lower cost sensors</td>
</tr>
<tr>
<td>Transformer</td>
<td>$4,200</td>
<td>$500</td>
<td>Cost estimate based on raw material cost</td>
</tr>
<tr>
<td>Fiber optic cables</td>
<td>$131</td>
<td>$50</td>
<td>Use lower cost isolators</td>
</tr>
<tr>
<td>Total for 1 module</td>
<td>$15,173</td>
<td>$3,900</td>
<td></td>
</tr>
<tr>
<td>Total for 21 modules</td>
<td>$318,624</td>
<td>$117,000</td>
<td></td>
</tr>
<tr>
<td>Enclosure</td>
<td>$7,124</td>
<td>$7,000</td>
<td></td>
</tr>
<tr>
<td>Central Control Board</td>
<td>$3,725</td>
<td>$2,500</td>
<td>Use distributed control</td>
</tr>
<tr>
<td><strong>Total cost for 1MW XFC</strong></td>
<td><strong>$329,473</strong></td>
<td><strong>$126,500</strong></td>
<td></td>
</tr>
<tr>
<td>Mass production cost</td>
<td>$230,631</td>
<td>$88,550</td>
<td>Assumes 70% of single unit cost</td>
</tr>
</tbody>
</table>
EVSE Optimization Through TCO Optimization

- Determine relative costs between the medium voltage extreme fast charger and a conventional approach.

- Quantify capital, operating costs over the lifespan including: capital or initial costs; installation, including land purchase requirements; total energy consumption for an assumed power level, EVSE efficiency and vehicle use case; revenue from ancillary services; reliability; and future expansion costs.

- Document difference in components and installation procedures and labor needed for future upgrades and expansions for the two systems.

- Document needs and technology solutions targeting underserved communities.

- Create a series of total cost of ownership models based on considered variables.
  - Costs will vary across utility territories and geographic regions.
  - Target is to identify the scenarios where the extreme fast charger is most financially viable.

Iterative Process Defining the Optimal SST Design Using the Total Cost of Ownership Analysis
Workforce Development

- At NCSU, expect to engage 16 PhDs and 10 Undergrads in the project.
- Builds on successful track record: currently 2 PhDs from FREEDM are doing internships at Danfoss and one participant DE-EE0008450 is now a Danfoss employee.
- Establish Summer Research Internship for Undergraduates (SRIU) and Summer Bridge Programs (SBP);
  - SRIU will be open to NCSU and undergrads from minority serving institutions that participate in the SPB program
  - Participants will create EVSE adaptations for people with disabilities that are Americans with Disabilities Act (ADA) compliant.
Project Management

In BP1, focus on Total Cost of Ownership Analysis:

- Quarterly Team Meetings
- Weekly Total Cost of Ownership Meetings
- Weekly SST Development Meetings

TCO Analysis
Lead: NCECT
Participants: NYPA, ComEd, GoTriangle

SST Design
Lead: FREEDM
Participants: Danfoss

SRIU/SBP
Lead: FREEDM
Participants: Advisory Board

SRIU/SBP
Lead: FREEDM
Participants: NYPA, ComEd, GoTriangle

Clear Expectations on what will be delivered
Technology Transfer Plan

- NCSU plans to follow multiple paths to market for the MV SST Technology licensing and startup formation.
- Plan to protect the Intellectual Property though Patent filings working with North Carolina State University’s Office of Research Commercialization (ORC).
Risks and Risk Mitigation

- SST design requires flexibility in initial stages to account for findings of TCO analysis. Mitigated by focusing on more generic and systematic challenges initially, including transformer design, protection requirements and design, and system level control.

- A reliable transformer design and manufacturing with multiple outputs and without the use of oil is a major challenge. Rely on know-how and industry connections for manufacturing from Danfoss.

- Supply chain constraints present an issue even for prototyping and cause major delays. To mitigate the issue, the team will pre-order hard to source items such as SiC MOSFEETS.

- Supply chain constraints and inflation present a risk to the overall budget. Scope of the demonstration plans may need to be reevaluated in the later stages of the project.