TRANSPORTATION AND POWER SYSTEMS

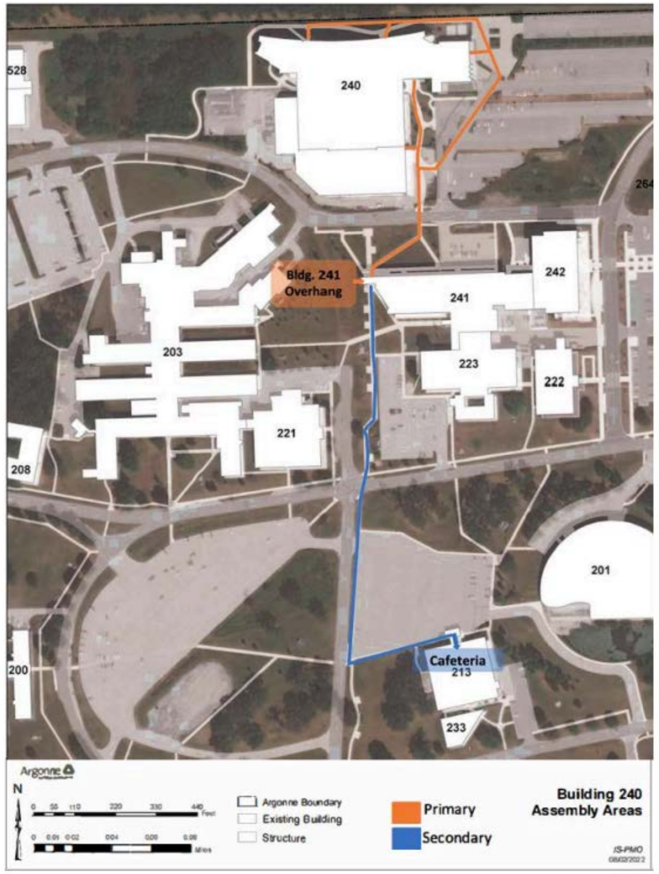
EVs@Scale Lab Consortium Semi-Annual Stakeholder Meeting

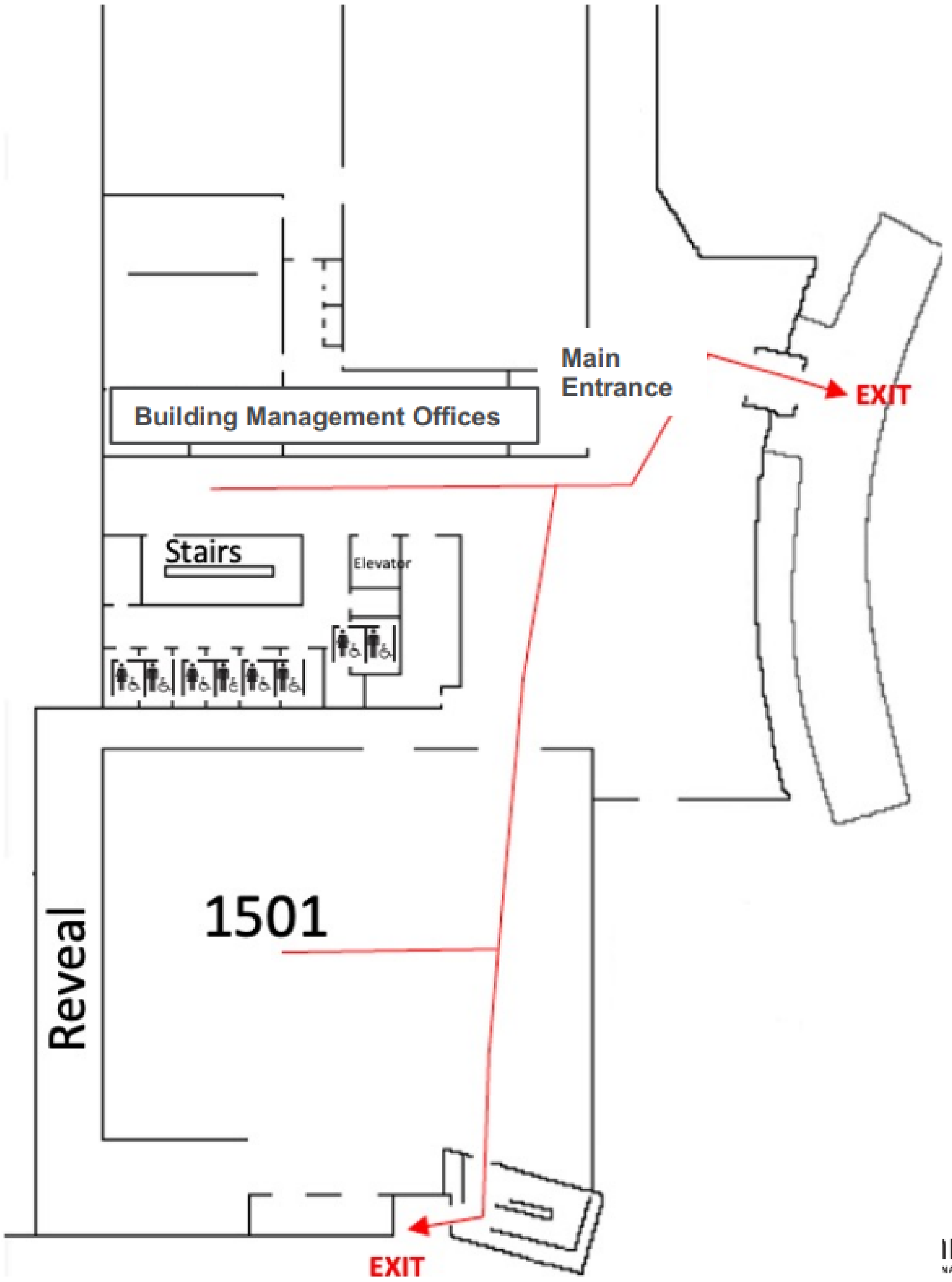
EMERGENCY INFORMATION FOR BLDG. 240 ROOM 1501

DIAL 9-1-1 ON AN ARGONNE PHONE OR 630-252-1911 ON YOUR CELL PHONE AND FOLLOW OPERATOR INSTRUCTIONS

ROOM 1501 EMERGENCY EVACUATION ROUTE

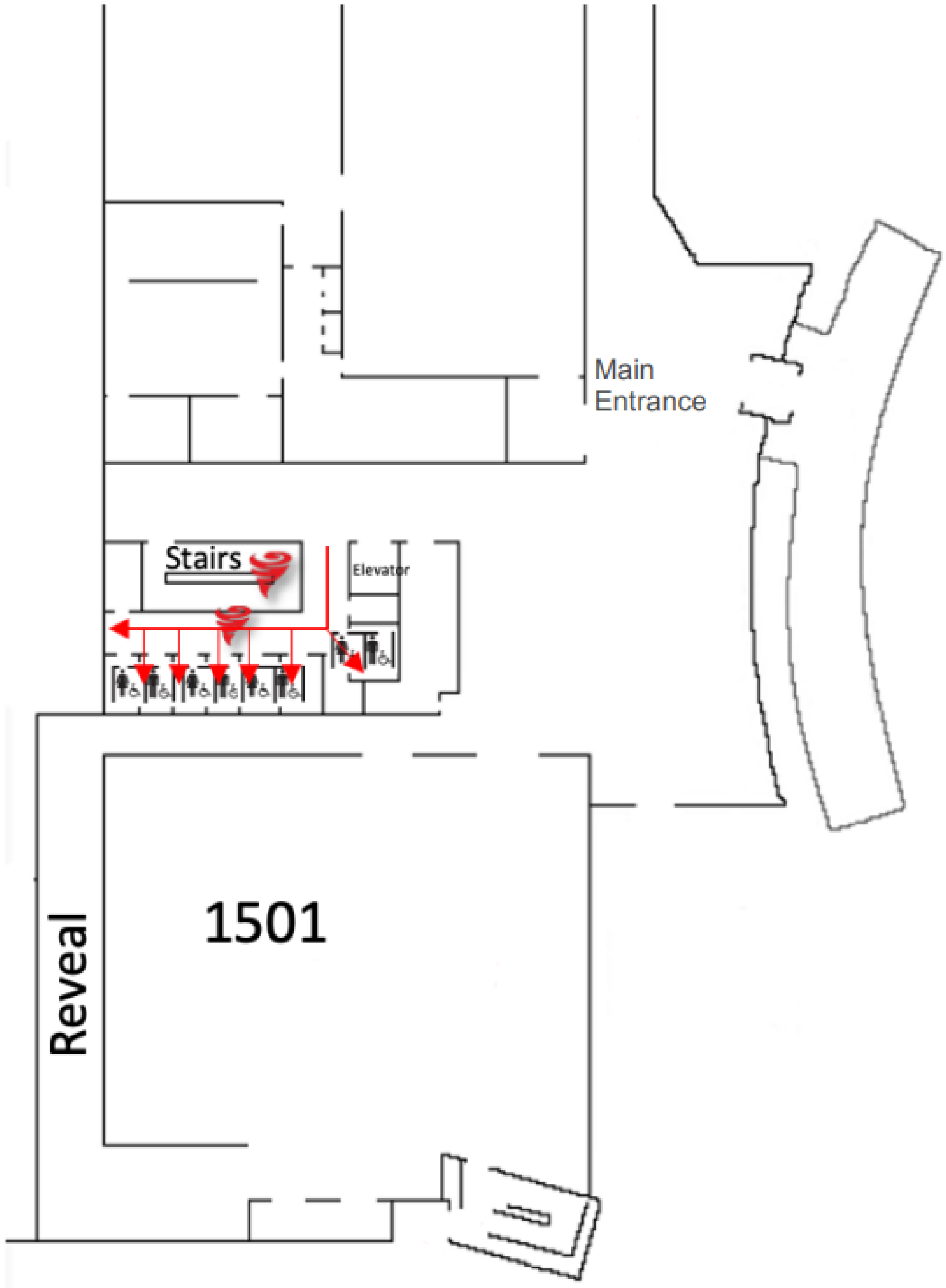
In case of evacuation emergencies follow the exit signs





EMERGENCY SHELTER LOCATIONS

In case of severe weather relocate to shelter areas; central stair well, the first floor restrooms and adjacent hallway




TRANSPORTATION AND POWER SYSTEMS
EVs@Scale Lab Consortium Semi-Annual Stakeholder Meeting

Welcome from the European Commission

Piotr Szymanski

Director for Energy,
Mobility and Climate

EC-Joint Research Centre

Welcome


TRANSPORTATION AND POWER SYSTEMS
EVs@Scale Lab Consortium Semi-Annual Stakeholder Meeting

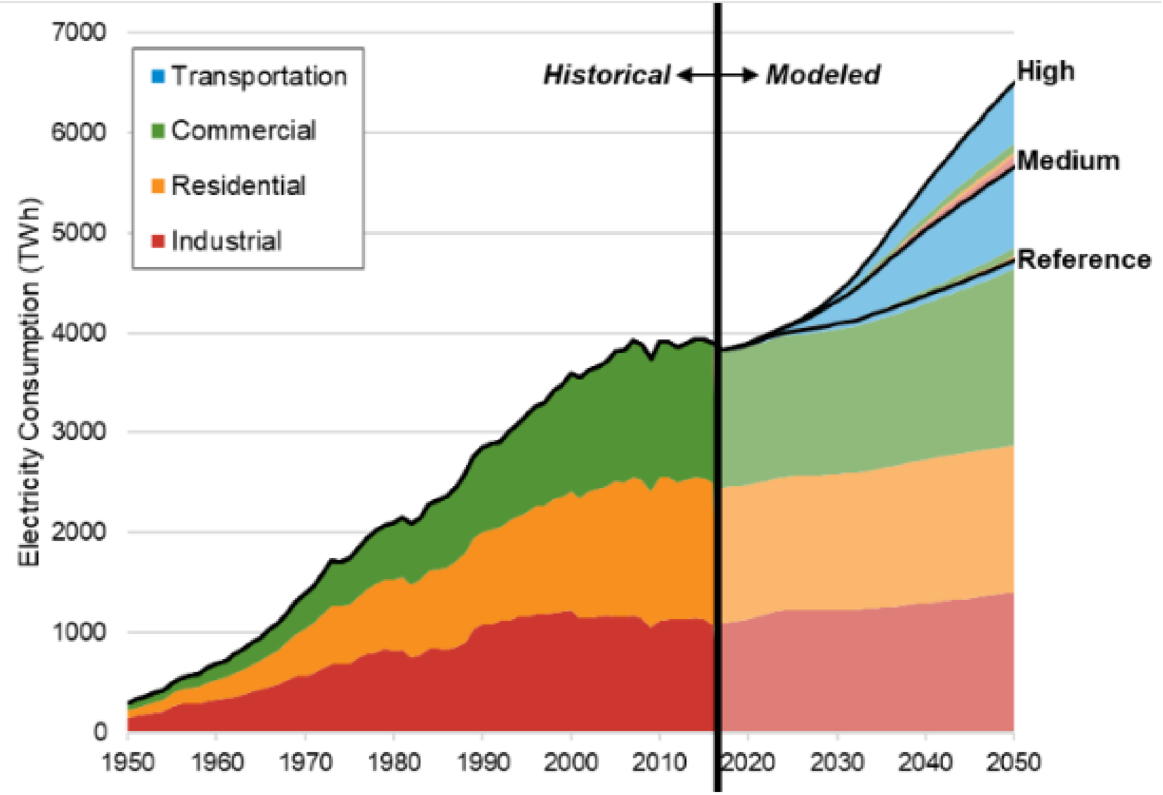
EVs@Scale
U.S. Department of Energy

Consortium Overview and Stakeholder Engagement

Andrew Meintz

April 5, 2023

Impact of Transportation Electrification



Historical and Projected annual electricity consumption[3]

EVs@Scale Consortium RD&D will support electrification by answering:

- How will electricity generation and the transportation sectors work together?
- What research can we do to ensure a safe, smooth, and seamless transition?
- How could a grid-integrated charging network support intermittent generation?

[3] Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. NREL/TP-6A20-71500

Consortium Objectives

- Develop charging technologies and standards needed to meet U.S. goals of **transitioning to a nationwide fleet of on-road vehicles powered by electricity**, bringing the transportation sector closer to a net-zero-emission future
- Bring together the **national laboratories' hardware and software expertise, capabilities, and facilities** related to EV charging, charge management, grid services, grid integration, and cyber-physical security.
- Enable **highly coordinated, targeted research** to be initiated and successfully conducted that is in step with rapid changes in the EV charging

Installation of smart charging system at NREL's Flatirons Campus (Dennis Schroeder / NREL)

Consortium Structure

Leadership Council

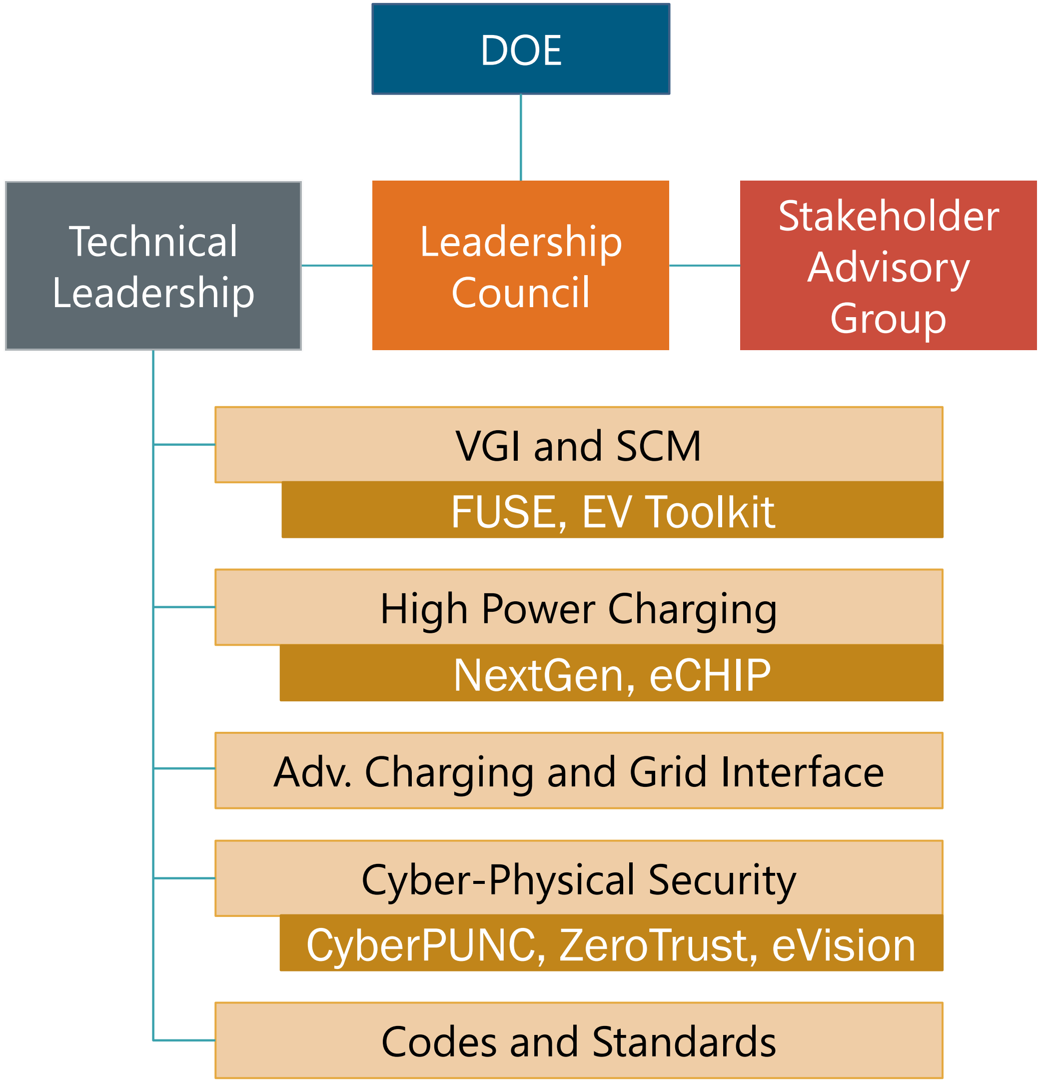
- Andrew Meintz (NREL, chair), Tim Pennington (INL, rotating co-chair), Don Stanton (ORNL), Summer Ferreira (SNL), Lori Ross (PNNL), Dan Dobrzynski (ANL), Bin Wang (LBNL)

Stakeholder Advisory Group

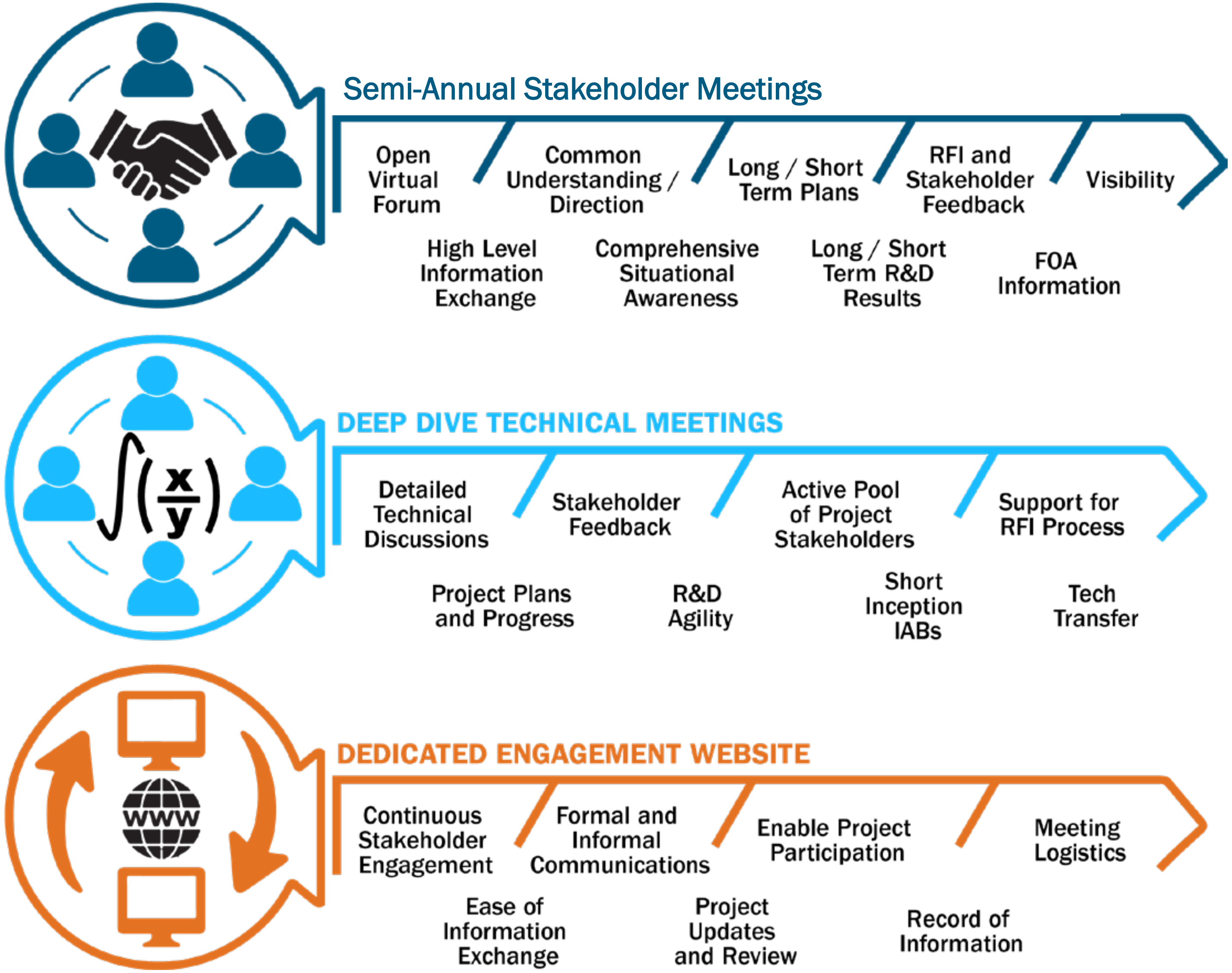
- Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure

Consortium Pillars and Technical Leadership

- Vehicle Grid Integration and Smart Charge Management (VGI/SCM): Jesse Bennett (NREL), Jason Harper (ANL)
- High Power Charging (HPC): John Kisacikoglu (NREL)
- Advanced Charging and Grid Interface Technologies (ACGIT): Madhu Chinthavali (ORNL)
- Cyber-Physical Security (CPS): Richard "Barney" Carlson (INL), Craig Rodine (SNL)
- Codes and Standards (CS): Ted Bohn (ANL)



EVs@Scale Lab Consortium Stakeholder Engagement and Outreach



Collaboration and Coordination

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U.S. Department of Energy

Stakeholder Advisory Group

- Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure

Direct interaction for each pillar projects

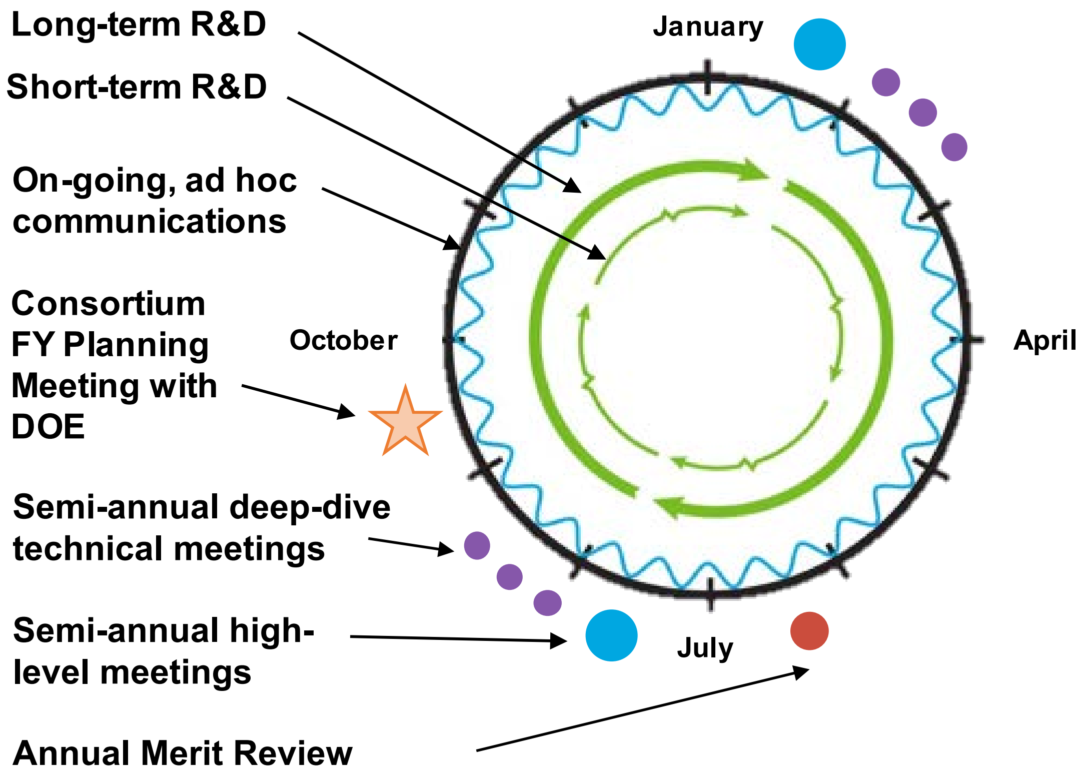
- Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure
- Webinars / Project discussions

Semi-annual high-level meetings

- Rotation among labs with discussion on all pillars

Semi-annual deep-dive technical meetings

- VGI/SCM, HPC & WPT, and CPS with C&S incorporated into all meetings



Two semi-annual high-level meetings were held in August 2022 and April 2023 with attendance reaching 100 stakeholders with several attending the follow-on deep dive discussions

Upcoming Stakeholder Engagement Events

We have the following upcoming stakeholder engagement events planned and will send out invites to registrants of this event for the deep-dives next week.

- **Deep Dive Meetings**
  - Cyber-Physical Security Deep-Dive
    - CyberPunc, ZeroTrust, and eVision Projects
    - Tuesday October 10th and Wednesday October 11th
  - SCM&VGI Pillar Deep-Dive
    - FUSE Project
    - Thursday October 26th
  - High-Power Charging Pillar Deep-Dive
    - NextGen Profiles and eCHIP Projects
    - Tuesday November 7th
- **Semi-Annual Meeting**
  - NREL will host in Golden, Colorado
  - February 28th and 29th

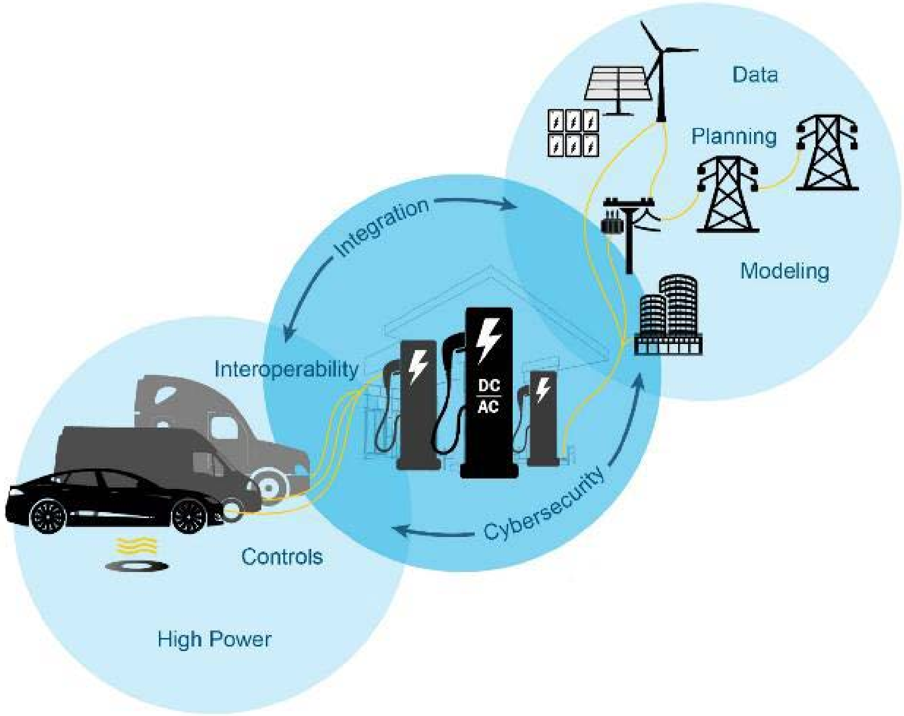
Summary

The EVs@Scale Lab Consortium will

1. Address challenges, develop solutions, and enabling technologies for transportation electrification ecosystem **through national lab and industry collaboration**

2. Formulate and evaluate EV smart-charging strategies that consider travel patterns, charging needs, and fluctuating power generation loads

3. Overcome barriers to EVs@Scale and provide answers to fundamental questions with activities that
   - Assess potential **grid impacts and grid services**
   - **Develop and evaluate hardware and system** designs for high power and wireless charging systems
   - Create design guidelines and evaluate approaches to **secure charging infrastructure** and the grid
   - Support consensus-based **standards development** through evaluation and industry engagement



The EVs @ Scale Lab Consortium will consider these key components of the transportation electrification ecosystem

*We need **<u>your input today and tomorrow</u>** to tell us where we can improve on delivering these outcomes !*

Housekeeping for Today's Discussion

- We are using PollEV to ask for your input
  - Pillar Presentations
  - Panel Discussions
  - Roundtable Questions
- Please be thinking during the discussions
  - "Are the principal thrusts proposed within this pillar on target and appropriate for DOE to be pursuing?"
  - "Are there additional barriers / challenges within this pillar that DOE should be addressing?"

Poll Everywhere

JOIN THE MEETING!

Text **ArgonneEvents** to **22333**

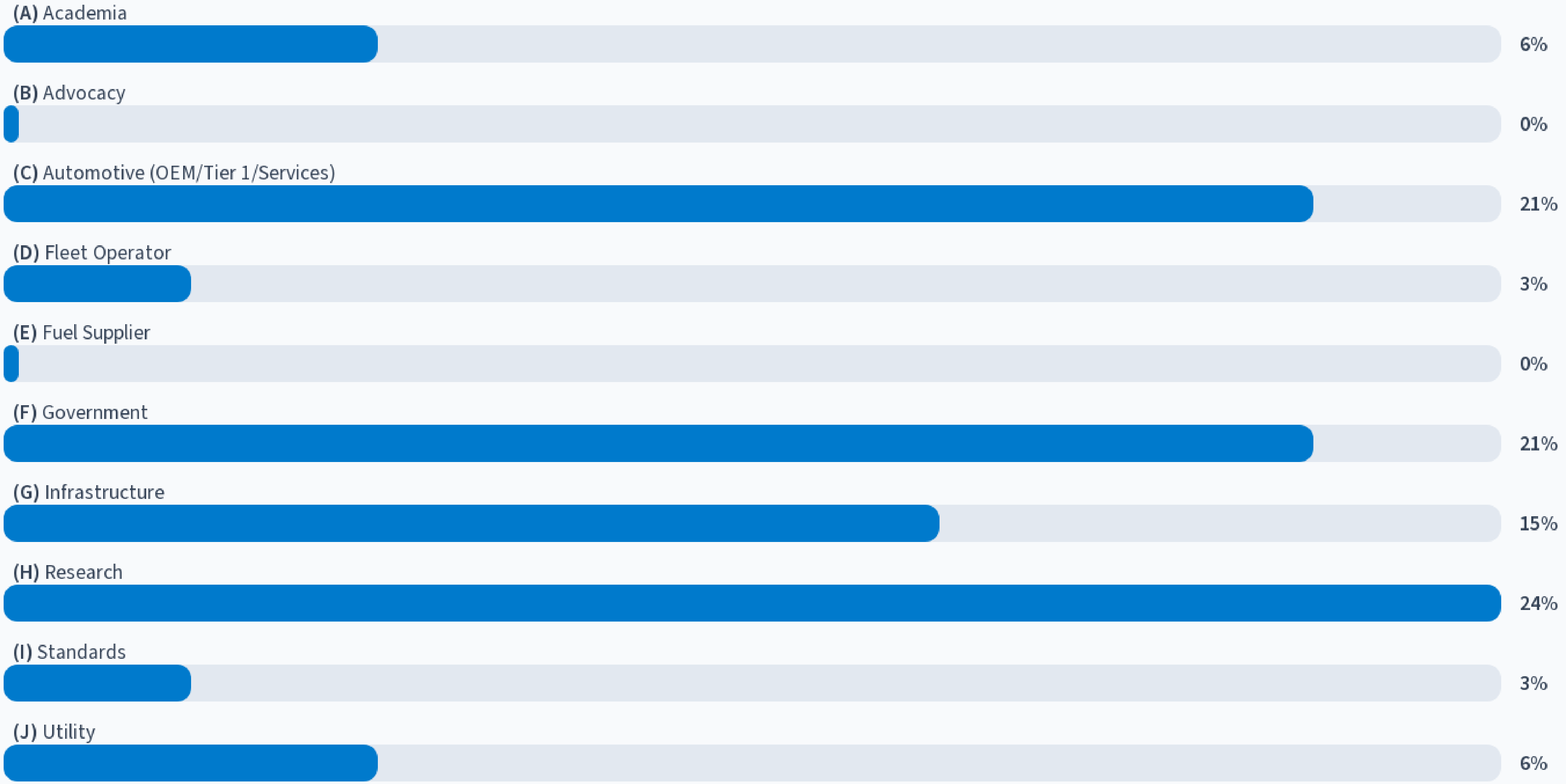
Trouble Texting?

Download the Poll Everywhere App

PollEv.com/ArgonneEvents

Poll Everywhere

How would you characterize your organization/sector?



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High-Power Electric Vehicle Charging Hub Integration Platform (eCHIP)

John Kisacikoglu, NREL

September 27, 2023

Outline

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- Project Overview
- DC Charging Hub Overview
- Site Energy Management System (SEMS) Platform Development
- C-HIL Platform Real-Time Simulation Results
- DC Hub Charging Hub Hardware Development and Results
- DC-DC Charger Power Electronics Development and Controller Integration
- Conclusion and Next Steps

Objective: Develop plug-and-play solution allowing charging site to organically grow with additional chargers and distributed energy resources through predefined compatibility with standards that will ensure interoperability and reduce upfront engineering expense

Outcomes:

– Develop and demonstrate solutions for efficient, low-cost, and **high-power-density DC/DC** for kW- and MW-scale charging

– **Broadly identify limitations and gaps** in DC distribution and protection systems that allow for modular HPC systems

– Determine interoperable hardware, communication, and control architectures for high-power charging facilities that support **seamless grid integration and resilient operation**

- John Kisacikoglu (PI)
- Shafquat Khan
- Alastair Thurlbeck
- Emin Ucer
- Ed Watt

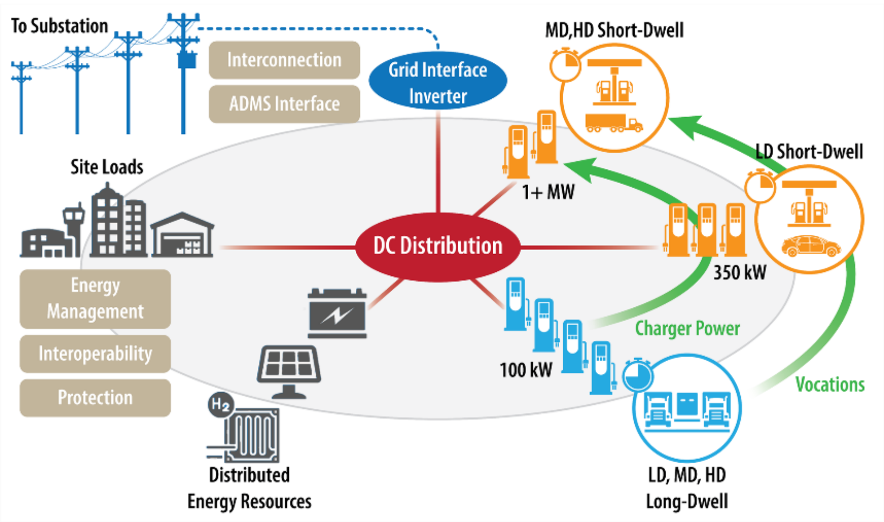
- Jason Harper
- Akram Ali
- Bryan Nystrom

- Prasad Kandula
- Steven Campbell
- Madhu Chinthavali

NREL

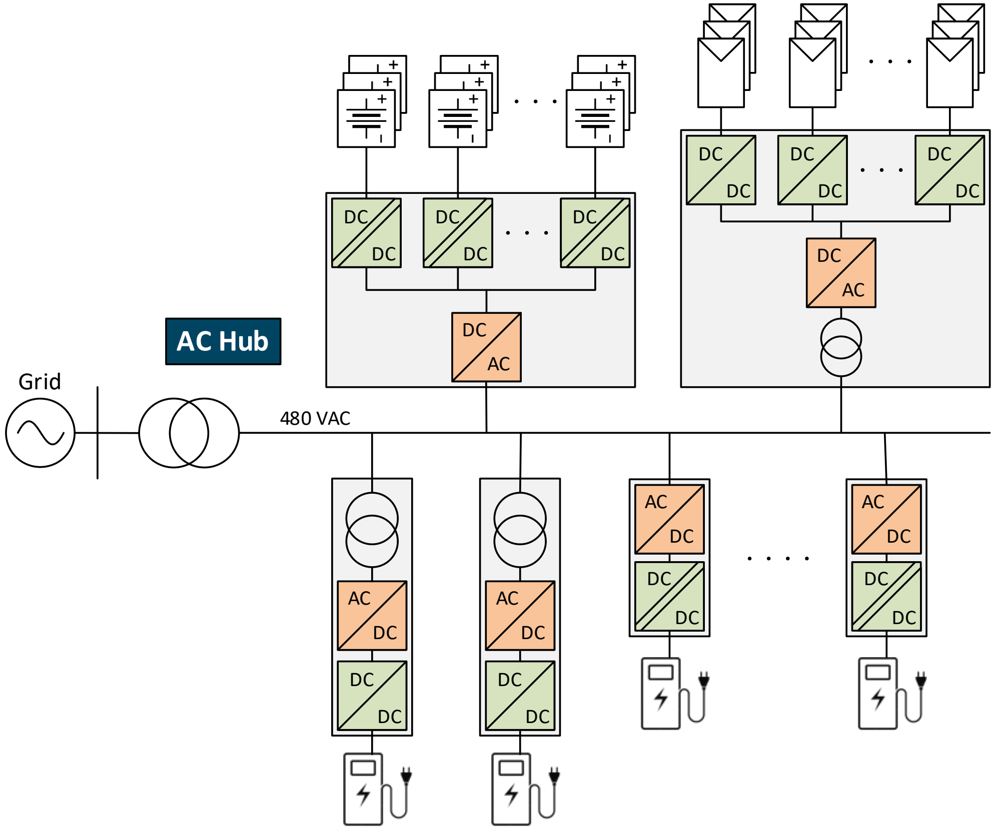
Argonne NATIONAL LABORATORY

OAK RIDGE National Laboratory



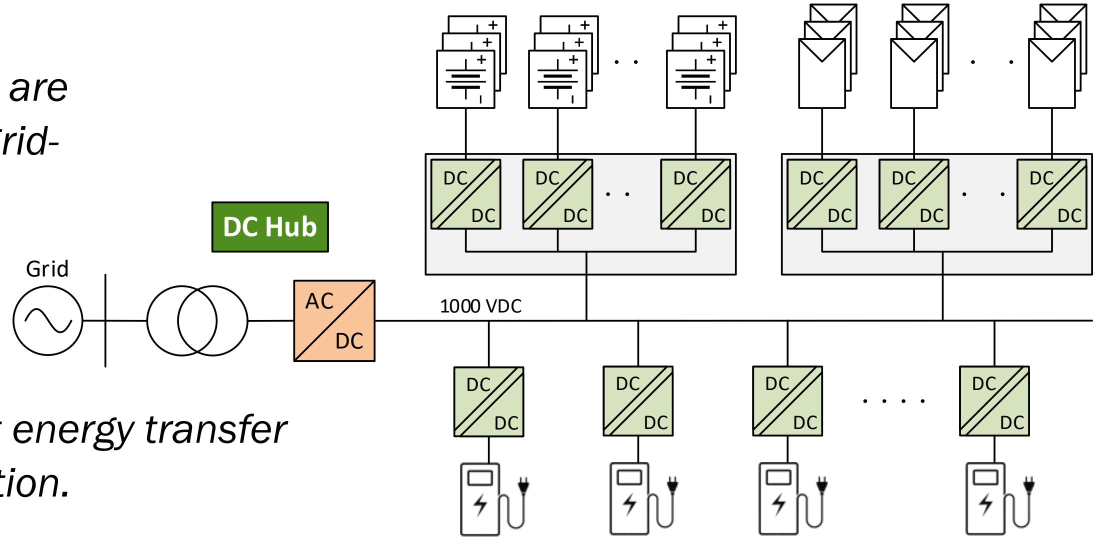
Overview of AC and DC Hub Approaches

AC Hub: High-power charging station with an AC-coupled architecture
DC Hub: High-power charging station with a DC-coupled architecture



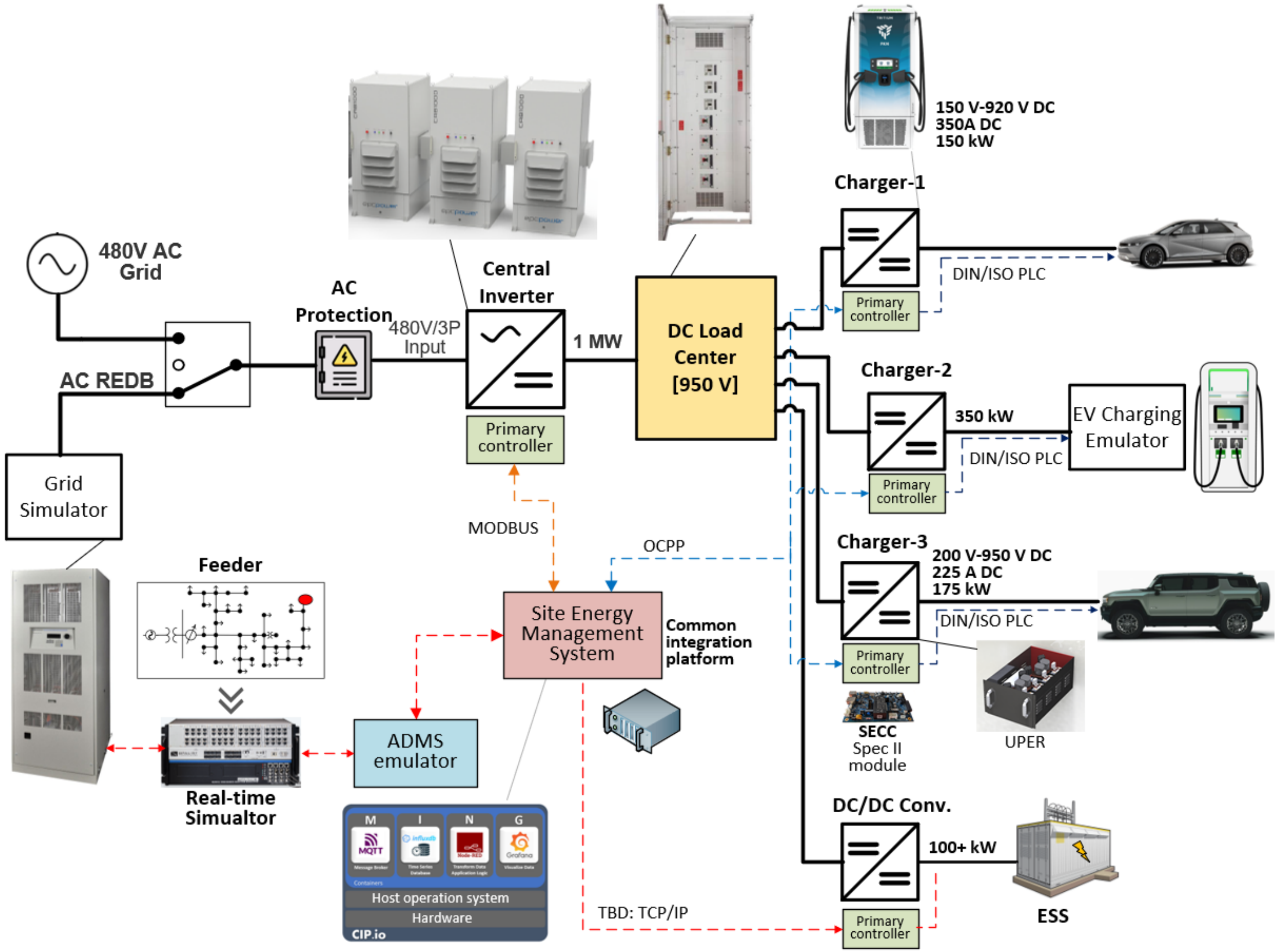
AC/DC conversions are shifted to point of grid-connection.

More efficient energy transfer within the station.



Overview of DC-Hub HPC Station Architecture

- Representative power and communication architecture for DC-hub chargers
- Three research topics are investigated:
  - Site energy management (SEM)
  - Power architecture development
  - Grid integration



Site Energy Management System (SEMS) Platform Description

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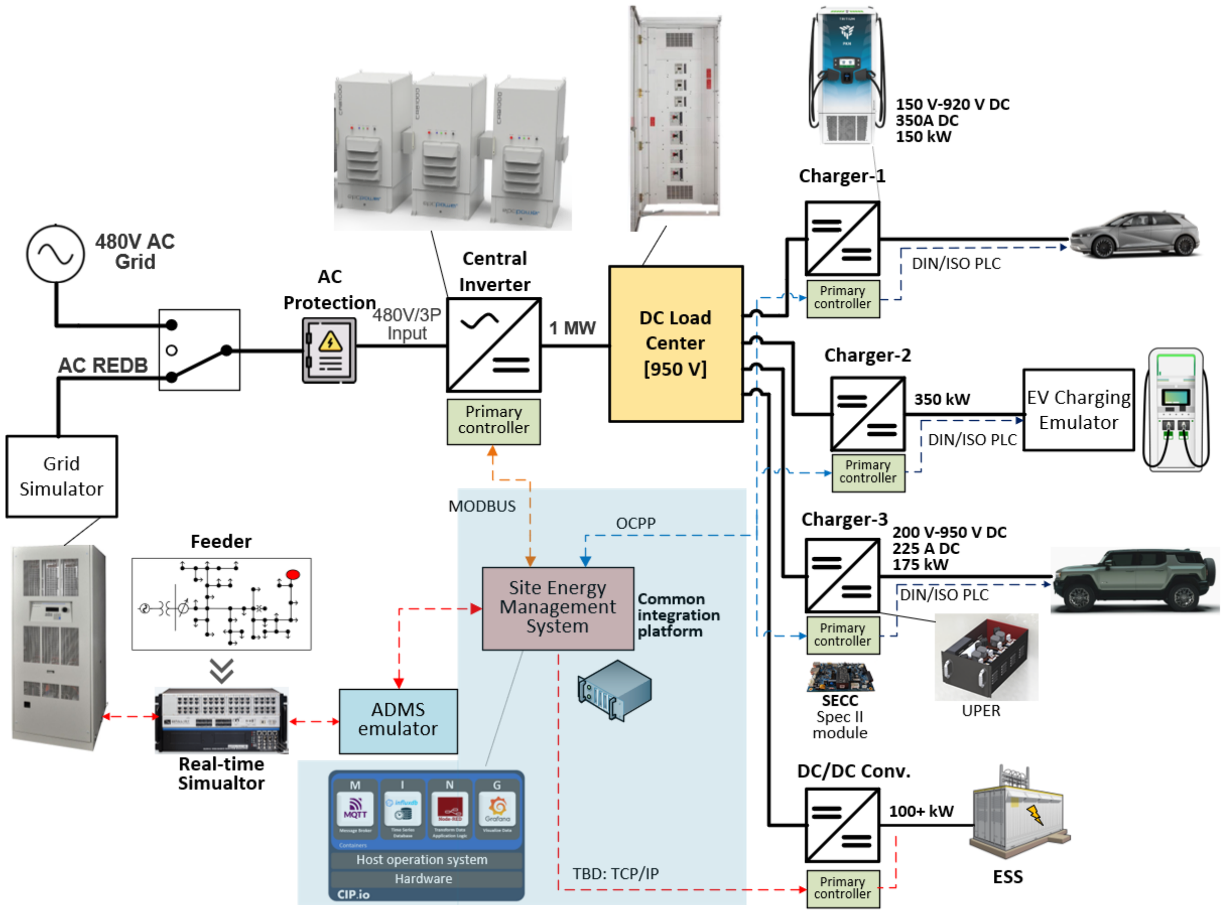
Open-source SEMS platform is developed.

- **Common Integration Platform** (CIP.io)
  - Protocols for communication with EVSEs, DERs, and building systems
  - The CIP.io Platform Leverages the “MING” Stack
    - MQTT: Communication broker to facilitate communication between applications
    - InfluxDB: Time-series database
    - Node-RED: Application logic and bridge between comm. protocols
    - Grafana: Create plots and quickly visualize data
- **Implementation**
  - Implemented data reporting to CIP.io via MQTT on SpEC II
  - Implemented OCPP 1.6-J client on SpEC II
  - Implemented Custom MQTT protocol with SEMS



SEMS Platform, Cont'd.

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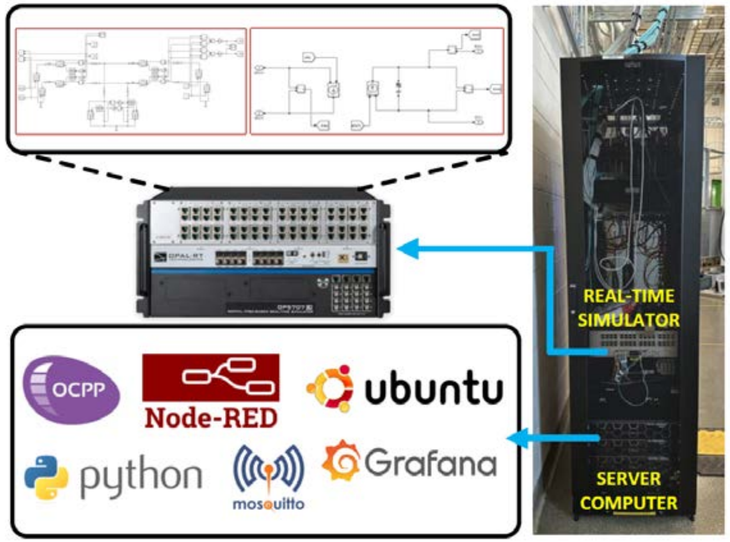
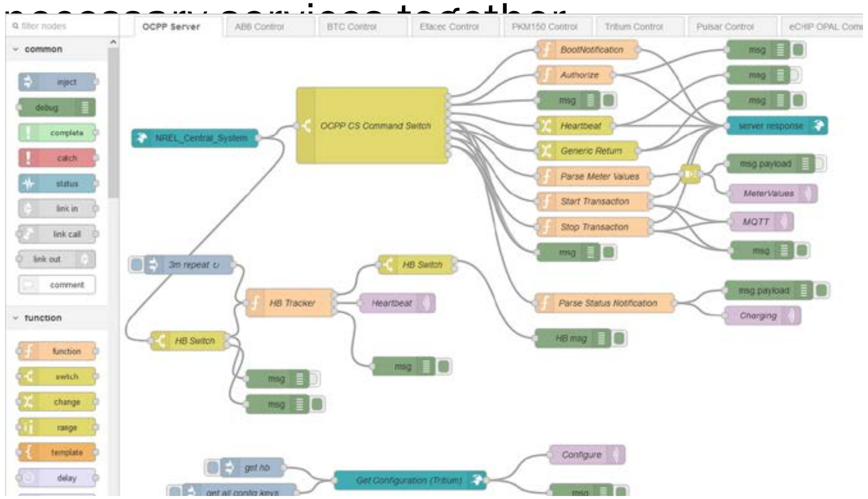
- Testing and verification of SEMS in both Controller-HIL and Power-HIL setups completed
- Communication between **EVSEs** and **SEMS** performed via **OCPP** and **MQTT**
- **Grafana** and **Influx DB** provide a control and monitoring interface and database system
- **Site-level controller** is implemented in **Python**, providing a flexible software interface that abstracts and eliminates back-end implementation details and connects all the necessary services together



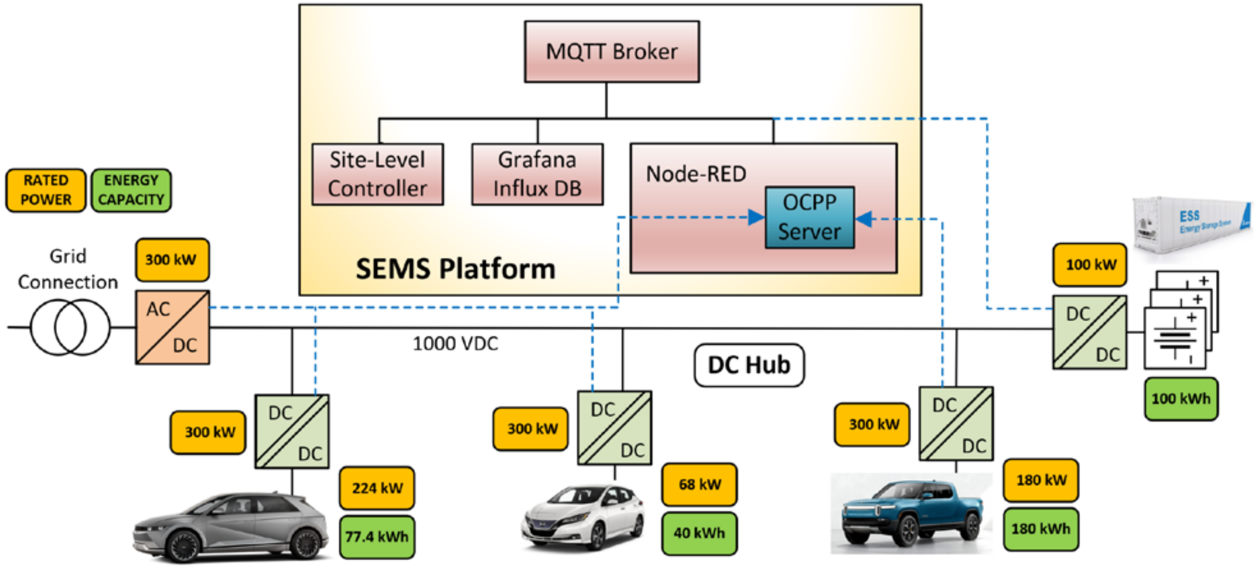


Node-RED Interface

Grafana Dashboard

C-HIL Platform Development

- Real-time simulation platform
  - to build and scale any DC charging hub architecture,
  - to test and verify communication protocols
  - To demonstrate performance of new site controllers
- SEMS platform developed and tested on a mid-size DC charging hub in real-time
- Next Targets: Hub scaling, SpEC module integration, and site-level controller development



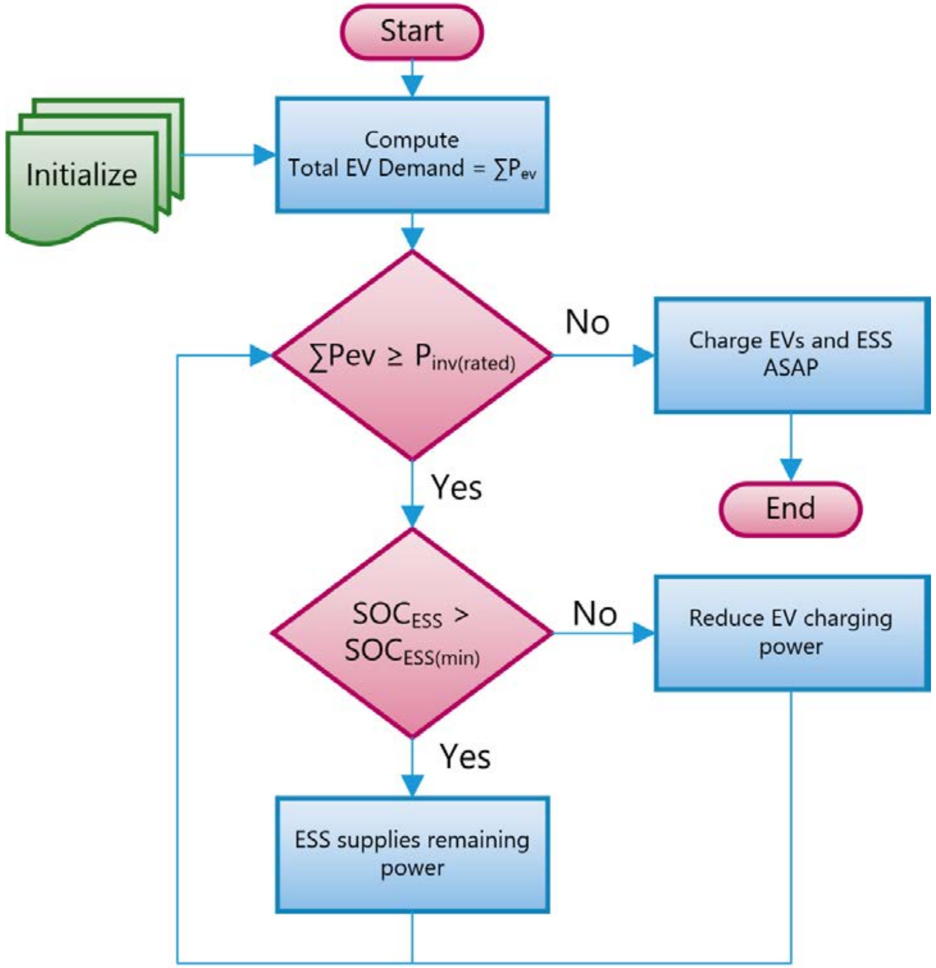
Developed real-time simulation platform using average models for power electronics.

Demonstration of Rule-Based SEMS

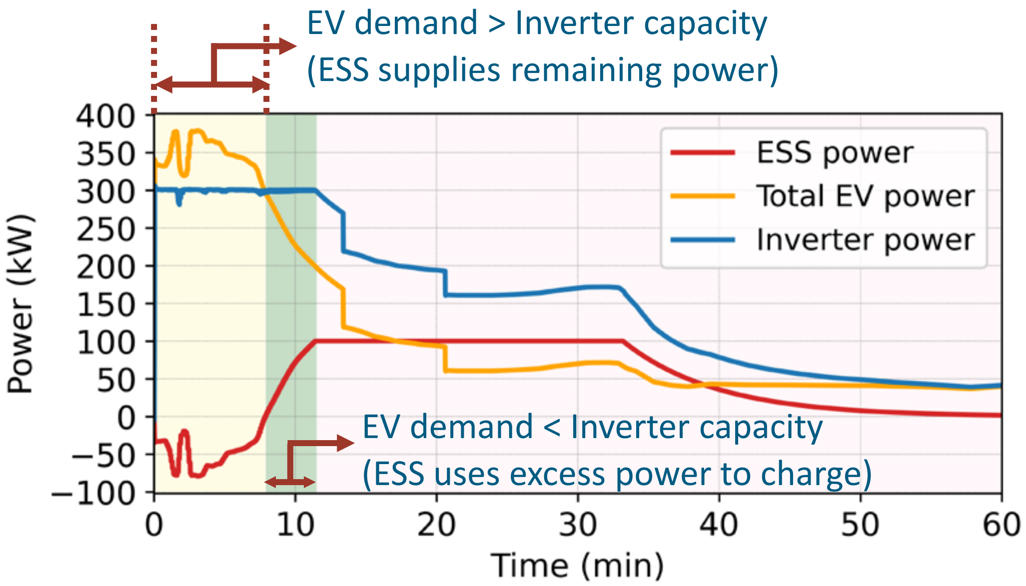
Example of Rule-Based SEMS:

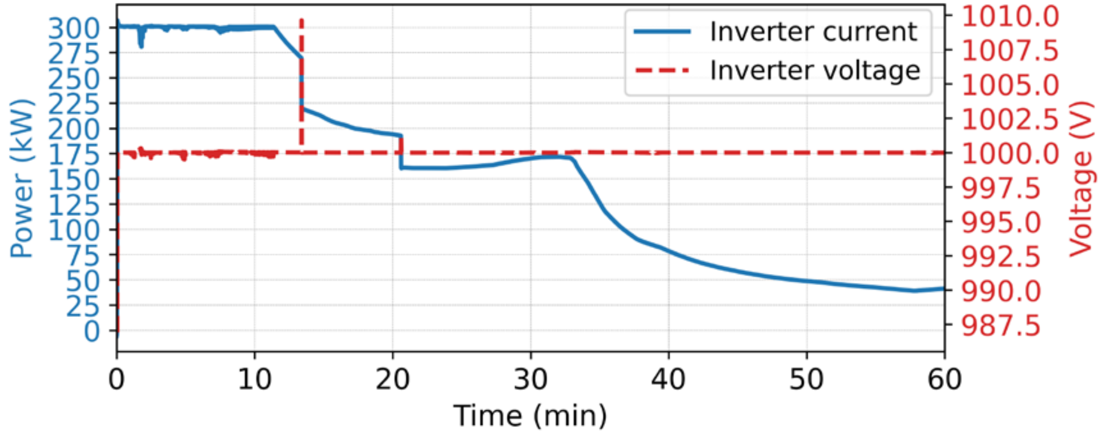
Goal: Charge EV and energy storage system (ESS) as soon as possible without exceeding inverter capacity

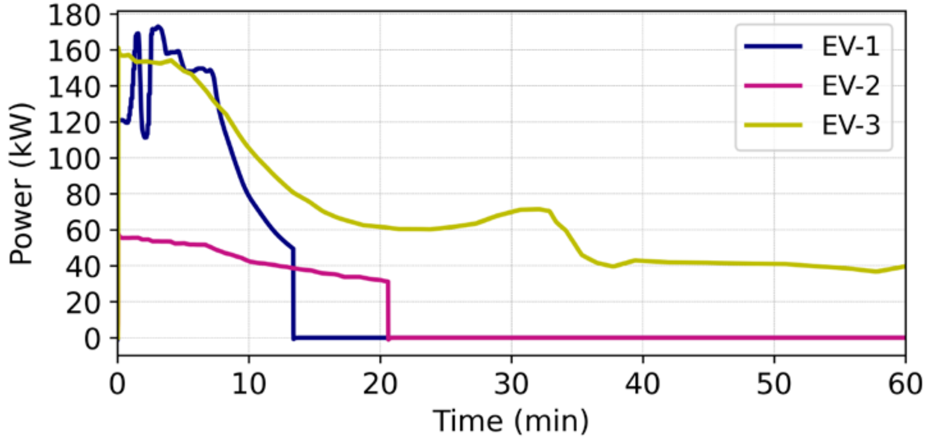
- Inverter will supply EV load first
- If inverter supply is not enough, ESS will provide remaining power
- If both inverter and ESS are not sufficient to meet load, then EV charging power will be reduced
- If excess inverter capacity exists, EVs and ESS will be charged as soon as possible.

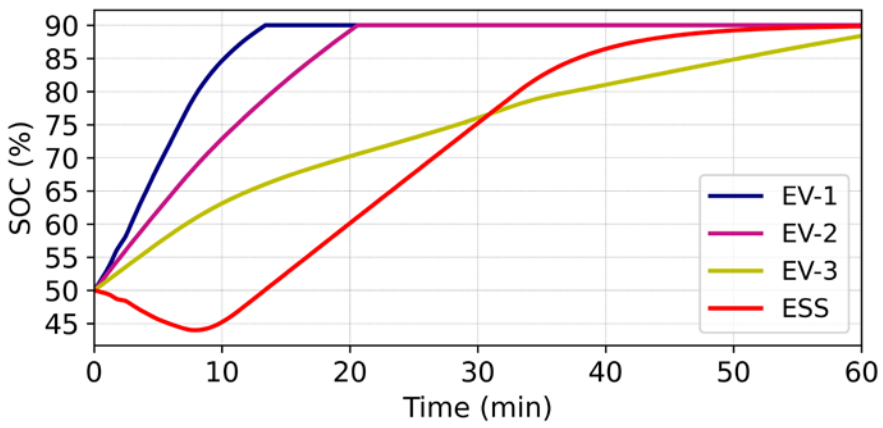


Preliminary C-HIL Results









[1] E. Ucer, et. al "Controller Hardware-in-the-loop Modeling and Operation of a High-power DC Charging Hub" to be presented at ECCE, Oct. 2023

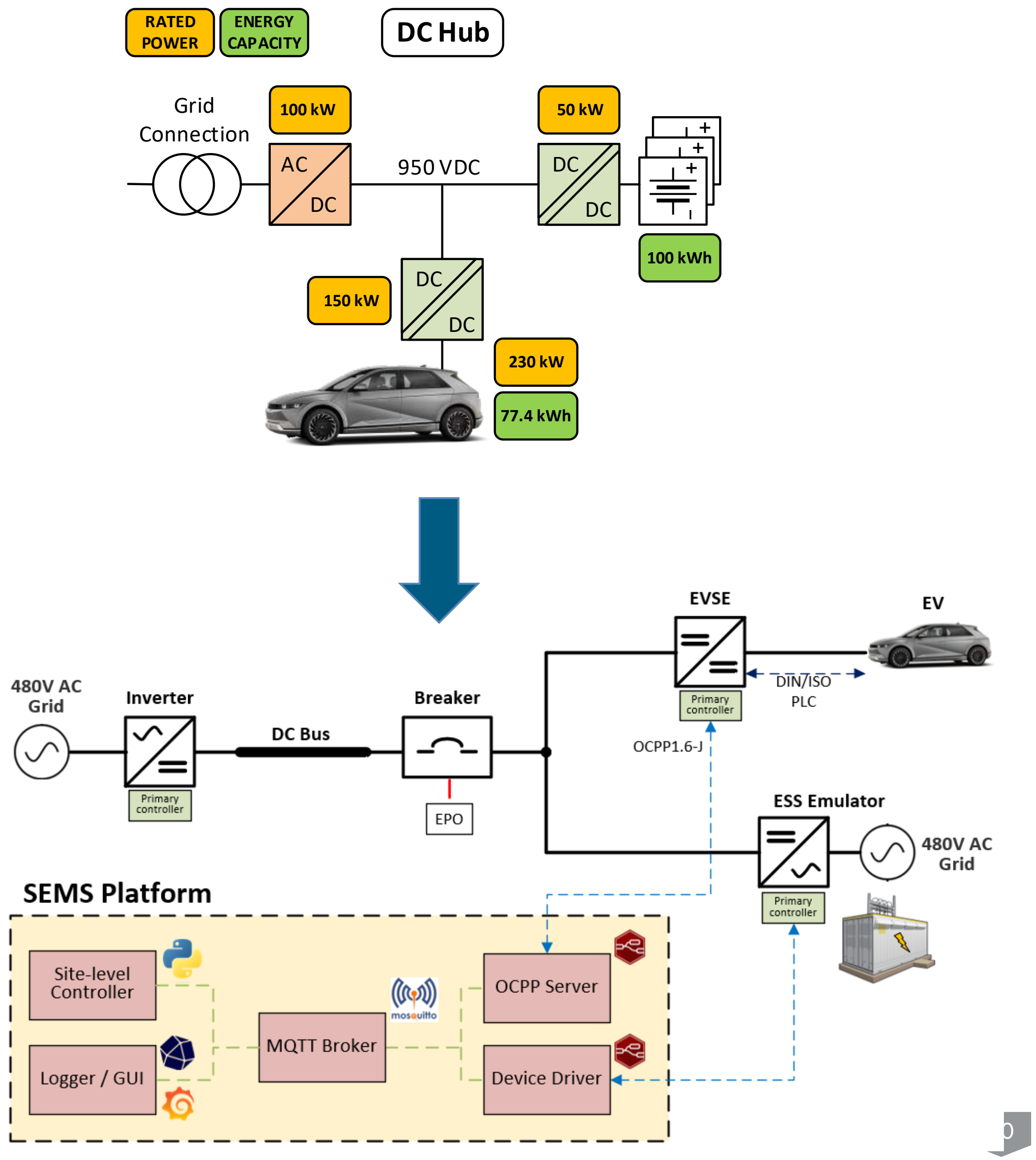
DC Hub Demonstration with Emulated ESS: Setup

Overview

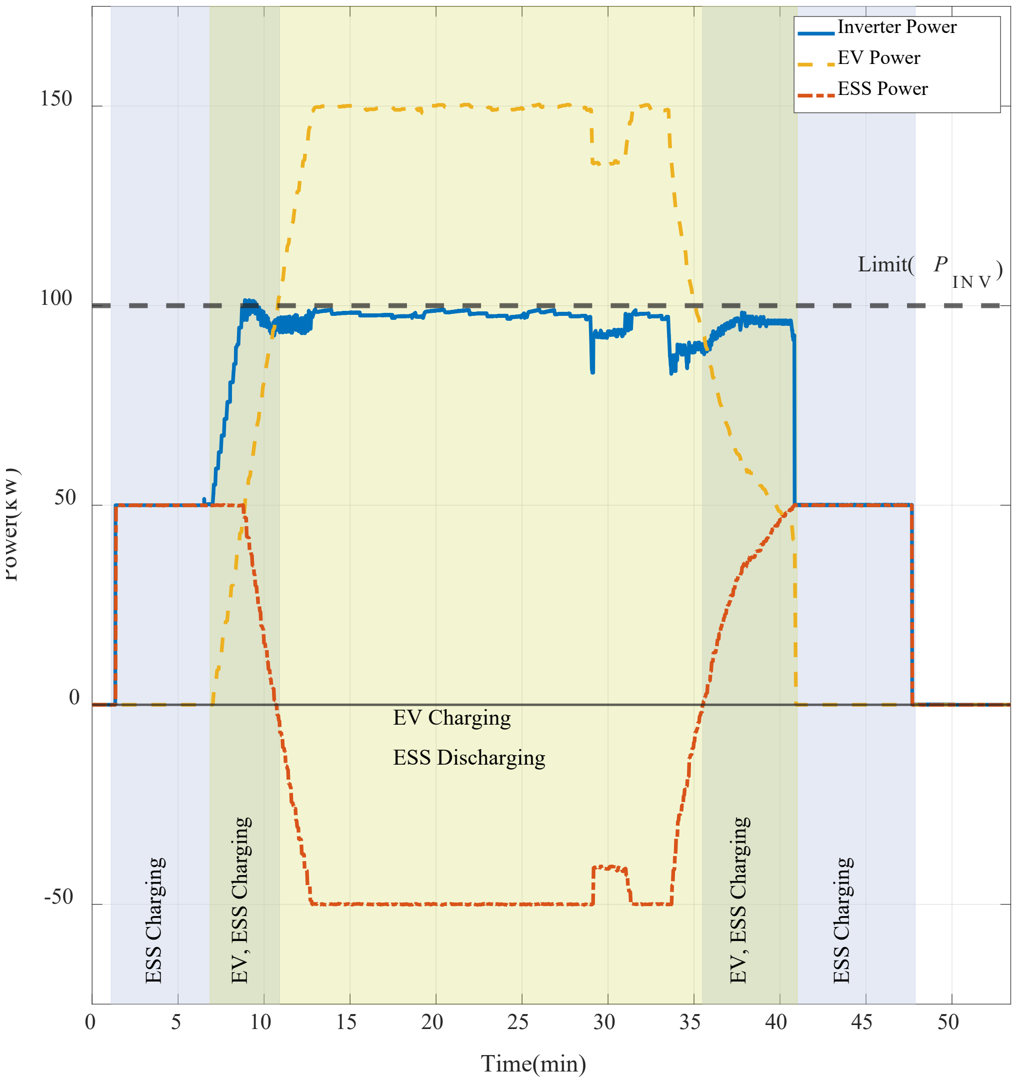
- P-HIL platform demonstrates DC-hub use-case with ESS.
- 150 kW EVSE gets power from inverter derated to 100 kW, and 50 kW emulated ESS.

Use Case Highlights

- Grid-connected inverter is rated for less power than peak charging power.
- ESS discharges to meet peak charging power in combination with inverter.
- SEMS implements dynamic power allocation strategy to prioritize EV charging, while using inverter power to recharge ESS where possible.
- Dynamic power allocation strategy is necessary since knowledge of EV charging demand is currently unavailable (the dynamic current demand is not available through OCPP1.6-J).



DC Hub Demonstration with Emulated ESS: Results

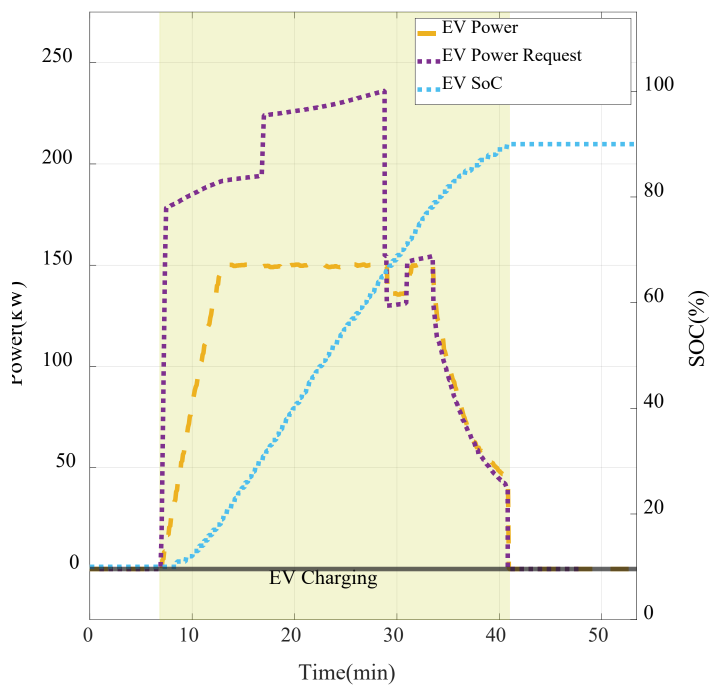


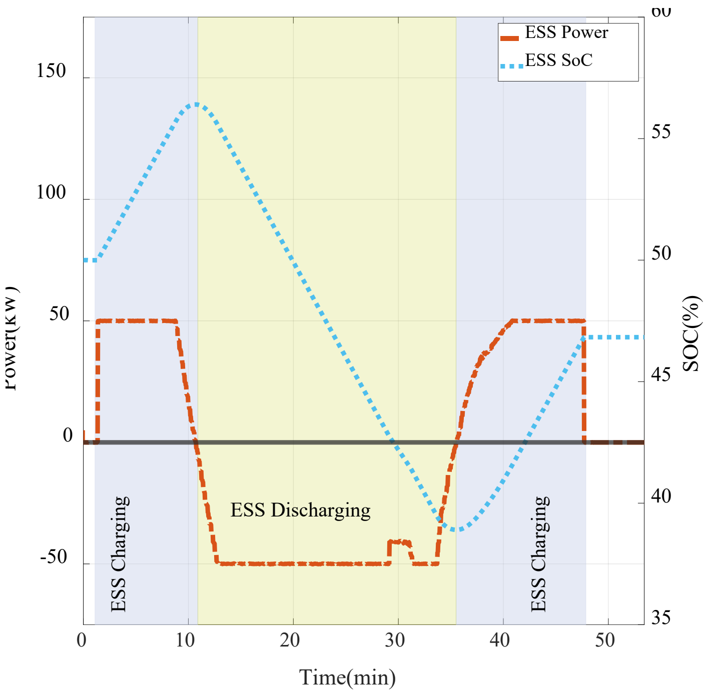
Results Highlights

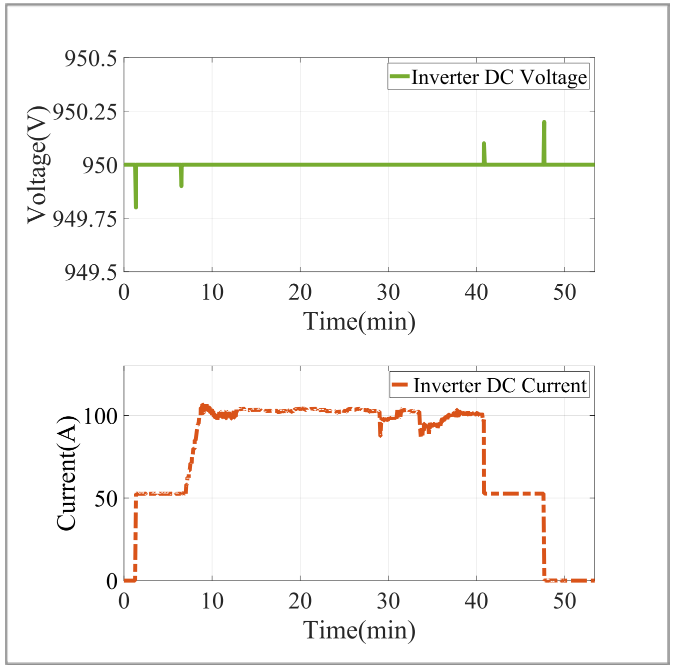
- Inverter power is derated to 100 kW, while EV charging capped at 150 kW.
- EV charging slowly increased under dynamic power allocation strategy because of lack of EV power request signal.
- ESS provided extra support when needed to supply charging demand.

DC Hub Demonstration with Emulated ESS: Results, Cont'd.

- First plot shows EV's potential charging power. However, actual charging power is limited to what is offered by the EVSE.
- Since this signal is not available to SEMS, dynamic power allocation strategy is used instead.
- While this achieves desired energy management objective, ramp time increases due to need to progressively ramp up charging power under this strategy.
- If EV power request was available to the SEMS, 150 kW could be offered to vehicle in a faster fashion.







[2] S. Khan, et. al "Development of a DC Distribution Testbed for High-Power EV Charging" to be presented at ECCE, Oct. 2023

DC Hub Demonstration with Emulated Energy Storage

Key Takeaways

- Use case demonstrates how more complex SEMS objectives can be achieved despite limited information transfer from EV to SEMS.
- Implementation of newer standards is critical to eliminating slow ramp-up tradeoff and enabling practical realization of more advanced SEMS.
- Implemented SEMS and dynamic power allocation strategy enable the central inverter to be sized smaller than the peak charging power without compromising max charging rates (by leveraging ESS).

Next Steps

- Integration of additional DC hub nodes and increased SEMS complexity.
  - Emulated PV generation
  - Emulated building loads
  - UPER integration and demonstration
    - ORNL designed DC-DC charger
- Development and demonstration of an updated SEMS to support multiple vehicles, PV generation, and building loads.
- Evaluate DC hub response to grid ADMS signal.

DC-DC Charger Development

A 1000 V class 175/350 kW charger and 1500 V class 350 kW charger are being developed.

Multi-Dimensional Improvement v/s SOA

High power Building block
Enable MW+ Charging
350 KW instead of 125-150 kW

Power density
Frequency > 20 kHz, η > 99%
Enable two men carry < 80 Lbs.

Higher Working voltages
Distribution DC voltage increased to 2 kV
Vehicle voltage increased to 1500 V

Bidirectional Power (V2X)
Controls to enable
bidirectional power transfer
while maintaining low loss

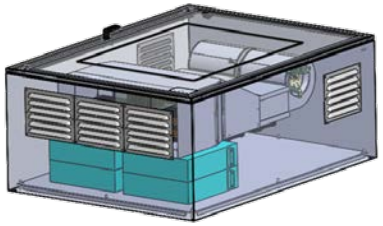
UPER: Universal Power Electronics Regulator

1700 V, 280 A/560 A, SiC

1000 V class 175 kW/350 kW charger	
Vin	800-1200 V
Vout	200-950 V
Imax	225 A/ 450 A
Eff	>98.5%
Temp	-30°C to 50°C
Comms	CAN
Powerflow	Bidirectional

3300 V, 500 A, SiC

1500 V class 350 kW charger	
Vin	1500-2000 V
Vout	500-1500 V
Imax	250 A
Eff	>99%
Temp	-30°C to 50°C
Comms	CAN
Powerflow	Bidirectional

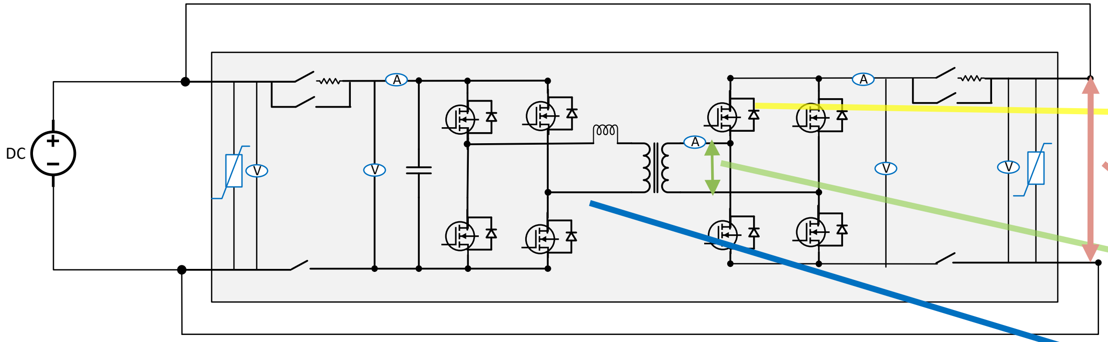


Specifications of charger under development

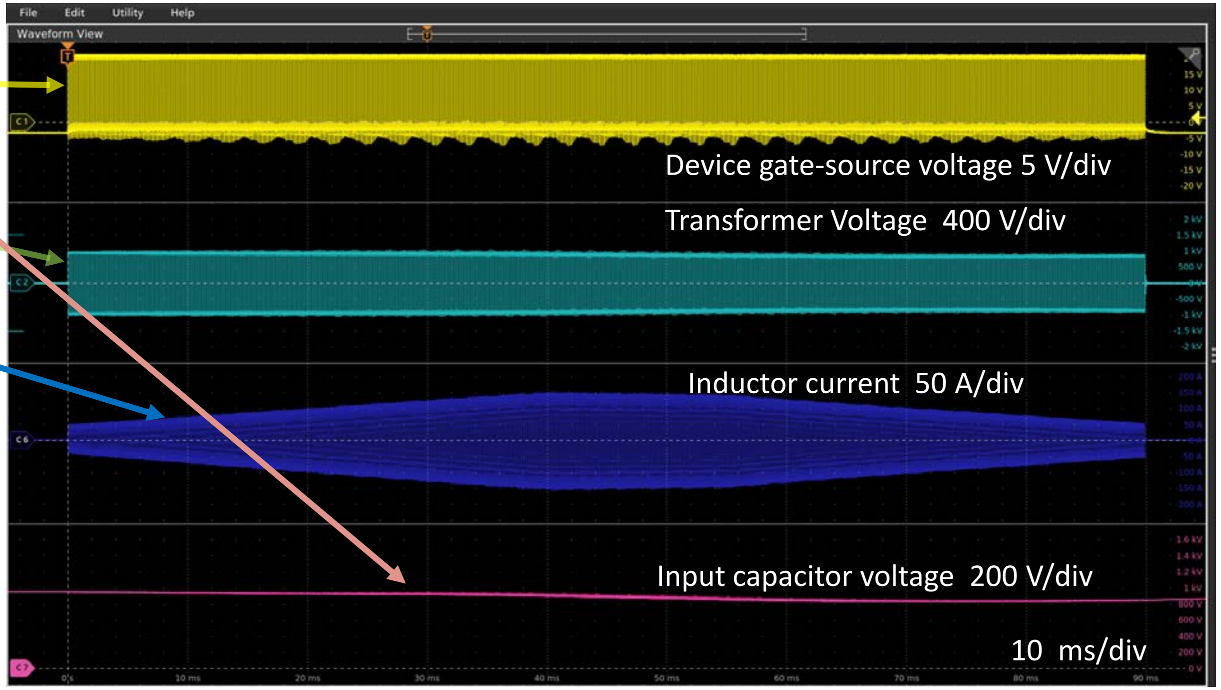
1000V Class Charger Test Results

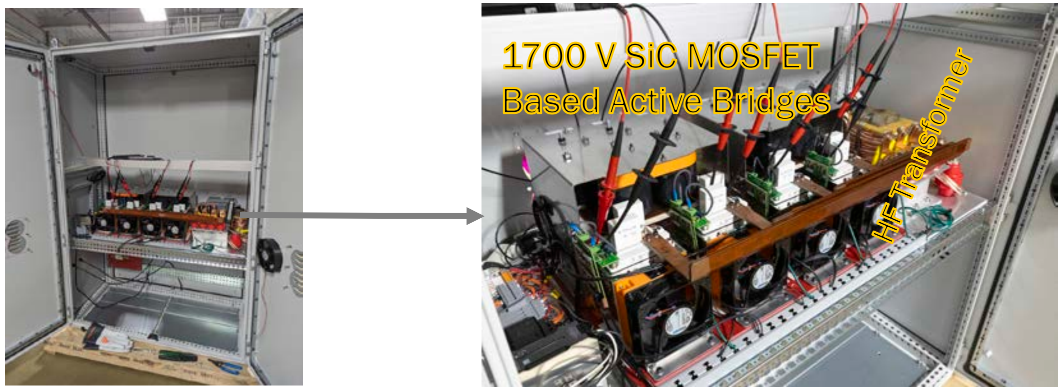
1000 V, 175 kW Dual-Active-Bridge (DAB) based charger was built and tested.

- Optimal operation of charger over a wide voltage range (250 – 950 V) has been addressed through a combination of innovative modulation techniques and mechanical tap changers
- Improved packaging for ease of power scaling, shipping and handling



Charger Test Results at 950 V and 150 A: ~150 kW



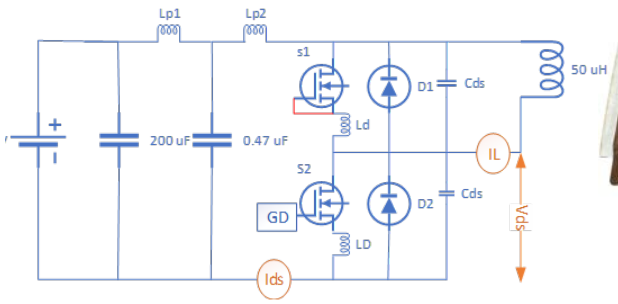


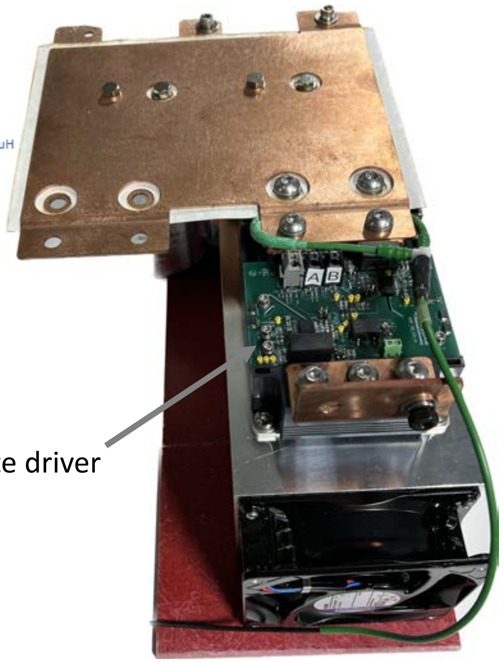
1000 V, 175 kW, 20 kHz DC/DC Charger

1500V Class Charger Development

- 3.3 kV SiC device (Wolfspeed) has been characterized at 2 kV and 450 A
- Includes verification of custom-built gate driver : 5 kV isolation, 10 A peak current, optical interface
- Next steps include building the complete 2 kV class charger

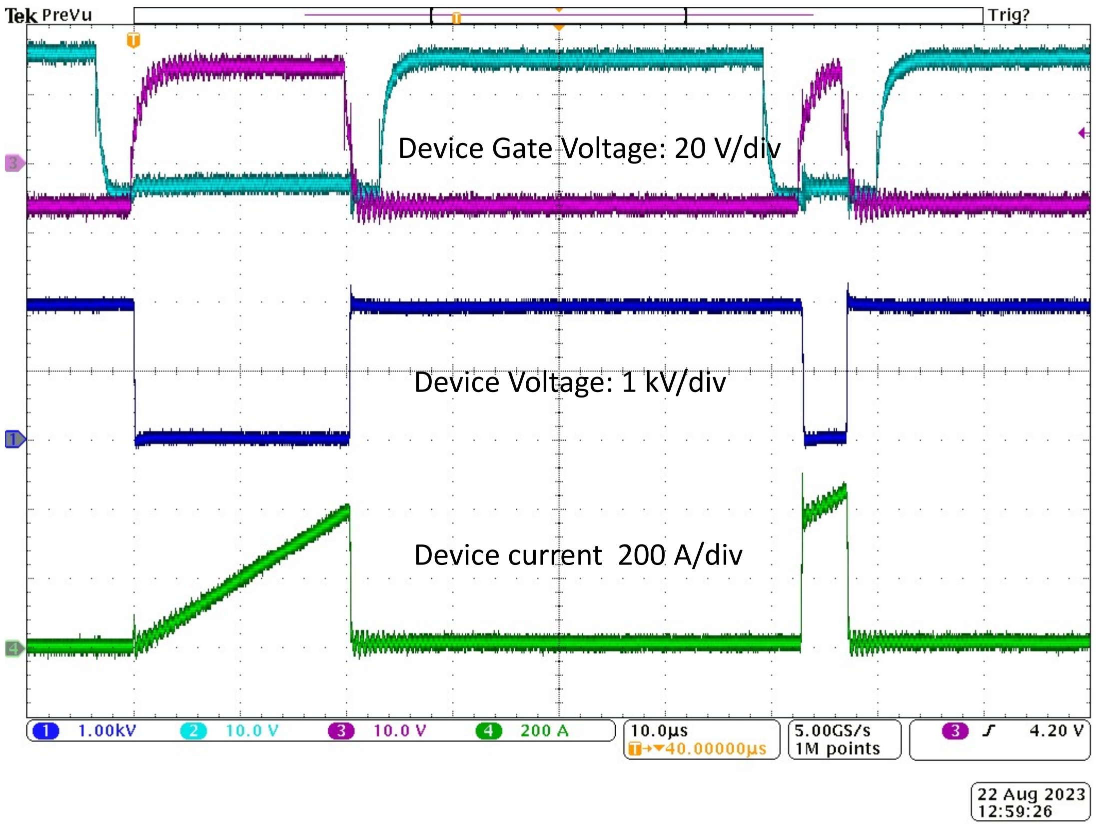
Double Pulse Test Setup





ORNL 3.3 kV SiC Gate driver

Characterization results of 3.3 kV SiC at 2 kV and 450 A



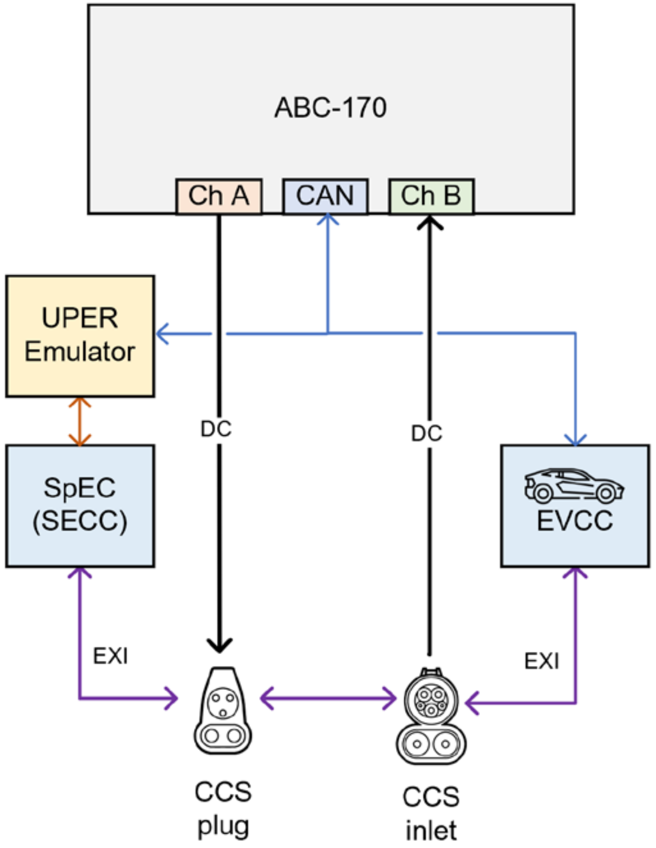
Spec Module-UPER Integration

- **Implementation and testing**
  - Charger application with UPER CAN interface ported over from SpEC I to **SpEC II**
  - Implemented **ISO 15118-2** charging and BPT message set on SpEC II
  - Successfully performed **DIN 70121** and **ISO 15118-2** BPT sessions on actual EV using SpEC II and UPER Emulator connected to ABC-170

- **Next steps**
  - Test with an **actual** UPER controller at ORNL to verify CAN communication, state machine and power delivery
  - Integrate UPER/SpEC charger at NREL
  - Demonstrate ISO 15118-2 DC/DC BPT at NREL
  - Identify and incorporate message set for COTS DC/DC module for low power tests

SpEC II module (ANL)

UPER Emulator (ANL)



Test Setup

Conclusion and Next Steps

Conclusions and Review

- Open-source SEMS platform development completed
- C-HIL real-time simulation setup with SEMS platform implementation
- DC Hub charging hardware with ESS is tested with SEMS platform charging Hyundai Ioniq-5
- Testing of 175 kW DC-DC converter completed
- Spec II module is tested with UPER emulator

Next steps

- Integration of PV and building loads
- Implementation of distributed SEMS algorithms both C-HIL and P-HIL setup using a scaled-up charger
- Instrumentation of DC Hub with more measurement units
- Spec-II module integration with UPER
- Integration of 1000 V Class UPER Charger with DC Hub

Thank You!

Join us for the

HPC Deep Dive on

Tuesday Nov 7, 2023

John.Kisacikoglu@nrel.gov

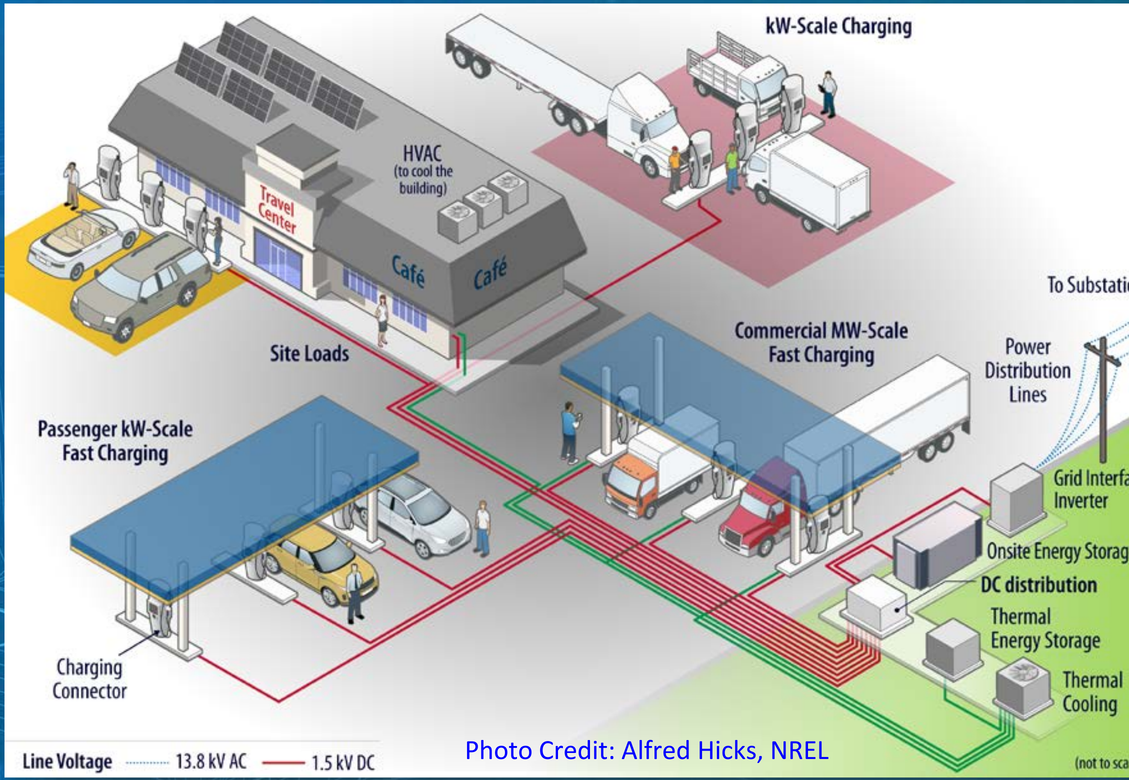


Photo Credit: Alfred Hicks, NREL

EVs@ Scale

U.S. Department of Energy

Semi-Annual Meeting:

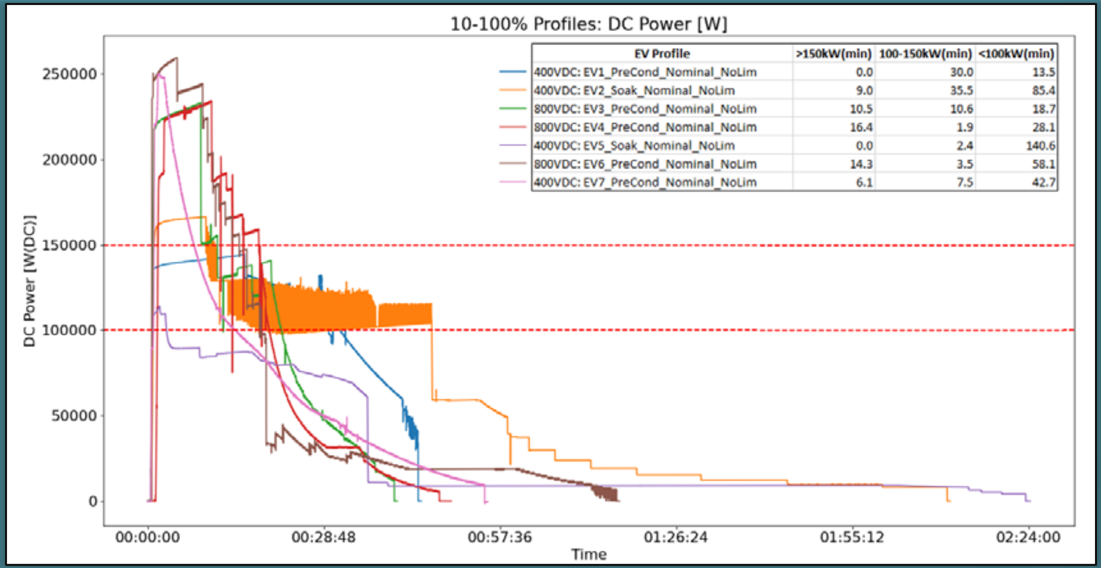
Next-Gen Charge Profiles

Sam Thurston

Sept 27th, 2023

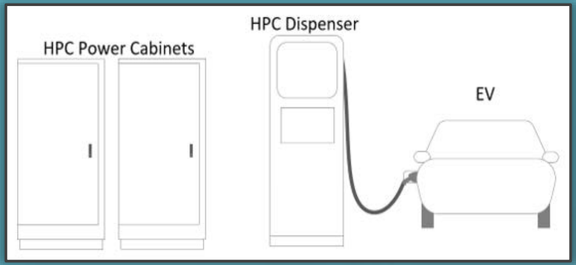
Next-Gen Profiles Overview

- EVs@Scale > High Power Charging > Next-Gen Profiles
- *"To further understand the most recent technological capabilities of the electric mobility industry related to charging performance."*
- Many Things to consider when assessing HPC (>200kW):
  - Baseline vs Boundary, Conductive vs Wireless
  - System responses to grid disturbances & charging management.
- 3 categories of HPC under investigation in Next-Gen Profiles:

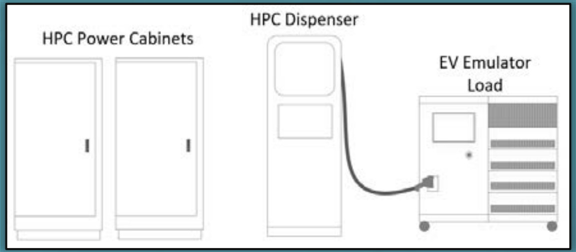


EV Profile	>150kW(min)	100-150kW(min)	<100kW(min)
400VDC: EV1_PreCond_Nominal_NoLim	0.0	30.0	13.5
400VDC: EV2_Soak_Nominal_NoLim	9.0	35.5	85.4
800VDC: EV3_PreCond_Nominal_NoLim	10.5	10.6	18.7
800VDC: EV4_PreCond_Nominal_NoLim	16.4	1.9	28.1
400VDC: EV5_Soak_Nominal_NoLim	0.0	2.4	140.6
800VDC: EV6_PreCond_Nominal_NoLim	14.3	3.5	58.1
400VDC: EV7_PreCond_Nominal_NoLim	6.1	7.5	42.7

1. EV Profile Capture



2. EVSE Characterization



3. Fleet Utilization

EV Profile Capture:
Testing Procedures & Results

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Overview: EV Profile Capture

- EV Assets:
  - Production EVs ~400VDC or ~800VDC HV battery topology
  - OEM rated 150-350kW peak DC charge power
- EVSE Assets:
  - Production DCFCs capable of 1000VDC/500A Max
  - Dual power cabinet, single dispenser topology
  - Handle options: CCS, Tesla, Pantograph, WPT
- Nominal test conditions:
  - 10-100% EV state of charge
  - Nominal (23°C/75°F) ambient temperature
  - EV pre-driven for 30-40min
- Off-nominal test conditions:
  - 25-100%, 50-100% EV state of charge
  - Hot (40°C/100°F), Cold (-7°C/20°F) ambient temperature
  - EV temperature soaked for 4-hours, or pre-driven 30-40min
  - Single power cabinet (EVSE Limited)
  - OCPP curtailed (65A for 2min)

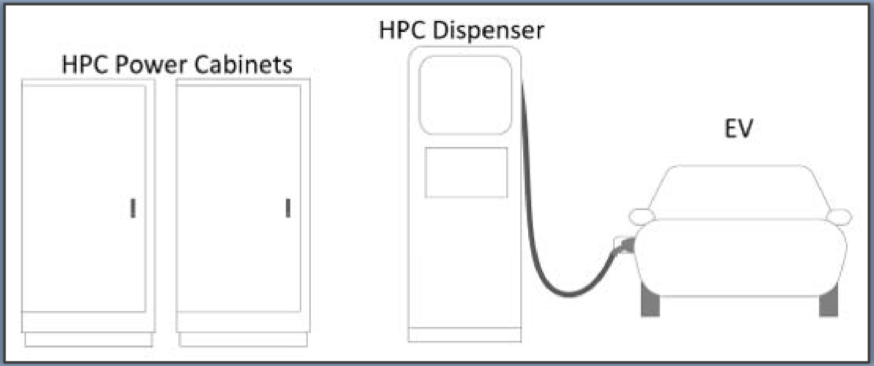


Table 2 – EV Profile Capture Boundary Conditions

EV Profile Capture - Boundary Conditions			
Condition Category	Condition Sub-Category	Condition Metric	Tolerance
Vehicle Condition	Starting State of Charge	10%	+/- 2% (Reported Useable*)
		25%	+/- 2% (Reported Useable*)
		50%	+/- 2% (Reported Useable*)
	Battery Temp	Ambient (23C)	+/- 2C
		Cooled - Pre-conditioned	Steady State**
		Heated - Pre-driven	Steady State**
WPT Alignment	X-Direction	Aligned (< 5% coil length offset)	+/- 2%
		10% coil length offset	+/- 2%
		25% coil length offset	+/- 2%
		40% coil length offset	+/- 2%
	Y-Direction	Aligned (< 5% coil length offset)	+/- 2%
		10% coil length offset	+/- 2%
		25% coil length offset	+/- 2%
		40% coil length offset	+/- 2%
	Z-Direction	Unloaded	+/- 50mm from nominal airgap
Temperature	Ambient Temp	Nominal - 23C	+/- 2C
		Hot - 40C	+/- 2C
		Cold - (-)7C	+/- 2C
Charge Management	Smart Charge Request	FALSE	--
		TxProfile	--
	Smart Charge Request Duration	No Limit	--
		2 minutes	+/- 1 minute
	Smart Charge Request Scheduling	No Request	--
		2 Minutes after charge session start	+/- 1 minute
	Current Request	No limit	--
		65A (AC input current)	--

Reported Useable* - State of Charge(SOC) value is based on the reported available SOC to the user; not the absolute SOC of the battery pack.

Steady State** - Battery pack is pre-conditioned (heated or cooled) to a steady temperature; required durations and temperatures vary by EV make/model; HPC EVSE should be soaked at a minimum duration of 4 hours.

-Signifies nominal test condition

Findings: Diversity of a Single EV's Charge Profiles

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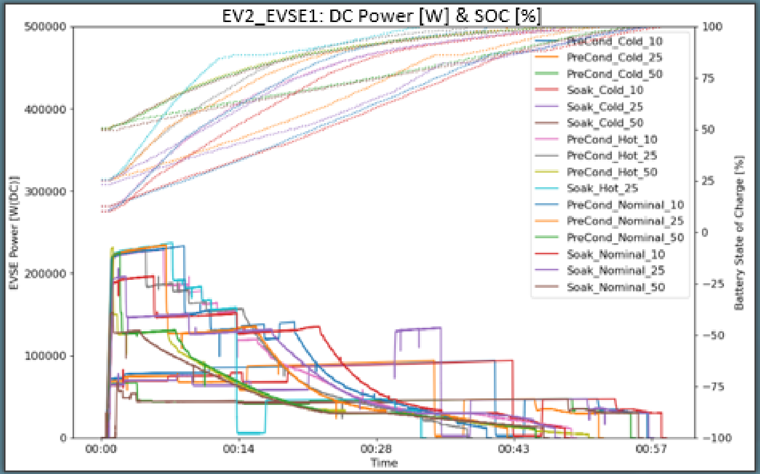
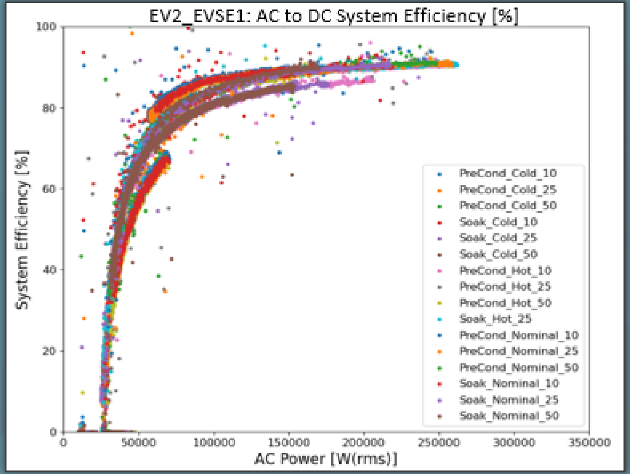
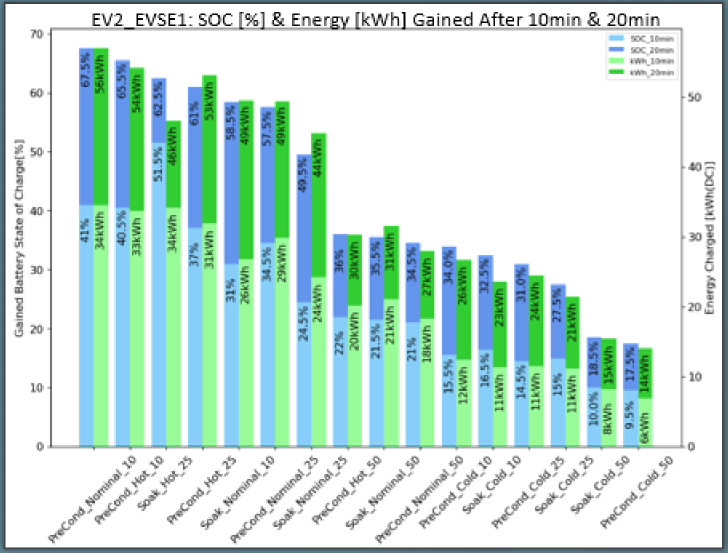
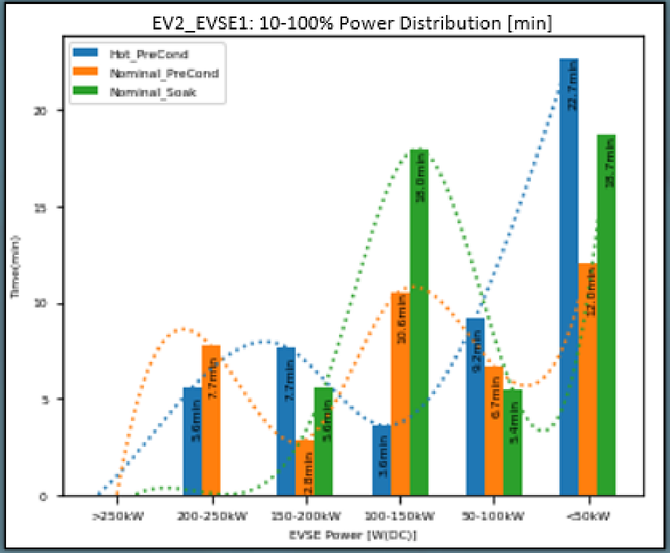
- **Goal:** To understand how a single EV performs under different boundary conditions
- **Findings:**
  - Charge profiles are very diverse based on initial conditions of the EV
  - OEM rated "peak performance" is difficult to achieve outside of nominal conditions
  - Even with a Nominal Soak condition, peak power is not always achieved
  - Grid Analysis POV: AC power curves, power distribution, system efficiency, etc.
  - Consumer Analysis POV: SOC gained, energy gained, range gained, etc.
  - Within a single EV lies a very diverse range of plots & charge characteristics.

EV Profile Set Analysis









Findings: Different EV Battery Topologies & DCFCs

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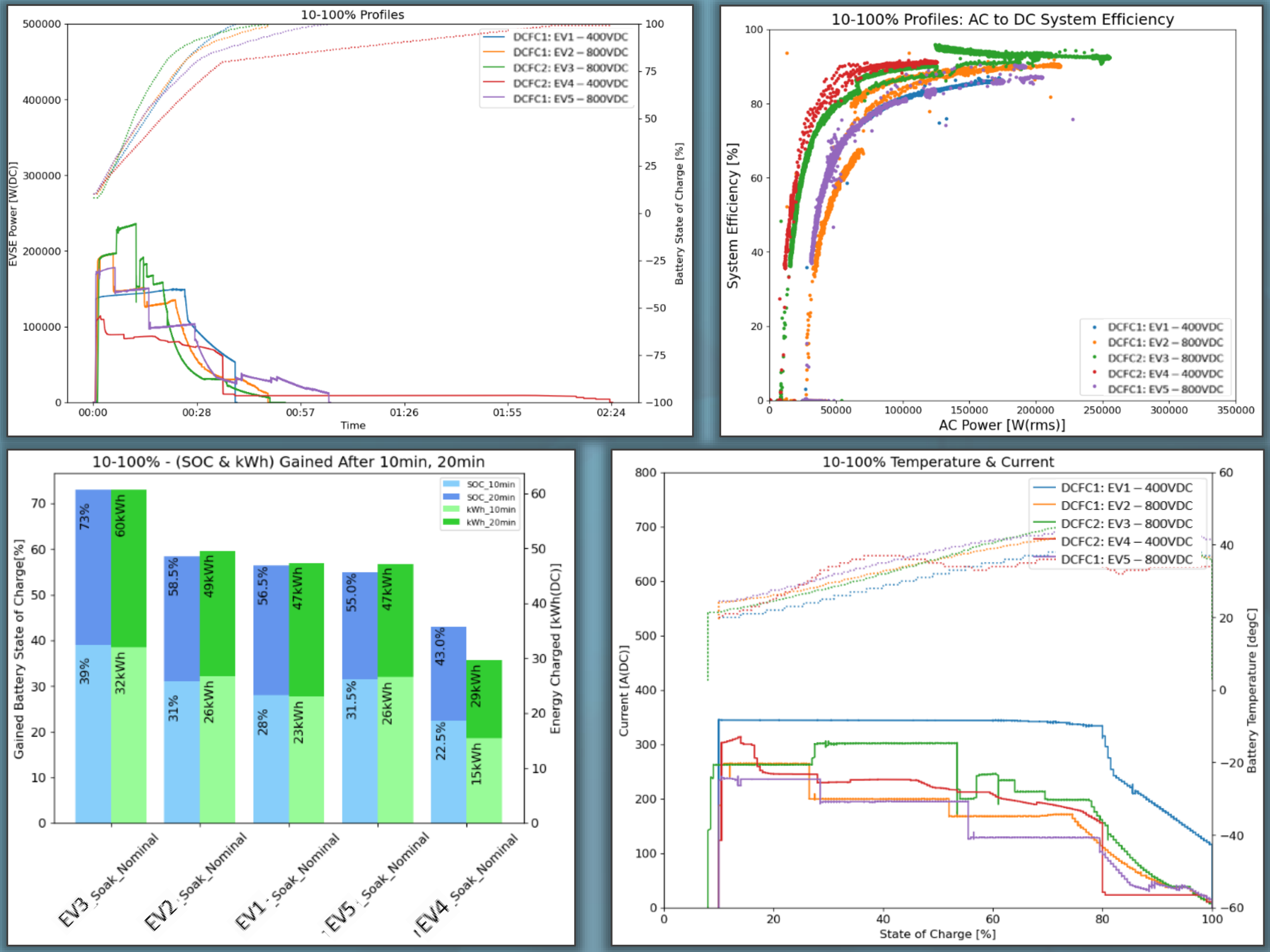
U.S. Department of Energy

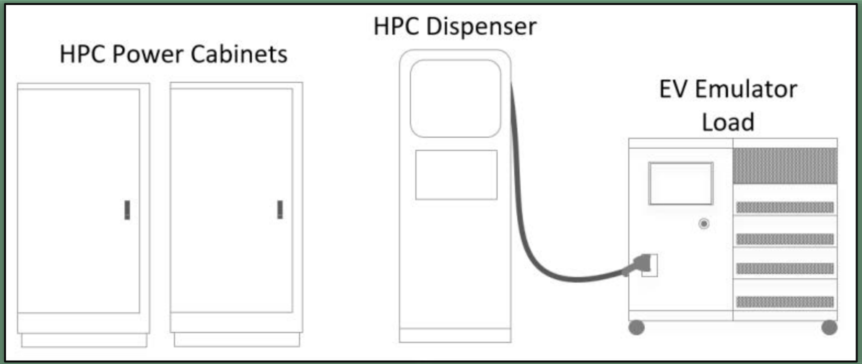
- **<u>Goal:</u>** **To understand how different EV topologies & DCFC compete with one another in similar conditions in terms of charge performance**
- **<u>Findings:</u>**
  - Double the necessary current for 400VDC battery to match the power output for a 800VDC system
  - DCFC cable limitations (500A max for our dual cabinet setup)
  - SOC gained is not entirely reflective of performance, kWh shows the relative battery pack size being charged
  - System efficiencies of 400VDC & 800VDC vary on different DCFC manufacturers
    - DCFC 1: Red, Green
    - DCFC 2: Blue, Orange, purple

Comparing EV Captures (10-100% Nominal Soak)



EVSE Characterization:
Testing Procedures & Results

Overview: EVSE Characterization



EVSE Characterization - Boundary Conditions			
Condition Category	Condition Sub-Category	Condition Metric	Tolerance
WPT Alignment	X-Direction	Aligned (< 5% coil length offset)	
		10% coil length offset	+/- 2%
		25% coil length offset	+/- 2%
		40% coil length offset	+/- 2%
	Y-Direction	Aligned (< 5% coil length offset)	
		10% coil length offset	+/- 2%
		25% coil length offset	+/- 2%
		40% coil length offset	+/- 2%
	Z-Direction	Unloaded	+/- 50mm from nominal airgap
Temperature	Ambient Temp	Nominal - 23C	+/- 2C *
		Hot - 40C	+/- 2C *
		Cold - (-)7C	+/- 2C *
Grid Condition	Voltage	Nominal - 480VAC	+/- 25VAC
		Swelled - 528VAC (110% nominal)	+/- 25VAC
		Sagged - 432VAC (90% nominal)	+/- 25VAC
	Harmonics	No Harmonics	
		5% Voltage distortion	+/- 1%
	Frequency	Nominal - 60Hz	+/- .2Hz
		Increased - 61.2Hz	+/- .2Hz
		Decreased - 58.8Hz	+/- .2Hz
Charge Management	Smart Charge Request	FALSE	--
		TxProfile	
		TxDefaultProfile	
		ChargePointMaxProfile	--
	Smart Charge Request Duration	No Limit	--
		2 Minutes	+/- 1 minute
	Smart Charge Request Scheduling	No Request	--
		1 minute into charge session	--
	Current or Power Request	No Limit	--
		65A (total AC input current)	--
		54kW (AC or DC as implemented by manuf.)	--

*HPC EVSE should be soaked at a minimum duration of 4 hours.

EVSE Power Transfer Characterization – Test Conditions			
Test Condition Category	DC Current Test Conditions	DC Voltage Test Conditions	Tolerance
Unplugged	0A		
Plugged in, prior to charge session initialization (no power transfer)	0A		
Steady State power transfer	50A to 500A in 10A increments (up to max power)	300V, 400V, 650V, 750V, 850V	+/-2%
Steady State power transfer	50A to 500A in 10A increments (up to max power)	350V, 700V, 800V, max V	+/-2%
Steady State power transfer	150A, 500A (or full power if 500A is not possible)	400V, 850V	+/-2%
Plugged in, immediately following the end of charge session (no power transfer)	0A		

- EV Assets:
  - EV Emulator (load bank) 50-1000VDC
  - OEM rated between 150-350kW peak DC charge rates
- EVSE Assets:
  - Production DCFCs, capable up to 1000VDC/500A Max
  - Typically, a dual power cabinet/single dispenser topology
  - Possible port types are CCS, Tesla, Pantograph, WPT
- Nominal test conditions:
  - Voltage: 300V, 400V, 650V, 750V, 850V
  - Current: 50 to 500A, 10A increments
  - Nominal (23°C/75°F) ambient temperature
  - Grid supply: 480VAC, 60Hz, no harmonics
  - WPT coils aligned
- Off-nominal test conditions:
  - Hot (40°C/100°F), Cold (-7°C/20°F) ambient temperature
  - Grid supply: [538, 432]VAC, [58.8, 61.2]Hz, 5% voltage distortion
  - OCPP Curtailed: 65A for 2min via *TxProfile, TxDefaultProfile,* and *ChargePointMaxProfile*

Findings: EVSE Nominal & Off-Nominal

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Goal: Characterize EVSE performance and operation across a wide range of voltage and current test conditions

Findings:

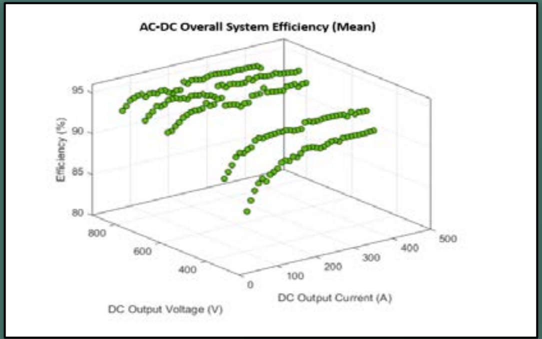
- 300V, 400V, 650V, 750V, 850V @ 10A increments [50, 500]A
- AC to DC Efficiency, Power Quality, Losses all have variation
- Losses due to cable, auxiliary loads, stand-by power

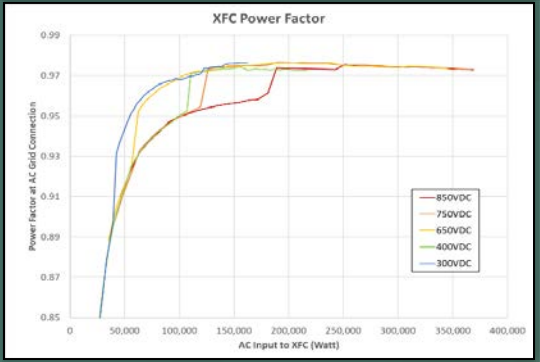
Goal: Characterize EVSE performance during voltage deviation, frequency deviation, and voltage harmonics grid conditions

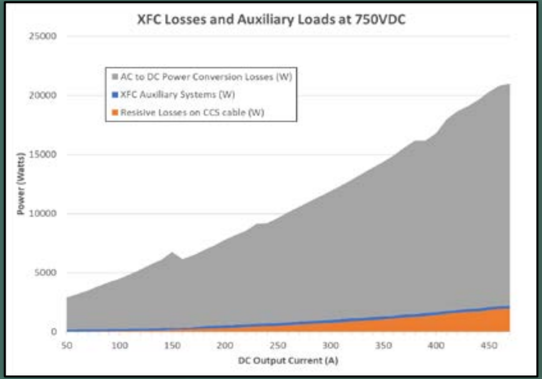
Findings:

- Voltage Deviation [90, 110]% of nominal (426VAC, 518VAC)
- Frequency Deviation [58.8, 62.1]Hz
- Harmonics Injection 5%
- DC Power transfer continues uninterrupted during all off-nominal, matching expected behavior
- WPT: 94.23% efficiency at 100kW power transfer

EVSE Nominal Conditions

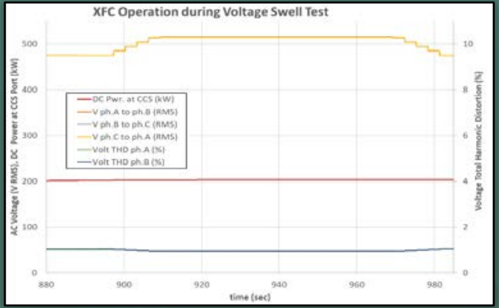




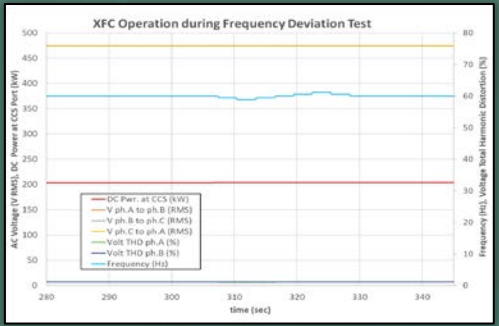


EVSE Off-Nominal Conditions

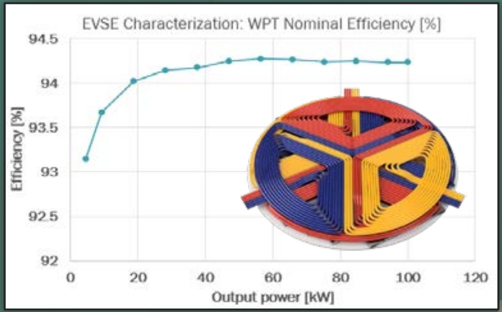
EVSE Voltage Variation Test



EVSE Frequency Variation Test



Wireless Power Transfer



Findings: High Utilization & OCPP Curtailment

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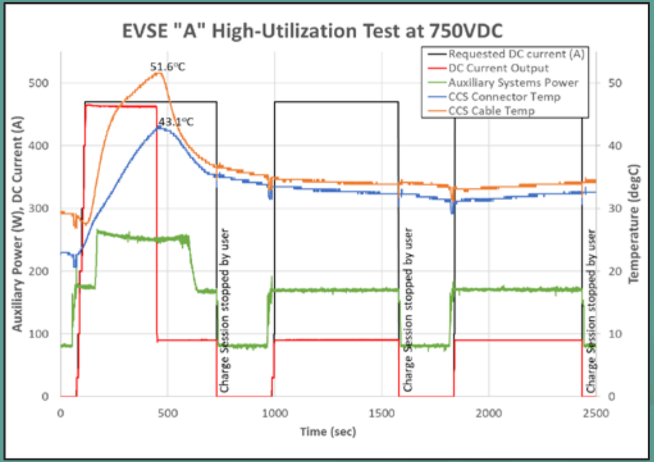
EVSE High Utilization Tests

Goal: Determine EVSE performance for consecutive 10min. full power charge sessions

Findings:

- Three 10-min charge sessions, 4-min rest between
- 500A requested, 465A delivered
- Cable thermal limit exceeded @ 6-min, limited current to 90A until reboot

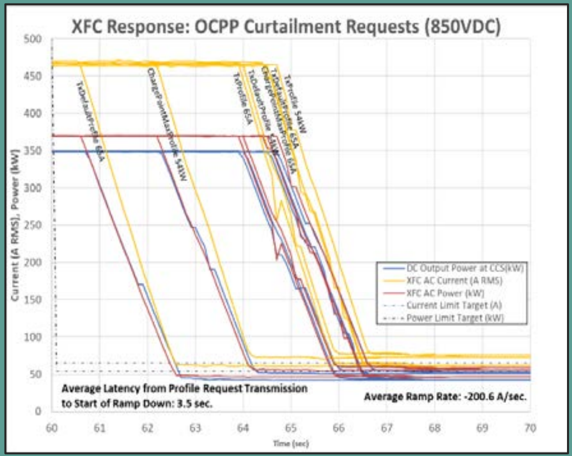


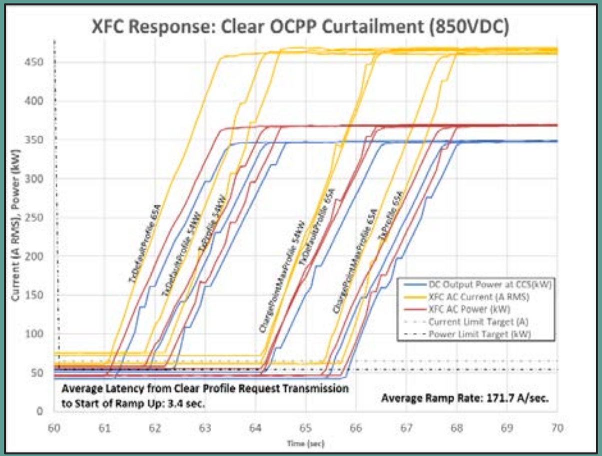
EVSE Thermal Control Testing Sequence and Test Conditions					
Step #	Duration	Test Condition Category	DC Current Test Conditions	DC Voltage Test Conditions	Tolerance
1	< 2min.	Plug in and start charge session	0A		
2	10 min.	Steady State power transfer (350kW*)	466A*	750V	+/-2%
3	< 5 min.	Stop Charge Session	0A		
4	10 min.	Steady State power transfer (350kW*)	466A*	750V	+/-2%
5	< 5 min.	Stop Charge Session	0A		
6	10 min.	Steady State power transfer (350kW*)	466A*	750V	+/-2%
7	5 min.	Stop Charge Session	0A		

*Operate at highest current possible, at the test voltage specified, up to EVSE full power capability

-Signifies required tests

EVSE OCPP Curtailment Request & Response





Goal: Characterize EVSE performance, latency, and ramp rates during energy management curtailments

Findings:

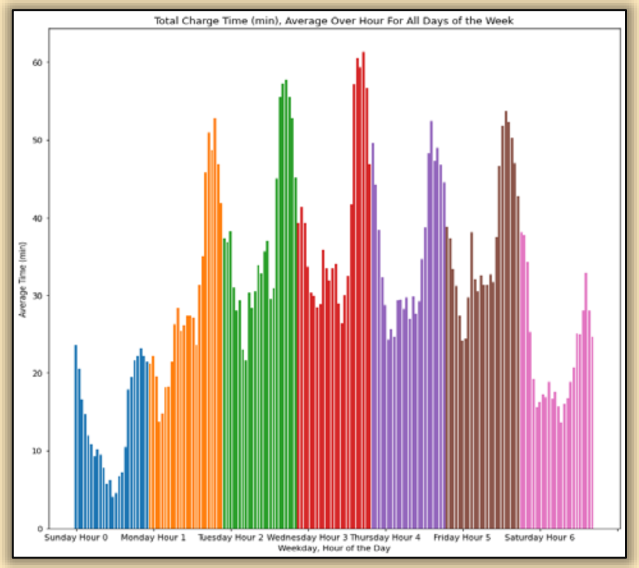
- Response latency varies [1, 11] sec
- Average response latency ~3 sec
- Ramp rate depends on power transfer initial & final values
- Ramp up rate [-200, -27] Amps/sec
- Ramp down rate [23, 172] Amps/sec

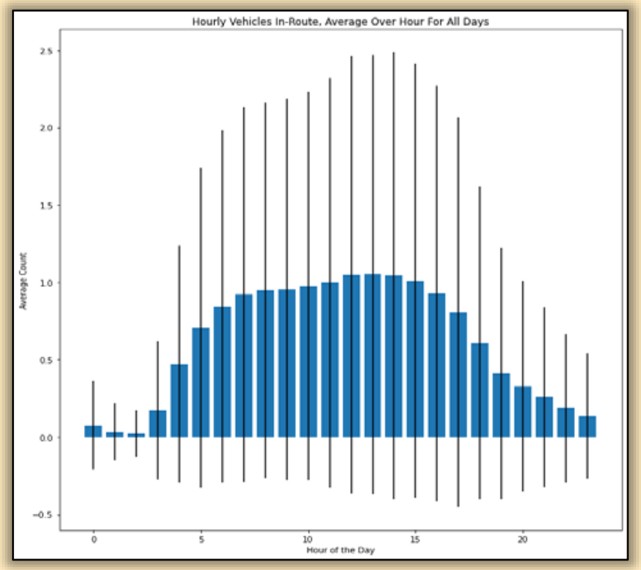
Fleet Utilization:

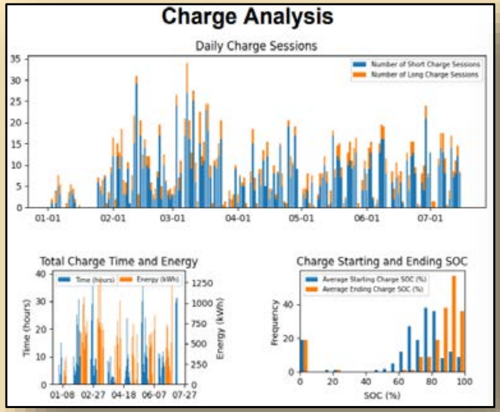
Testing Procedures & Results

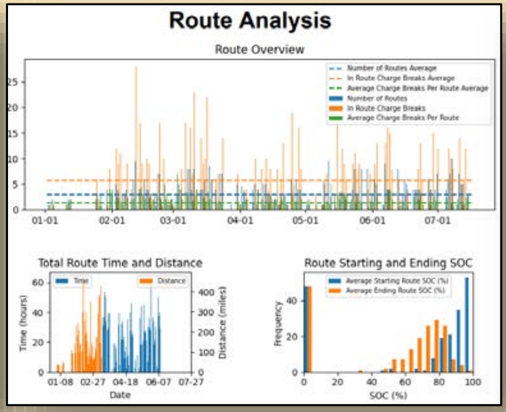
Overview: Fleet Utilization

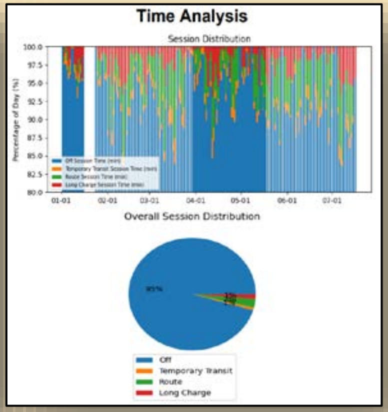
- Assets:
  - EV or EVSE Fleet, Conductive & Non-Conductive
- Types of Data
  - Time series data: Hourly, Daily, Weekly, Monthly, Annually
  - Data Categories: Charge, Route, Temporal Analysis
  - Types of Analysis: Utilization Rates, Avg Start/End SOC, Average Power [kW], Weekday usage rates [%], etc.
  - Heavily reliant on OEM collaboration & access to data
  - Lab developed scripts are highly malleable, able to work with different formats & cadence
  - Gives insight on how EV profiles & EVSE characterization is applicable to a live case study











Project Outcomes:
Data Reporting & Distribution

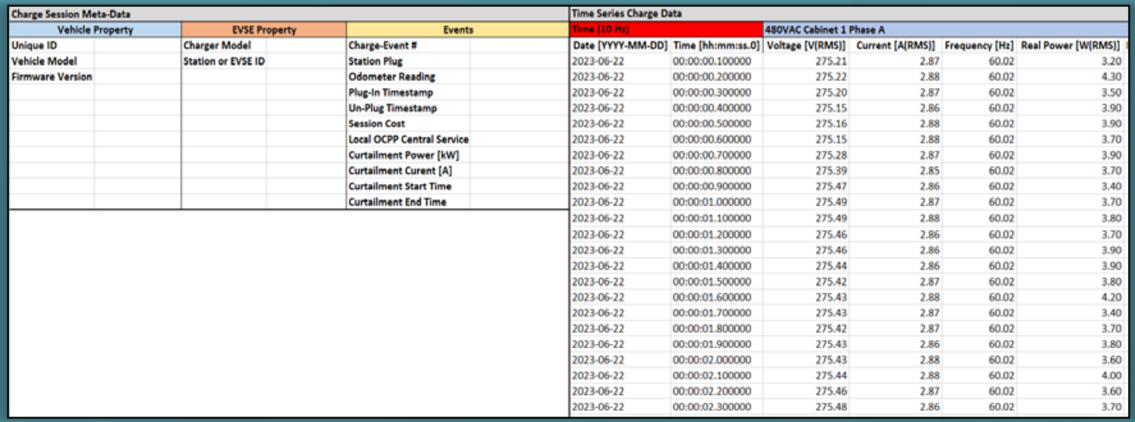
Reporting

NGP Annual Reports:

- *High-Level Analysis Report*
- *EV Profile Capture Report*
- *EVSE Characterization Report*
- *Fleet Utilization Report*

Time Series Data for participating OEMs:

- Full Time-Series with meta-data for sponsored assets
- Anonymized Full Time-Series without meta-data for non-sponsored assets



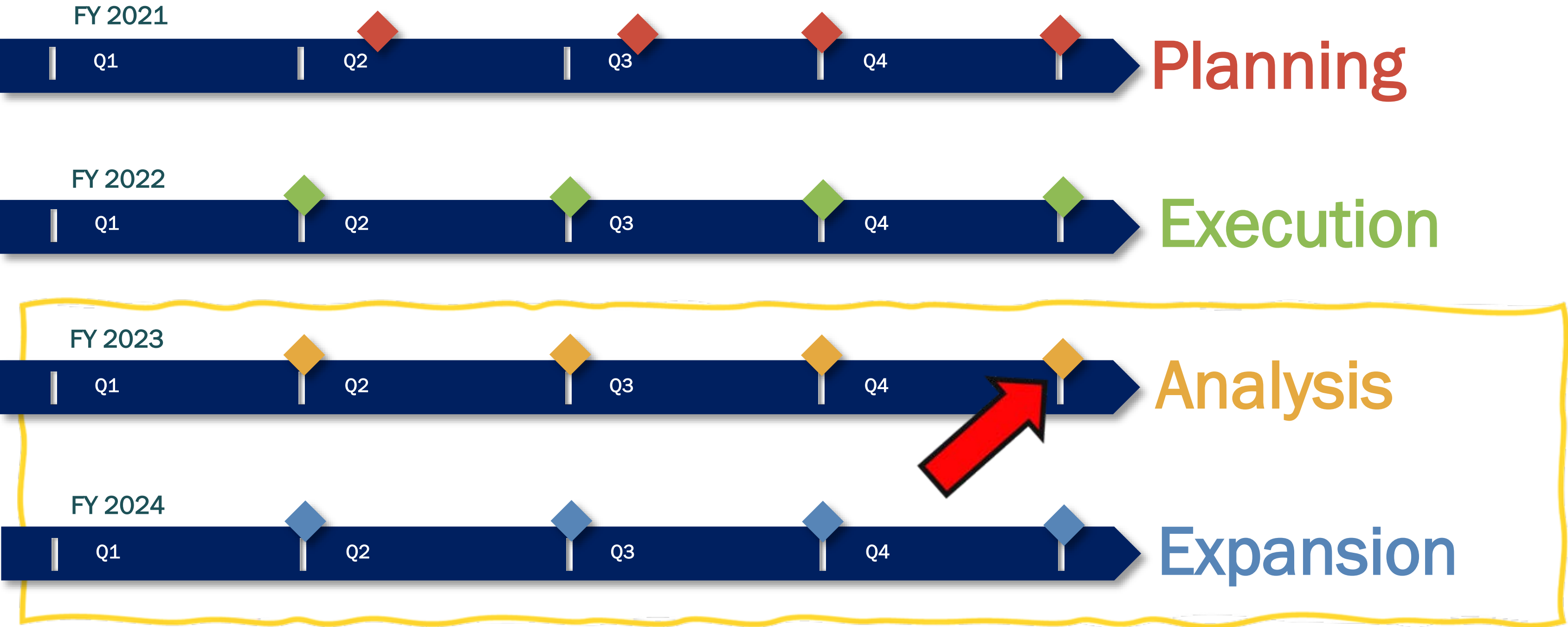
Charge Session Meta-Data

Vehicle Property	EVSE Property	Events
Unique ID	Charger Model	Charge-Event #
Vehicle Model	Station or EVSE ID	Station Plug
Firmware Version		Odometer Reading
		Plug-In Timestamp
		Un-Plug Timestamp
		Session Cost
		Local OCPP Central Service
		Curtailment Power [kW]
		Curtailment Curent [A]
		Curtailment Start Time
		Curtailment End Time

Time Series Charge Data

Time (10 Hz)		480VAC Cabinet 1 Phase A			
Date [YYYY-MM-DD]	Time [hh:mm:ss.0]	Voltage [V(RMS)]	Current [A(RMS)]	Frequency [Hz]	Real Power [W(RMS)]
2023-06-22	00:00:00.100000	275.21	2.87	60.02	3.20
2023-06-22	00:00:00.200000	275.22	2.88	60.02	4.30
2023-06-22	00:00:00.300000	275.20	2.87	60.02	3.50
2023-06-22	00:00:00.400000	275.15	2.86	60.02	3.90
2023-06-22	00:00:00.500000	275.16	2.88	60.02	3.90
2023-06-22	00:00:00.600000	275.15	2.88	60.02	3.70
2023-06-22	00:00:00.700000	275.28	2.87	60.02	3.90
2023-06-22	00:00:00.800000	275.39	2.85	60.02	3.70
2023-06-22	00:00:00.900000	275.47	2.86	60.02	3.40
2023-06-22	00:00:01.000000	275.49	2.87	60.02	3.70
2023-06-22	00:00:01.100000	275.49	2.88	60.02	3.80
2023-06-22	00:00:01.200000	275.46	2.86	60.02	3.70
2023-06-22	00:00:01.300000	275.46	2.86	60.02	3.90
2023-06-22	00:00:01.400000	275.44	2.86	60.02	3.90
2023-06-22	00:00:01.500000	275.42	2.87	60.02	3.80
2023-06-22	00:00:01.600000	275.43	2.88	60.02	4.20
2023-06-22	00:00:01.700000	275.43	2.87	60.02	3.40
2023-06-22	00:00:01.800000	275.42	2.87	60.02	3.70
2023-06-22	00:00:01.900000	275.43	2.86	60.02	3.80
2023-06-22	00:00:02.000000	275.43	2.88	60.02	3.60
2023-06-22	00:00:02.100000	275.44	2.88	60.02	4.00
2023-06-22	00:00:02.200000	275.46	2.87	60.02	3.60
2023-06-22	00:00:02.300000	275.48	2.86	60.02	3.70

Project Timeline



Integrated into EVs@Scale HPC Pillar

- Completed
- Ongoing
- Future Work
- Recently Added

Year 1 Milestones

- Solidify collaborator agreements (Ongoing)
- Parameter definitions/draft procedure (Completed)
- Procedure performance - refinement (Completed)
- Finalized project procedures (Completed)

Year 2 Milestones

- Fleet data collection review (Completed)
- Capture conductive profile sets (Completed)
- Complete EVSE characterization (Completed)
- Capture non-conductive profiles sets (Completed)

Year 3 Milestones

- Capture conductive profiles sets (Completed)
- Finalize fleet data collection (Completed)
- Complete R&D profile EVSE characterization (Completed)
- Analysis, results, and reporting (Ongoing)
- Capture Boost Converter EV Profiles (Ongoing)

Year 4 Milestones

- Refine testing procedures (Future Work)
- Acquire new test assets (Future Work)
- Conduct characterizations (Future Work)
- Amend analysis and reports (Future Work)
- Capture NACS/Adapter EV Profiles (Future Work)
- V2X EVSE Characterization (Future Work)

Thank You!

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Breaktime!

Presentations resume at…

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Cyber-Physical Security Pillar

Barney Carlson: Idaho National Lab

Sept. 27, 2023

Cyber-Physical Security Pillar Overview

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Objective: Contribute to the continuously evolving cyber-physical security methods and solutions needed to ensure EV charging infrastructure safety, reliability, & resiliency

Projects:

- *CyberPUNC* assessments, mitigation R&D, cyber workforce training
- *Zero Trust Architecture* for EV charging infrastructure
- *eVISION* for resilient EV charging infrastructure

Barriers Addressed:

- Rapidly expanding features, standards, & cyber provisions:
- Lack of holistic understanding of EV ecosystem vulnerabilities
- Inconsistent implementation of effective security methods
- Insufficient EV Charging Infra. (EVCI) cyber workforce
- Unknown potential cyber impacts of NACS
- Potential ISO 15118-2 & -20 compatibility vulnerabilities
- Lack of cyber metrics & verification methods for EVCI
- Lack of EV Charging Infra. cyber mitigation tools and solutions
- Previously secured & new vulnerabilities with Quantum computing capabilities
- Poor charging resiliency - lack of resiliency metrics, detection, response, recovery, controls, & evaluation

Idaho National Laboratory | Sandia National Laboratories | Pacific Northwest National Laboratory | Argonne National Laboratory | NREL Transforming ENERGY | Oak Ridge National Laboratory

Join us for the

Cyber-Physical Security Deep-Dive

Oct. 10 & 11 (11:00am – 1:00pm eastern)

Oct.10: Click here to join the meeting

Oct.11: Click here to join the meeting

or contact Barney Carlson (richard.carlson@inl.gov)

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CyberPUNC Project

Barney Carlson: Idaho National Lab

Sept. 27, 2023

CyberPUNC Project: Presentation Outline

CyberPUNC Project Tasks Results and Accomplishments:

- Securing EVCI with PKI
- EVCI cybersecurity tools and solutions
- EVCI cyber mitigation solutions & best practices: development & demonstration
- *CyberAUTO* Challenge: Support EV Charging Infrastructure testing and evaluation
- CyberStirke STORMCLOUD training

Upcoming *CyberPUNC* Tasks:

- Cybersecurity Evaluation of EPRI's EVSE Secure Network Interface Card (SNIC)
- Supporting V2G Technical Advisory Board Cybersecurity

PollEV Feedback Questions:

- For collaborative industry feedback

CyberPUNC - Securing EVSE with PKI Integration

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Implementing the latest security methods and best practices

Background

- Baseline cybersecurity requirements include ISO 15118-2 and -20 Certificate Profiles
- Research extends prior and upcoming EV charging industry PKI testing events with SAE

Current Focus and Progress

- Using open-source Emulytics (minimega/Phēnix/SCORCH) tools for PKI simulation and testing within NREL Cyber Range
  - Implementing 15118, OCPP, and PKI features required for resilience and robustness
  - Scaling to 1000 endpoints, implementing experiment orchestration
- Drafting a report on research progress of PKI emulation environment and uses

Insights

- Creating a unique scalable, repeatable environment for scenario evaluation including architecture, operations, and governance decisions

Future Directions

- Interface with pilot and production PKI hosts; align with industry and CESER/JO initiatives
- Increase scale to 10K-100K+ endpoints; deploy and test more complex PKI structures
- Fully automated testing of prioritized scenarios (experiments)

Outreach Completed

- DOE Cyber and Tech Innovation Conf
- Embedded Security in Cars (ESCAR)
- Network and Distributed System Security Symposium (NDSS) 2023 - Vehicle Security

Sandia National Laboratories

NREL Transforming ENERGY

CyberPUNC - Securing EVSE with PKI Integration

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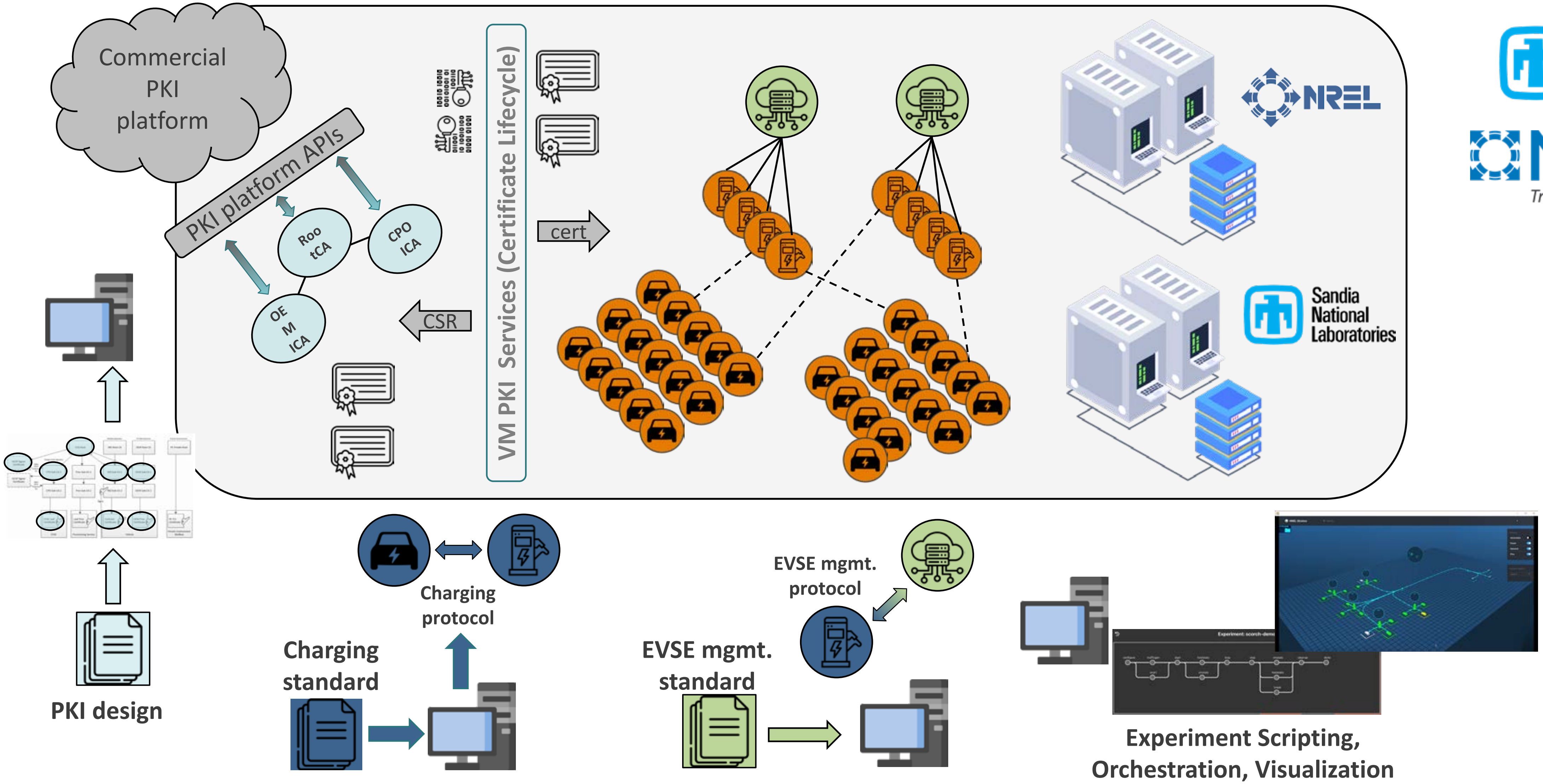
EV charging PKI emulation on minimega/Phēnix



Sandia National Laboratories

NREL Transforming ENERGY

CyberPUNC – Cyber Tools and Solutions for EVSE

Implementing the latest security methods and best practices

Background

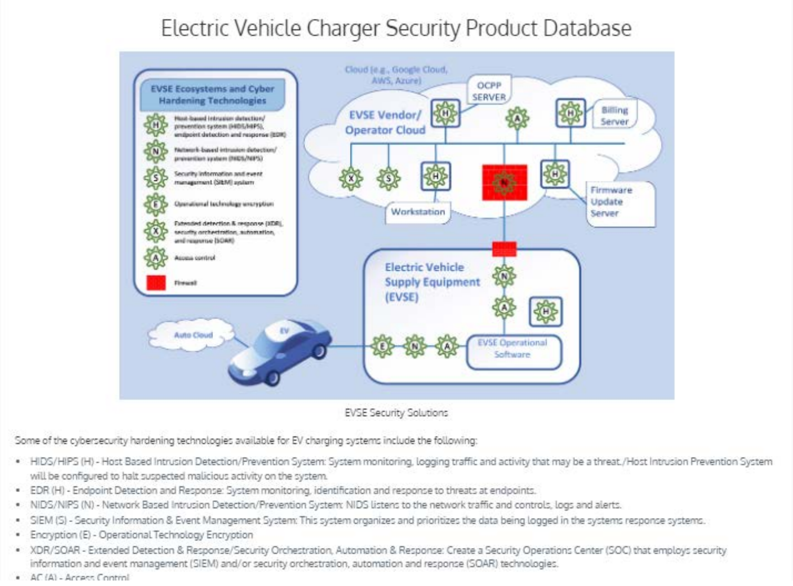
- Prior national lab work collected insights on subset of industry tools and capabilities
- Opportunity to map tools and capabilities to EVSE security functions and needs

Current Focus and Progress

- Previously constructed a dynamic database (OpenEI platform) for engaging with industry using initial security tool surveys
- Recently drafted EVSE specific cyber assessment question sets that align with DERCF

Future Directions

- Complete a cybersecurity assessment catalog of questions and mitigations
- Maintain and update EVSE tools site and industry engagements



CyberPUNC – EVSE / CSMS Backend Analysis

Current Work:

- Compiled list of FedRAMP CSMS applicants from GSA
- Performed open-source analysis of security posture, software/service components, certificate information, and dependencies
- Scanning systems for additional vulnerabilities and data enumeration
- Started creation of threat model and documentation

Accomplishments thru FY23 Q3:

- Create architectural level threat model (vendor agnostic)
- Identify common pitfalls and risks within CSMS deployments
- Create a best practices which highlight industry leaders and mitigates common vulnerabilities seen
- Document our findings and analysis in a technical report

CyberPUNC – Cyber Best Practices for DC Charging Infra.

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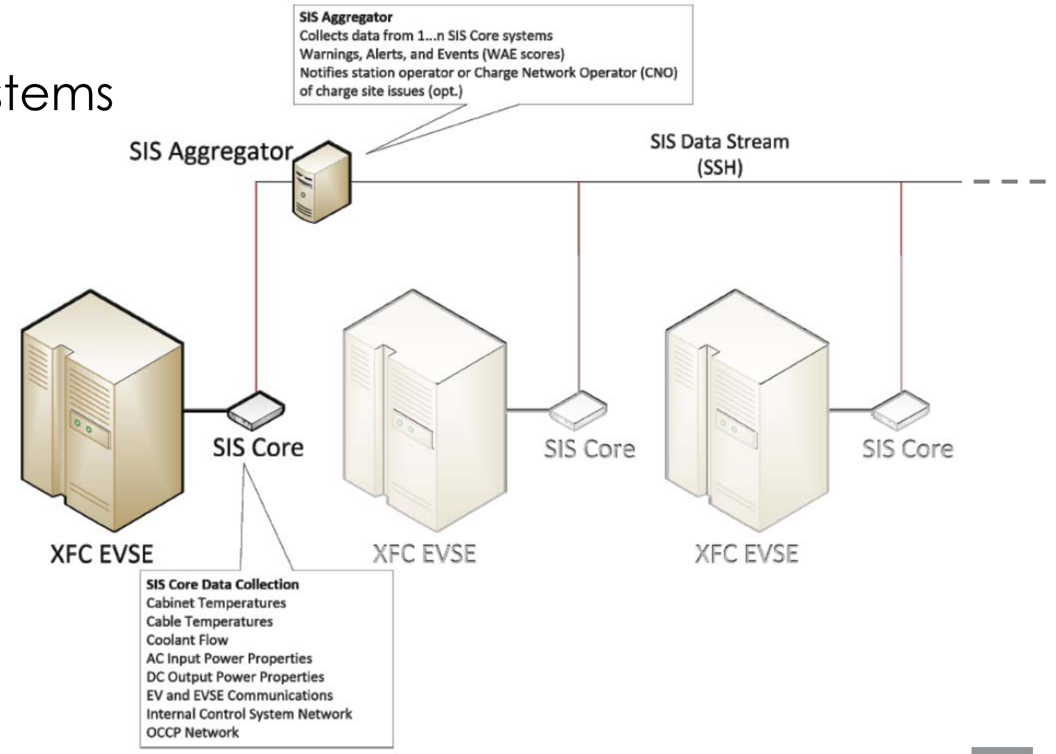
Development & Demonstration of Cyber Best Practices for High-Power Charging Infra.

- *Cerberus* mitigation solution developed and demonstrated for High-Power DC Charging Infrastructure
  - Detection, response, and recovery from EVCI exploitable vulnerabilities and anomalous events
    - EVSE Internal communication exploitation
      - » Thermal management
      - » Power Electronics control
      - » Data and information transfer amongst sub-systems
    - External communications with
      - » EV
      - » OCPP server
  - Charge site coordination across numerous EVSE
    - Core module integrated into each EVSE
    - Aggregator module coordinates across the site
  - R&D100 award winner 2023

Idaho National Laboratory



CESER - Cyber Best Practices for High-Power Charging Infra.

Development & Demonstration of Cyber Best Practices for High-Power Charging Infra.

- Demonstration event, called "EV SALaD", of Cyber Best Practices highlighted XFC mitigation solution effectiveness
  - Collaborative effort: Idaho, Sandia, and Pacific Northwest National Labs
  - Pre-scripted test effect payloads (exploits) launched with & without cybersecurity best practices enabled to:
    - » Highlight potential impact severity without cybersecurity solutions enabled
    - » Demonstrate cybersecurity best practices effectiveness

Idaho National Laboratory | Sandia National Laboratories | Pacific Northwest NATIONAL LABORATORY

Cybersecurity Recommended Best Practices:

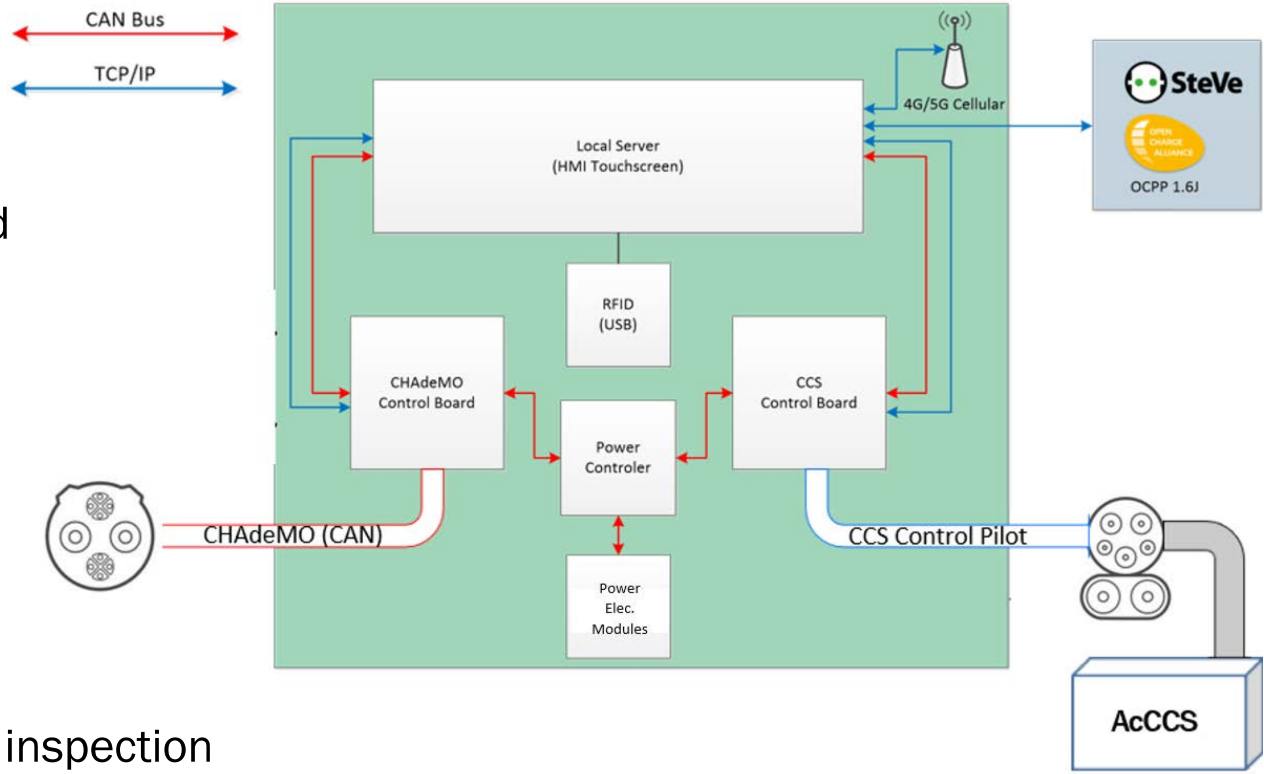
- **EVSE external communications with EV and energy management systems**
  - Zero Trust and Principal of Least Privilege
  - Network Security: Authorization, encryption, authentication, PKI
    - Smart Energy management: OCPP 2.0.1 (or similar) with full TLS
  - Cyber Informed Engineering
- **EVSE internal controls communications**
  - Network segmentation to isolate critical assets: Secure gateway, Firewalls
  - Network Monitoring: Message integrity, deep packet inspection
  - Cyber Informed Engineering
    - Monitor for abnormal or invalid values (i.e. SOC=254%)
    - Thermal management control & feedback based on DC current & CCS temp.
    - Cable contactor XOR control logic (not mutually exclusive)
  - Physical access security preventing communication connection access (JTAG, CAN, USB, Ethernet, etc.)

CyberPUNC – Cyber Best Practices for DC Charging Infra.

EVs@Scale U.S. Department of Energy

Development & Demonstration of Cyber Best Practices for High-Power Charging Infra.

- CyberPUNC identified a new exploitable vulnerability with high-power DC charging infrastructure
  - Access to the XFC internal network via the CCS charge cable Control Pilot wire
  - Accomplished using custom built "*AcCCS*" module
    - AcCCS establishes a TCP comm. session
  - With comm. established
    - Access to XFC internal network was achieved through the CCS communications control board
    - Network vulnerabilities were identified
    - Access to external systems connected to XFC internal network possible (ex. OCPP server)



<u>Recommended cybersecurity Best Practices</u>

- Network segmentation to isolate critical assets:
  - Secure gateway, Firewalls
- Network Monitoring: Message integrity, deep packet inspection

CyberPUNC – Cybersecurity Workforce Training

CyberAuto Challenge: Training the Next-Generation of Cyber Workforce

- Annual 1-week long, collegiate event in Mich. focused on automotive cybersecurity
- *CyberAuto* 2023: increased focus on electrified transportation and EV charging infra.
  - Three EVs, DC chargers, and OCPP 1.6J network
  - In-vehicle / in-EVSE evaluations and training: Automotive Ethernet, CAN bus comm., OCPP, ISO 15-118, reverse engineering, Ghidra, attack strategies/methodologies
  - Vulnerability assessments:
    - EVSE internal communications network access and port scan through the CCS-1 control pilot
    - Attempted root access of EVSE 64-bit main control board
- **July 2024 *CyberAUTO:* OEMs (EV & EVSE) are encouraged to participate**
  Contact: Karl Heimer (karl.heimer.pro@gmail.com)
- **2025 & beyond:** expand into ***CyberINFRASTRUCTURE Challenge*** focused on EV charging infrastructure (including bi-directional), DER, micro-grids, and the associated communications

CyberPUNC – Cybersecurity Workforce Training

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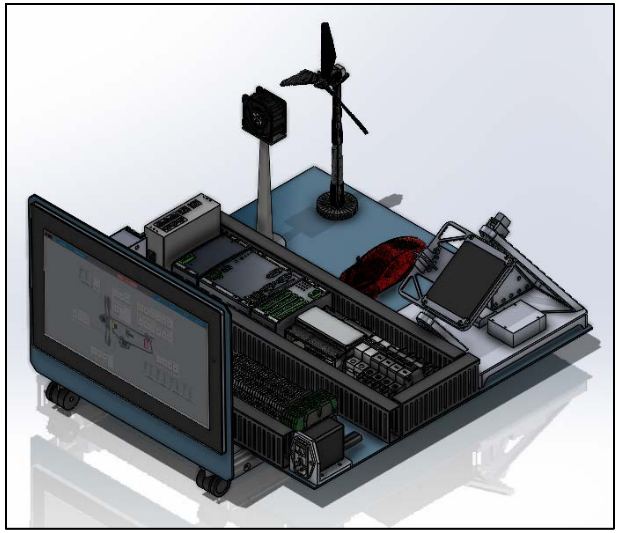
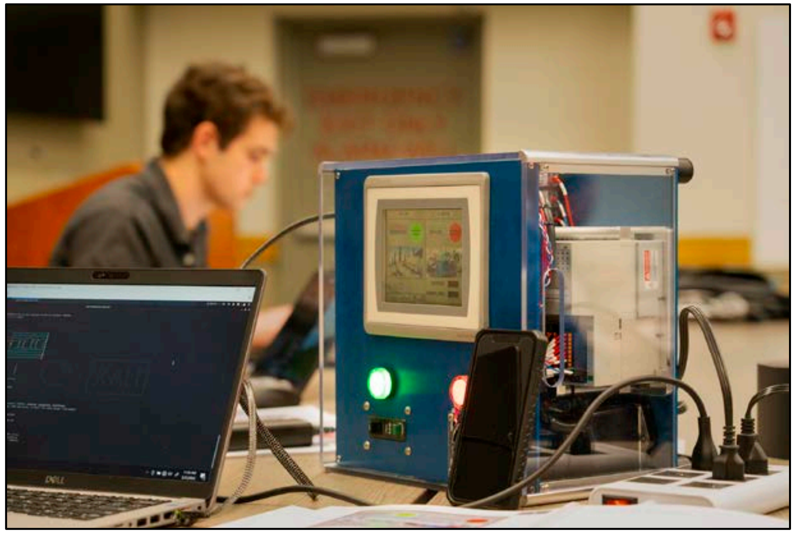
CyberStrike STORMCLOUD

- Sandia is working with INL to create CyberStrike STORMCLOUD, a cybersecurity training class which is focused on renewable and distributed systems.
- The team tested the solar version of the material at Secure Renewables in Washington DC earlier this year with good industry feedback.
- Sandia is working on the EVSE version of the lectures and training – crafting specific hands-on trainings for OCPP 1.6, CCS, and EVSE cloud APIs.
- A new promotional video has been created and will be online shortly after DOE CESER approves.

Sandia National Laboratories

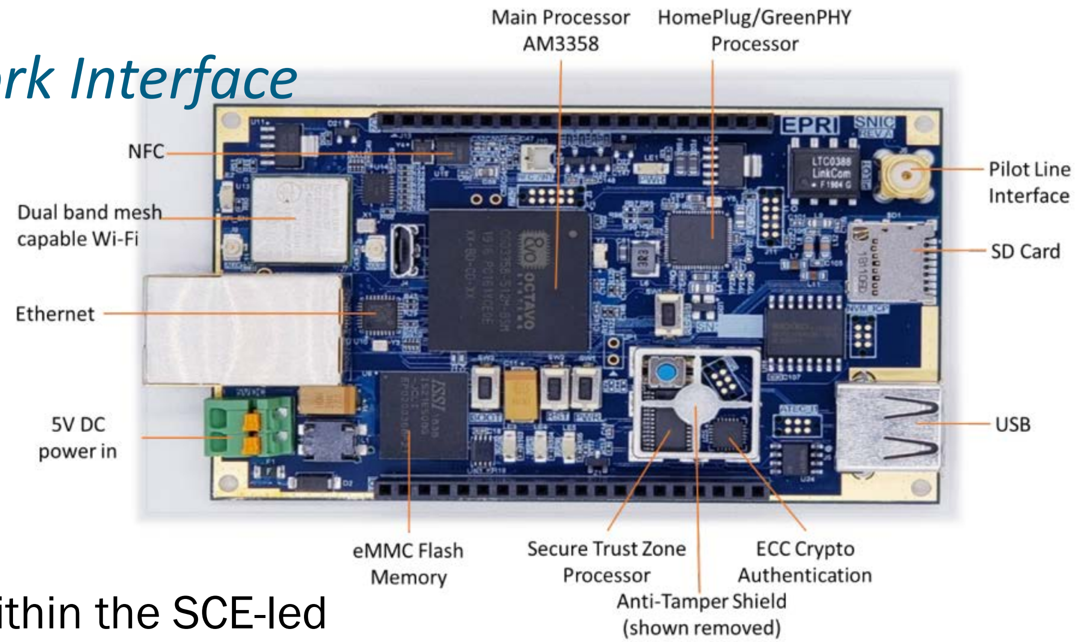




CyberPUNC – New Tasks and Project Areas

Cybersecurity Evaluation of EPRI's EVSE Secure Network Interface Card (SNIC)

- INL will evaluate the security of this EVSE comm. module
  - Overall design evaluation
  - Hardware security assessment
  - Software / code evaluation



Supporting V2G Tech. Advisory Board Cybersecurity

- INL is contributing to the EPRI-led cybersecurity work group within the SCE-led V2G technical advisory board
  - Determine cybersecurity measures required for countering MitM scenarios for the IEC/ISO 15118 (-2 or -20) originating at the EVSE
    - Identify issues/gaps, create mitigation solutions, present best practice solutions

CyberPUNC – Conclusion and Next Steps

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Review

- Securing EVCI with PKI
- EVCI cybersecurity tools and solutions
- High-power charging infrastructure security mitigation & best practices developed and demonstrated
- Successful 2023 CyberAUTO Challenge included three EVs, DC charging, & OCPP hands-on ‘white-hat’ eval.

Next steps

- Evaluation of a prototype secure EVSE communications module considered for reference architecture
- V2G cybersecurity working group focused on MITM exploits of IEC/ISO 15118 (-2 or -20)

Thank You!

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Join us for the
Cyber-Physical Security Deep-Dive
Oct. 10 & 11 (11:00am – 1:00pm eastern)

Oct.10: Click here to join the meeting

Oct.11: Click here to join the meeting

or contact Barney Carlson (richard.carlson@inl.gov)

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Evision Project Updates

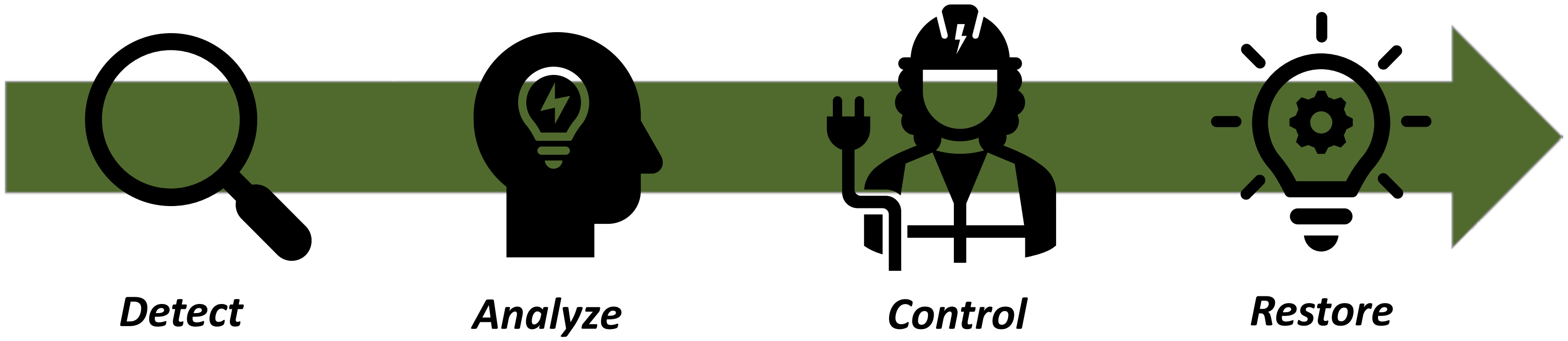
September 2023 Stakeholders Meeting

Michael Starke, PhD
Oak Ridge National Laboratory
9/27/2023

Resilient High Power Charging Facility: Objective

Challenges:

- Resilient and Reliable Electric Vehicle Charging Infrastructure is needed to support reduced range anxiety.
- Failing Chargers or non-functional charging infrastructure has become a highly reported topic.



Goal: Improve EV charging resilience

Resilient High Power Charging Facility: The Approach

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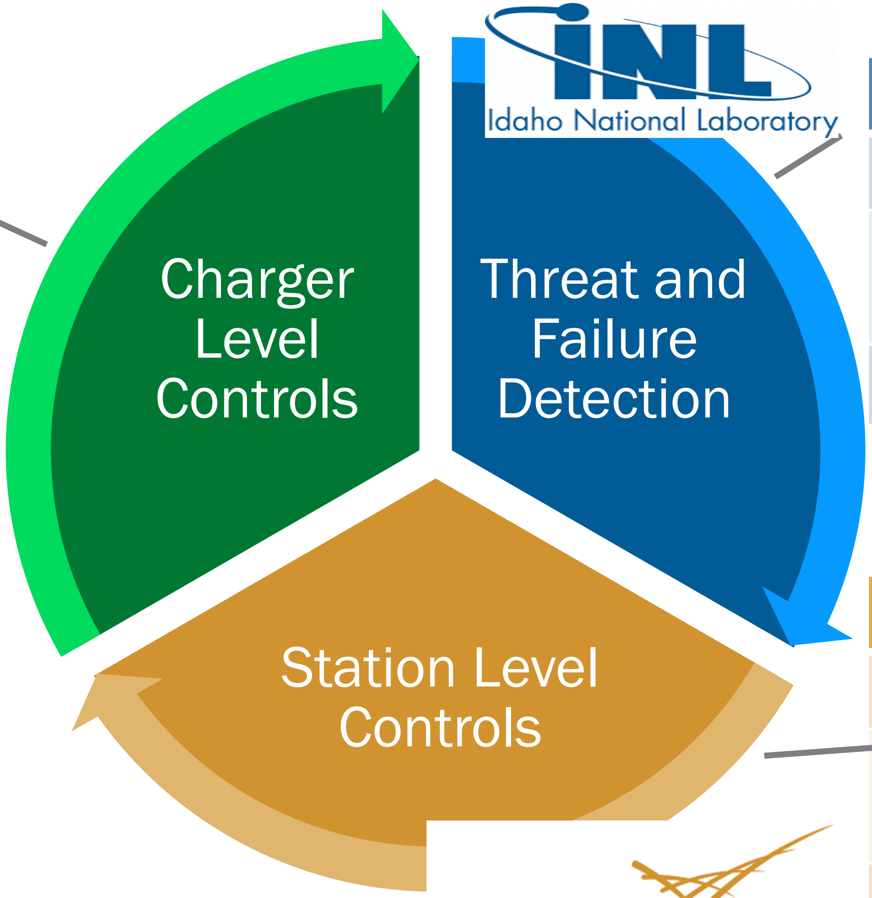
Overall Approach:

Develop control and anomaly detection techniques to improve the resiliency of the electric grid and charging stations.

CHIL RT-SIM

Charger Level Controls
- Electric vehicle charger topologies and controls
- Electrical vehicle charger fault identification
- Electrical vehicle charger resilient operations

Oak Ridge National Laboratory



Idaho National Laboratory

Hardware

Threat and Failure Detection
- Cyber security threats and attacks
- Physical equipment threats and attacks
- Communication failures

CO-SIM HIL

Station Level Controls
- Electrical charging network
- Supporting Energy Storage / Renewables
- Islanding Options

Pacific Northwest National Laboratory

Unique Capabilities Generated by Labs to Support EVision

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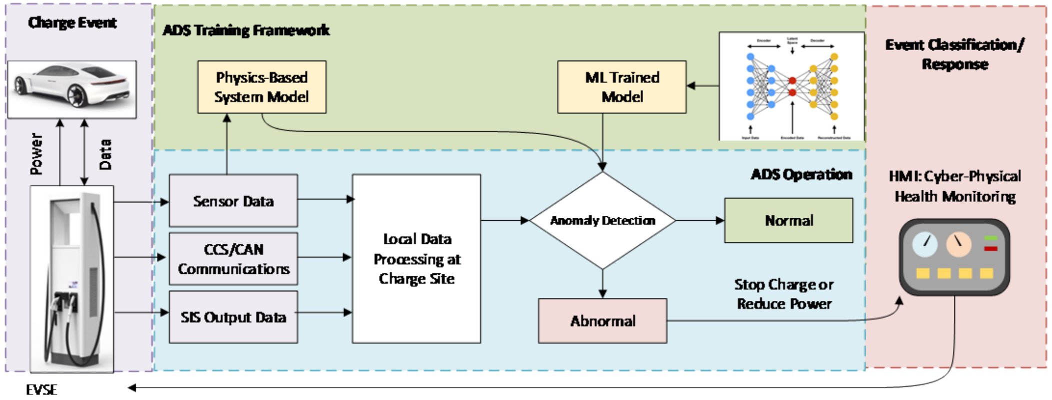
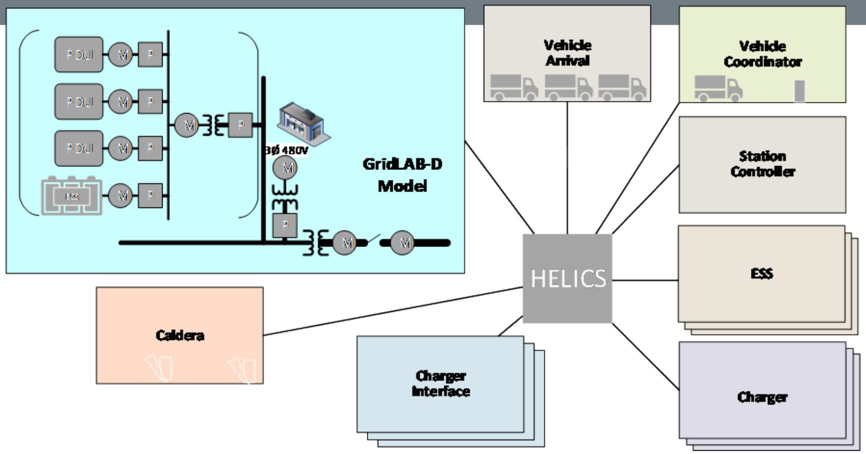
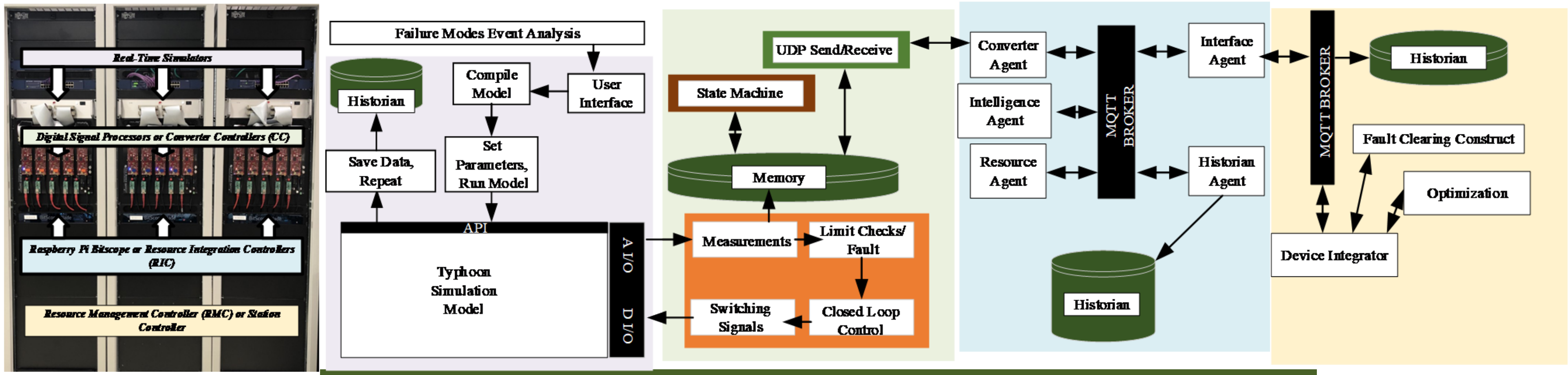


INL hardware and learning system for detection.



PNNL simulation system large scale modeling

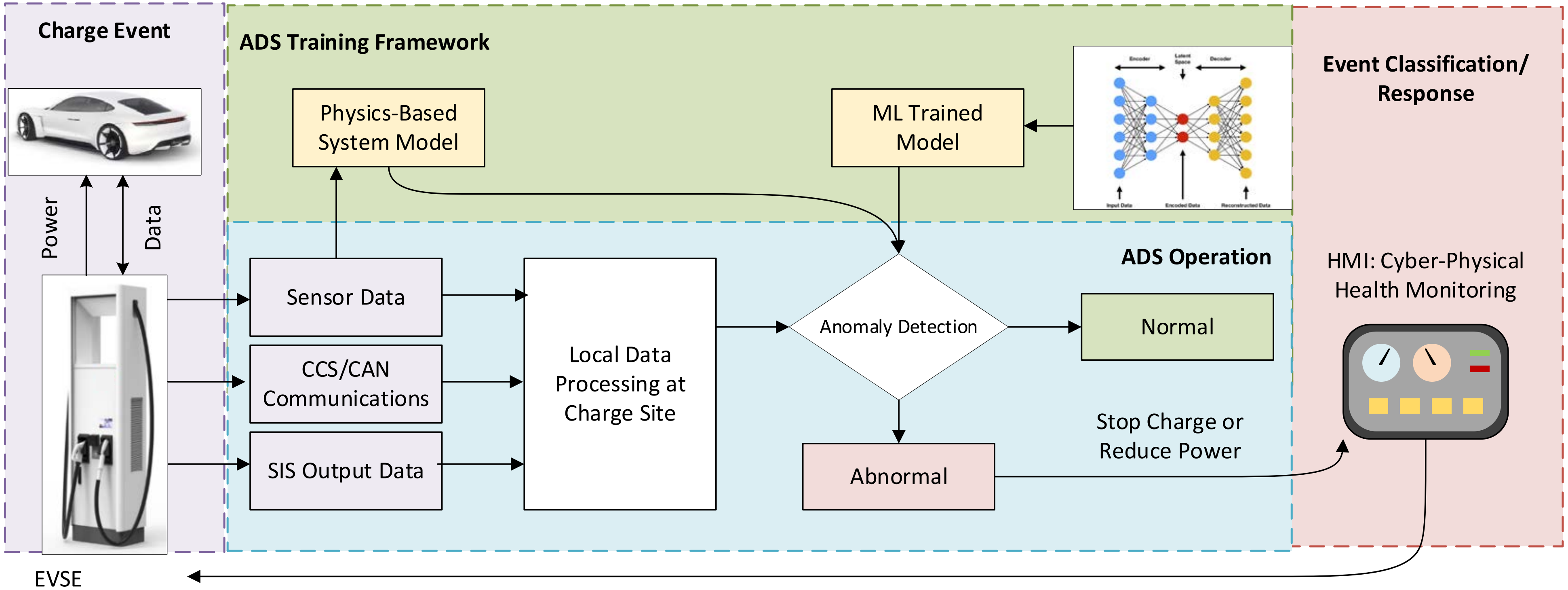


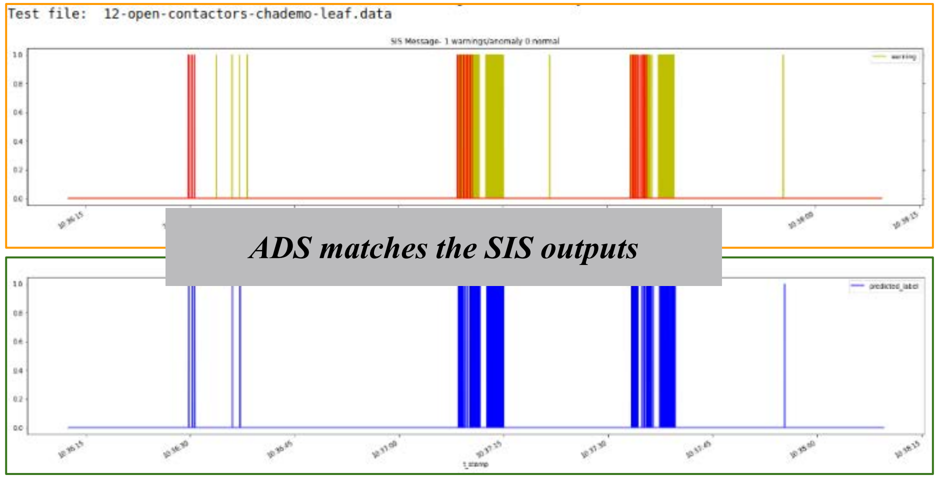
ORNL RT-simulation system for RT evaluation of control solutions

Machine Learning and Physcics Based Approaches

Detect

Analyze



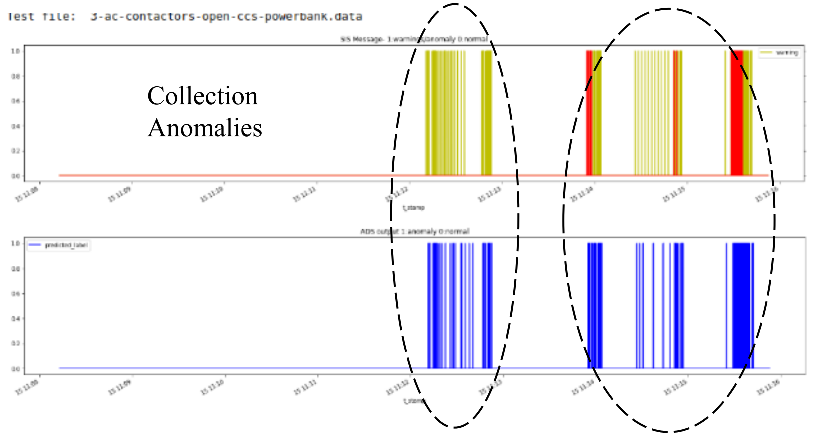


SIS outputs: red line represent anomalies (1: anomaly, 0:normal), *yellow line* (1:warning, 0: normal)

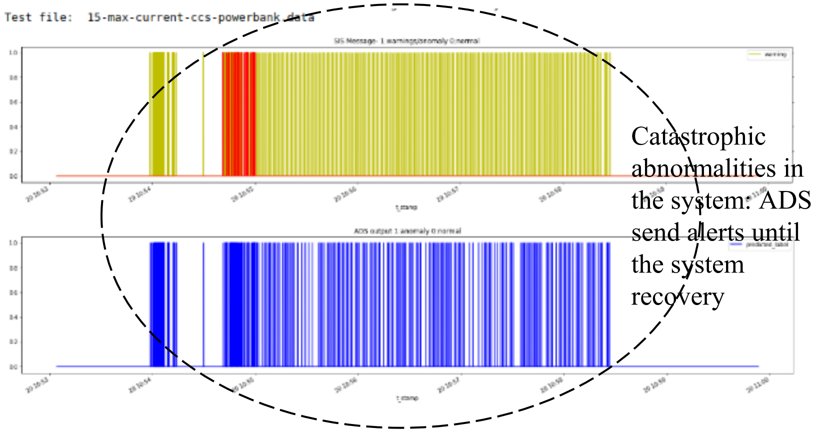
ADS output: *blue line* (1: detected anomaly, 0: normal behavior)

Initial Result Analysis

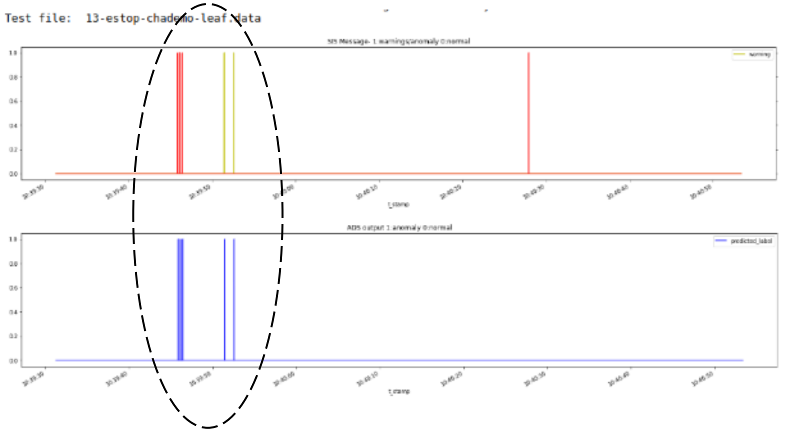
Main AC contactors opened during high-power charging (files 3, 8, 12) - cyber, malicious



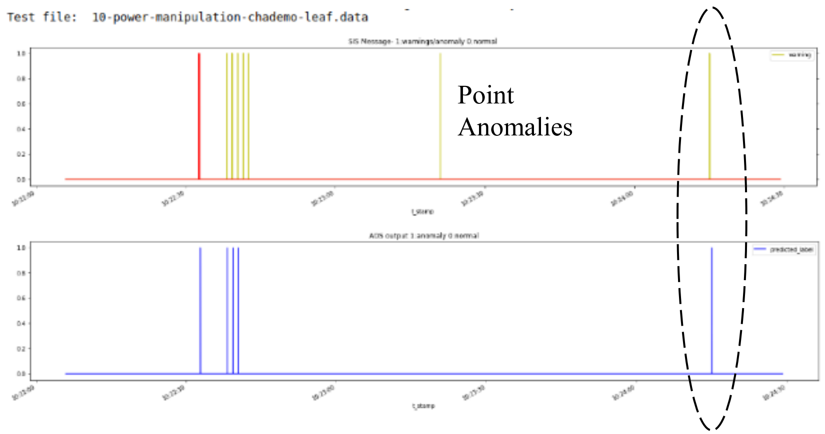
Max Current CCS Blocked Chiller Air Inlet: (files 14, 15, 17) - physical, benign



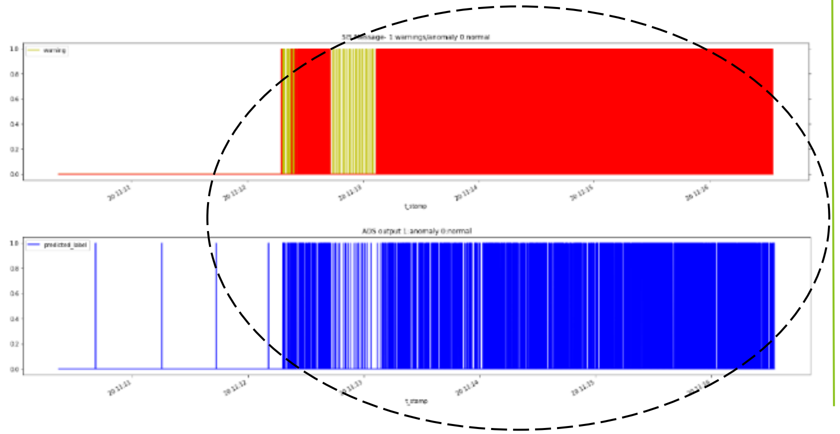
Cyber: e-Stop (files 4, 13) - cyber, malicious



Power Module Manipulation: (files 2, 7, 10, 11) - cyber, malicious



Max-current-ccs-chiller-disabled-powerban: (file 16) - cyber, malicious



Conclusion:
Initial ADS prototype
- Higher detection rate on anomalies
- Successfully detecting anomalies detected by SIS.

Potential Failure Modes in Charging Eco-System

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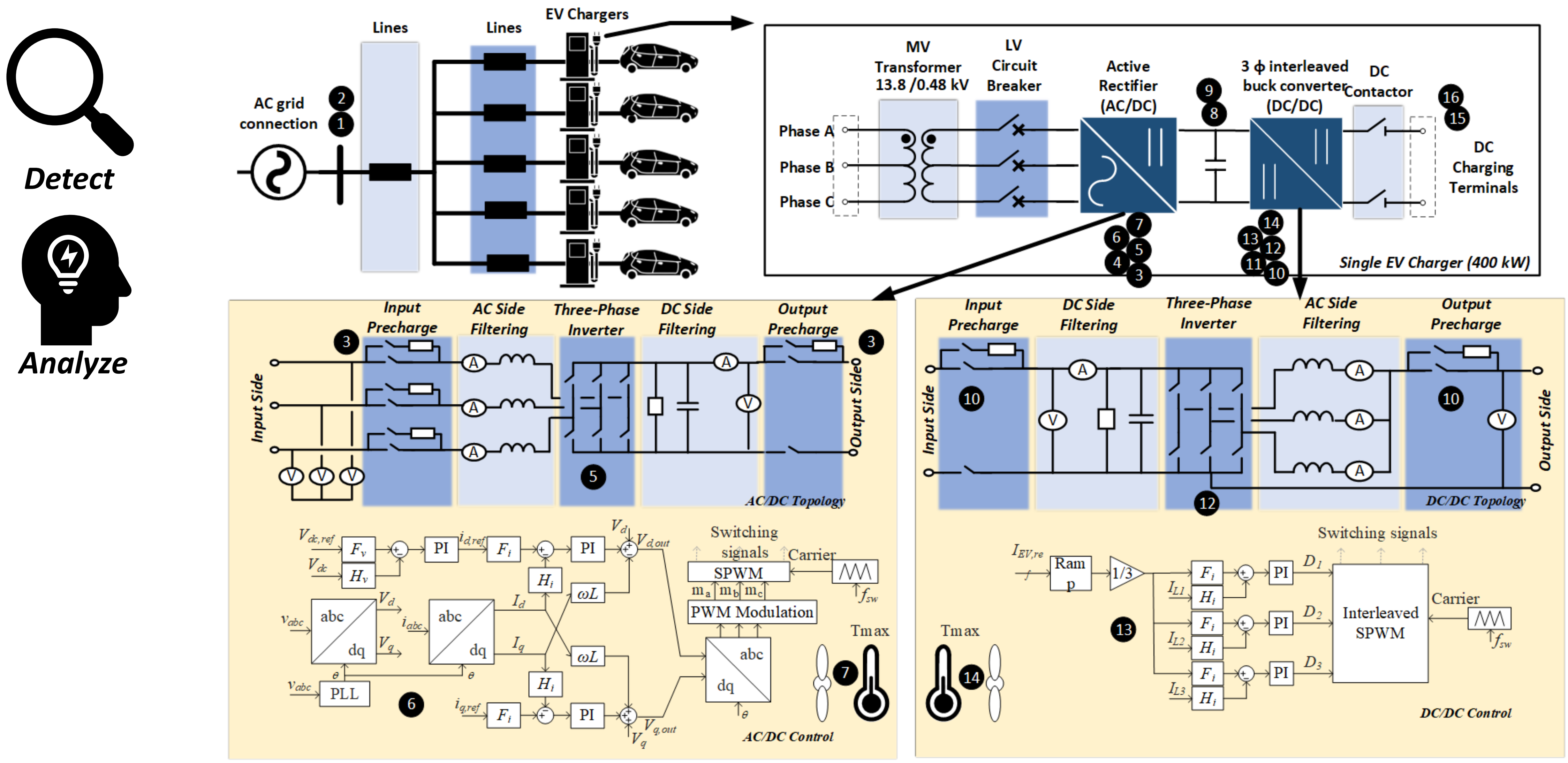


M. Starke, N. Kim, B. Dean, S. Campbell and M. Chinthavali, "Automated Controller Hardware-In-The-Loop Testbed for EV Charger Resilience Analysis," 2023 IEEE Transportation Electrification Conference & Expo (ITEC), Detroit, MI, USA, 2023, pp. 1-6.

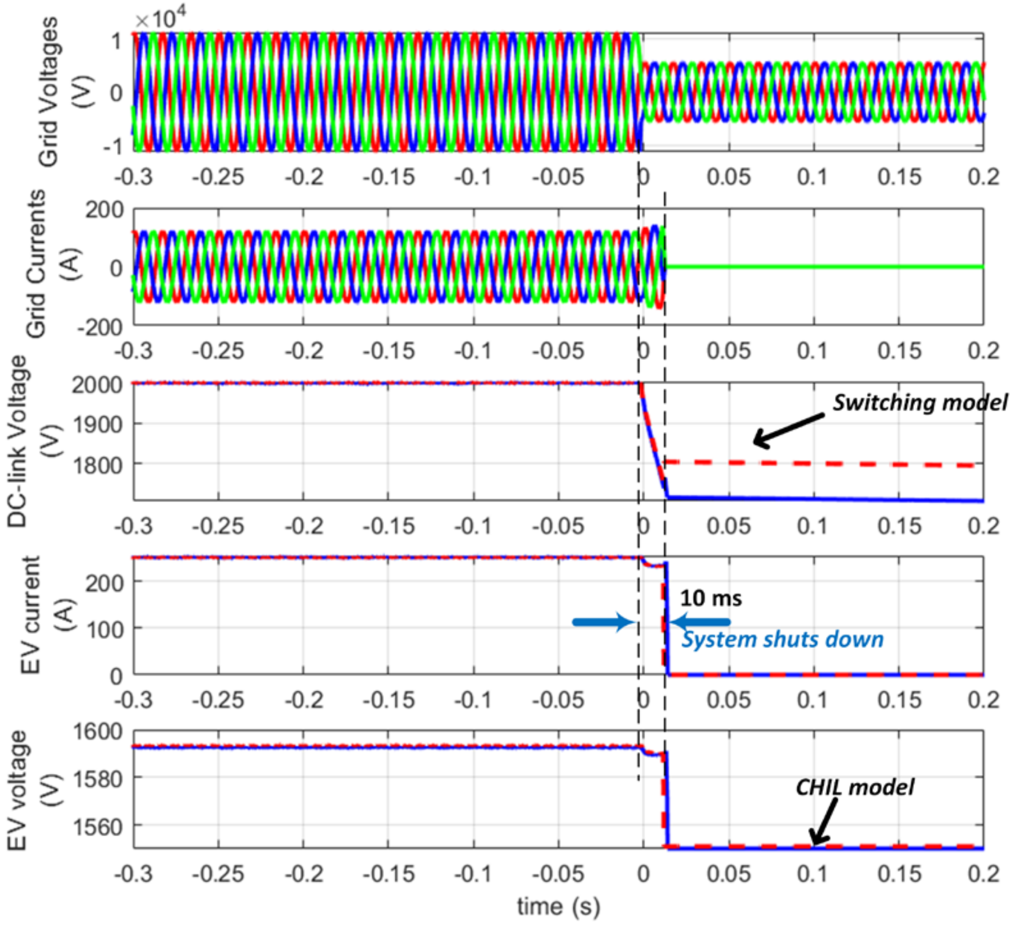
Oak Ridge National Laboratory

Use Case: DC/DC Converter Ride-through

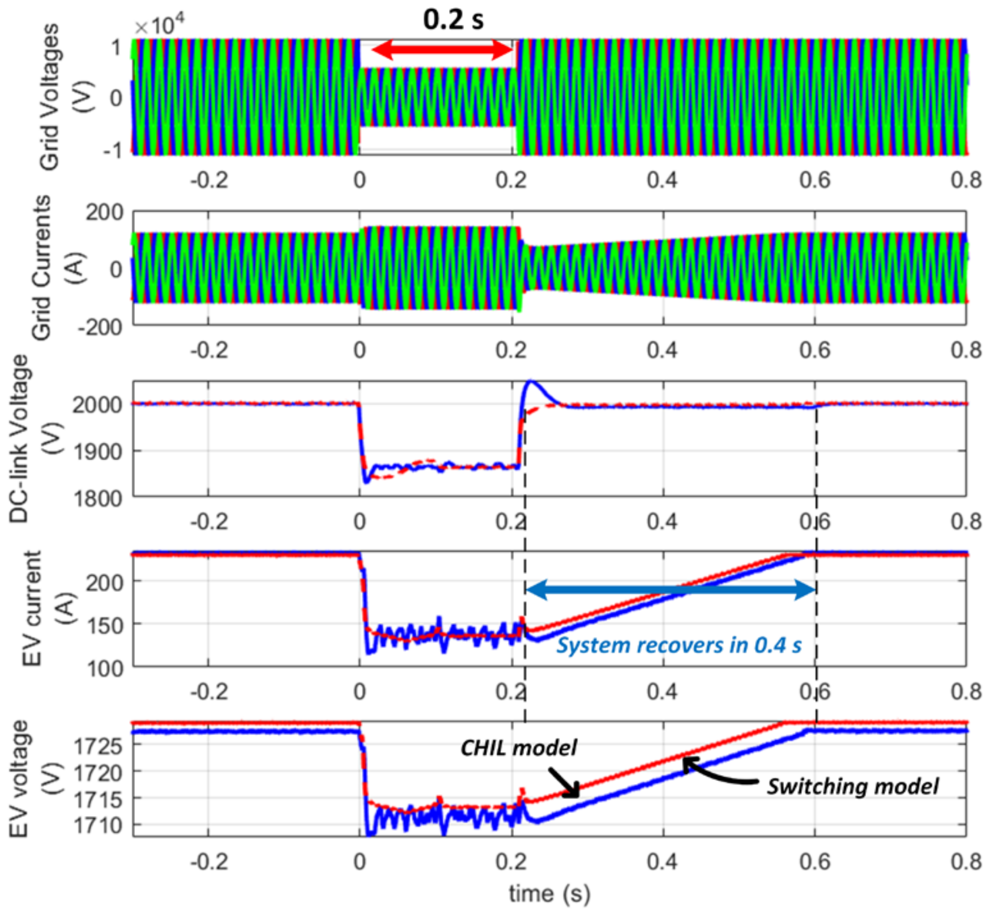
Control

Restore

Traditional Control

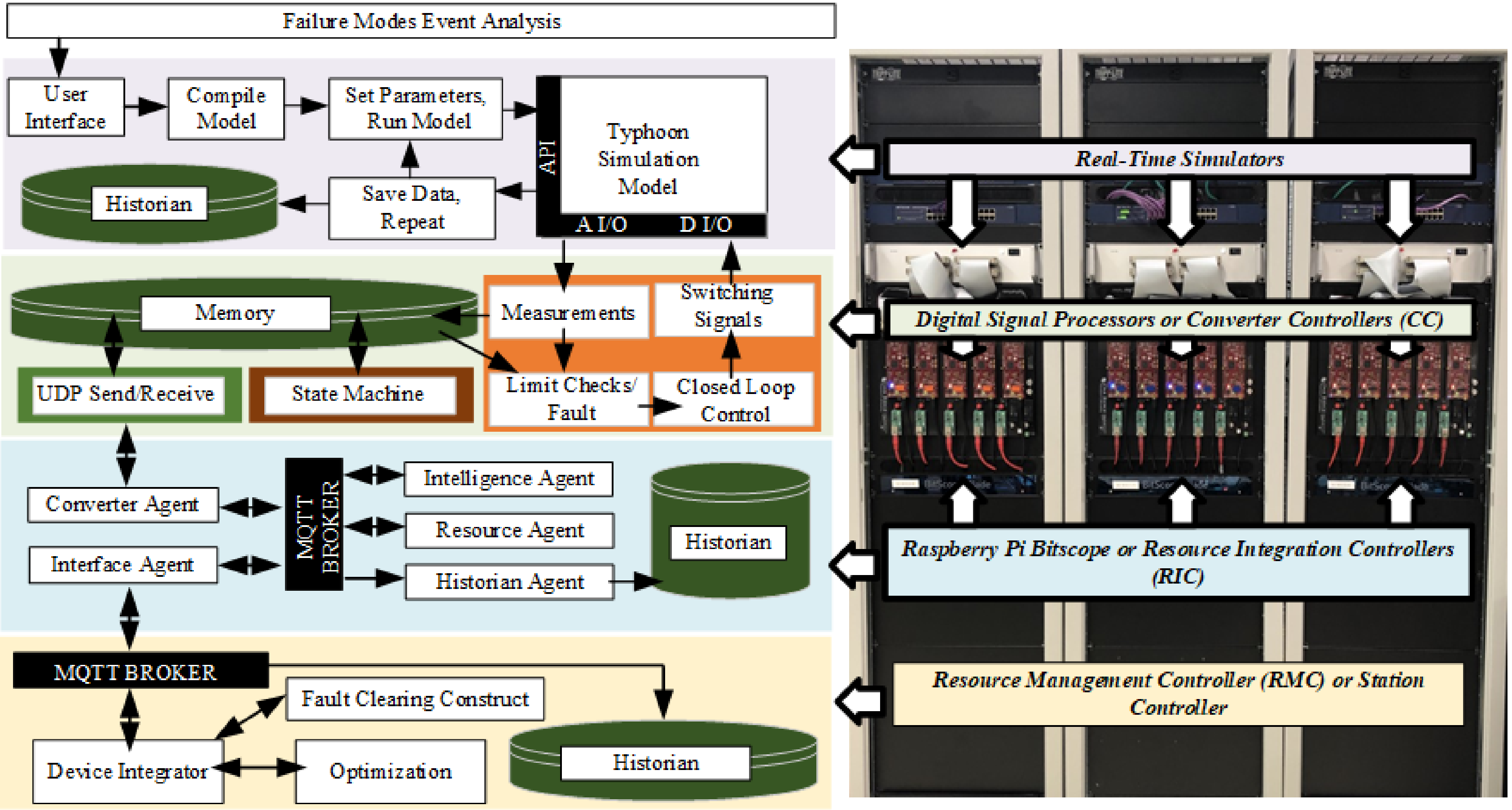


Ride-through Control



M. Starke, S. Bal, M. Chinthavali and N. Kim, "A Control Strategy for Improving Resiliency of an DC Fast Charging EV System," 2022 IEEE Transportation Electrification Conference & Expo (ITEC), 2022, pp. 947-952.

Automating and Integrating



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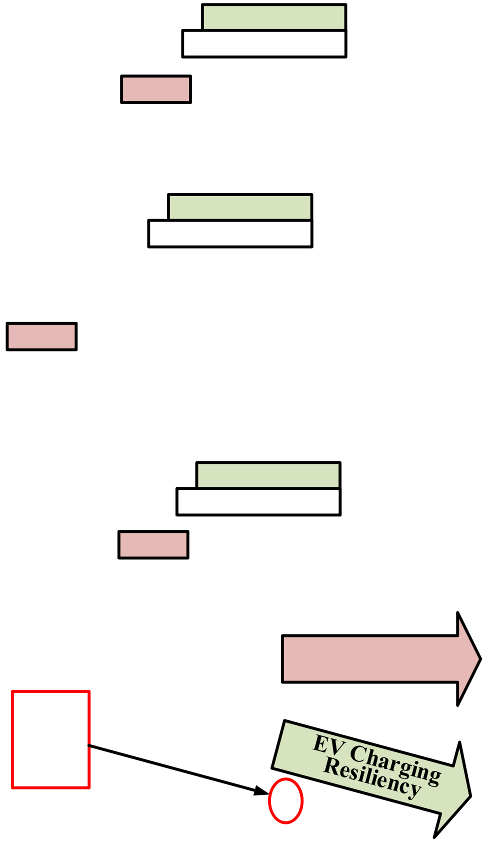
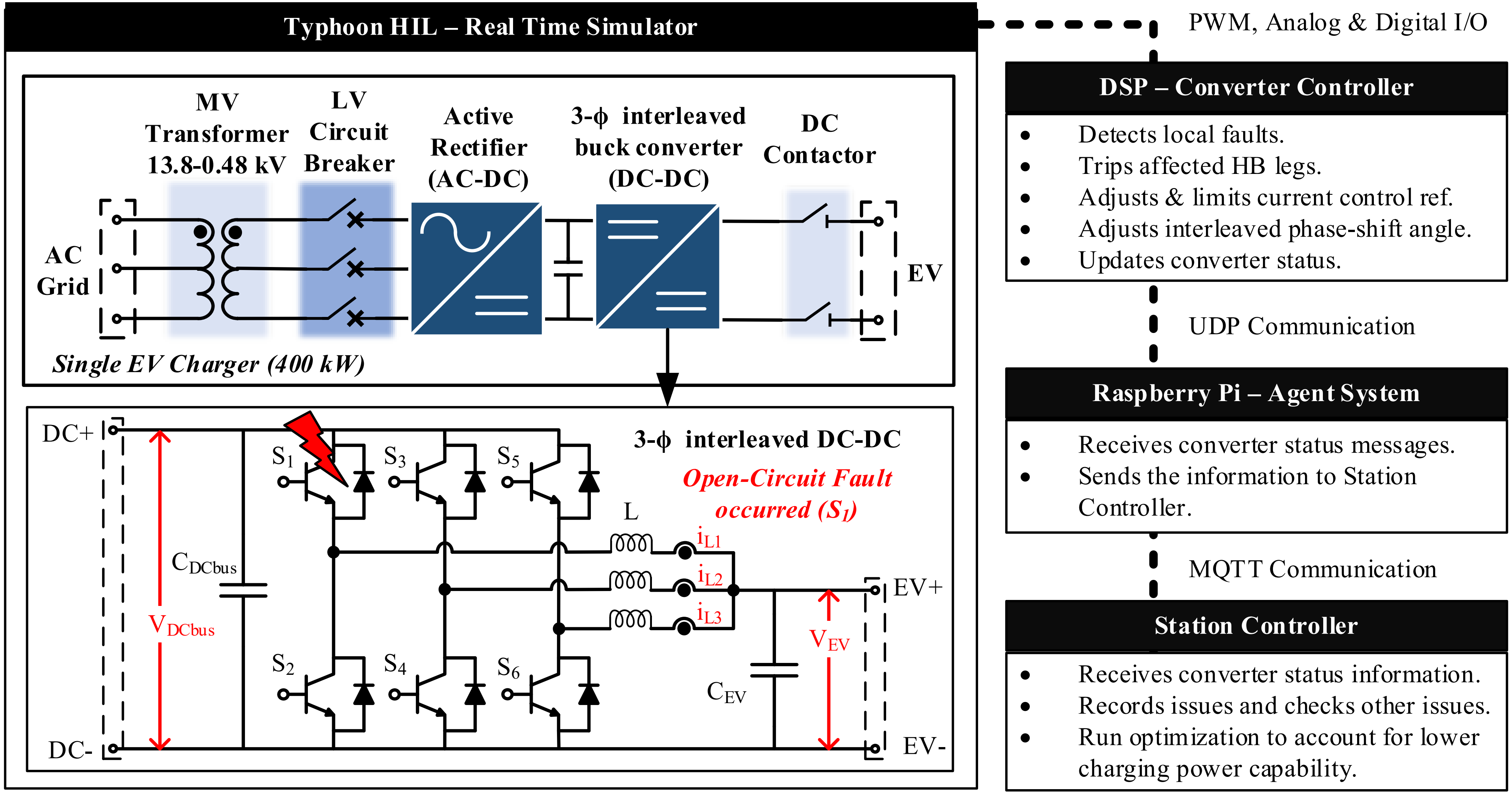


Use Case: Device Failure Ride Through (DFRT)

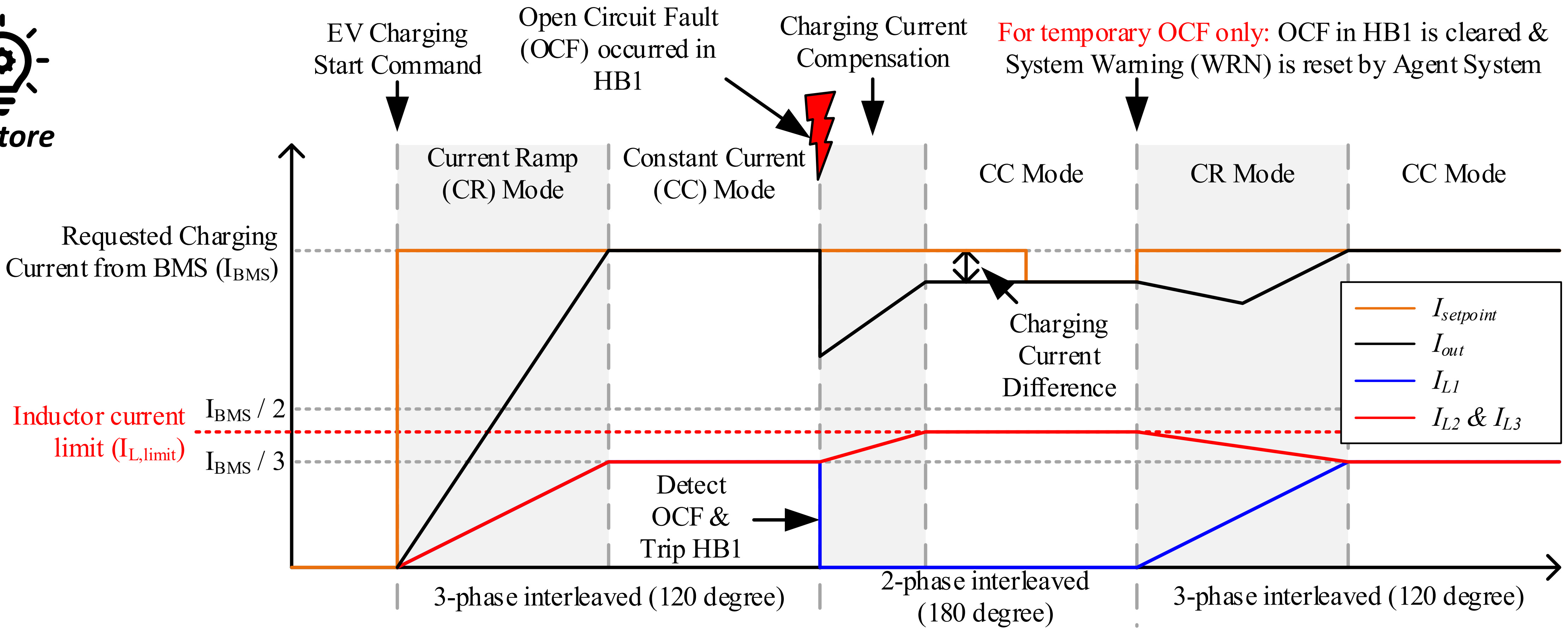


N. Kim, M. Starke, B. Dean, "Improving EV Charging Resilience under a Device Fault Condition," ECCE 2023 (**Accepted**)

Detection and Control Adjustment

Control

Restore



N. Kim, M. Starke, B. Dean, "Improving EV Charging Resilience under a Device Fault Condition," ECCE 2023 (**Accepted**)

System Level Responses

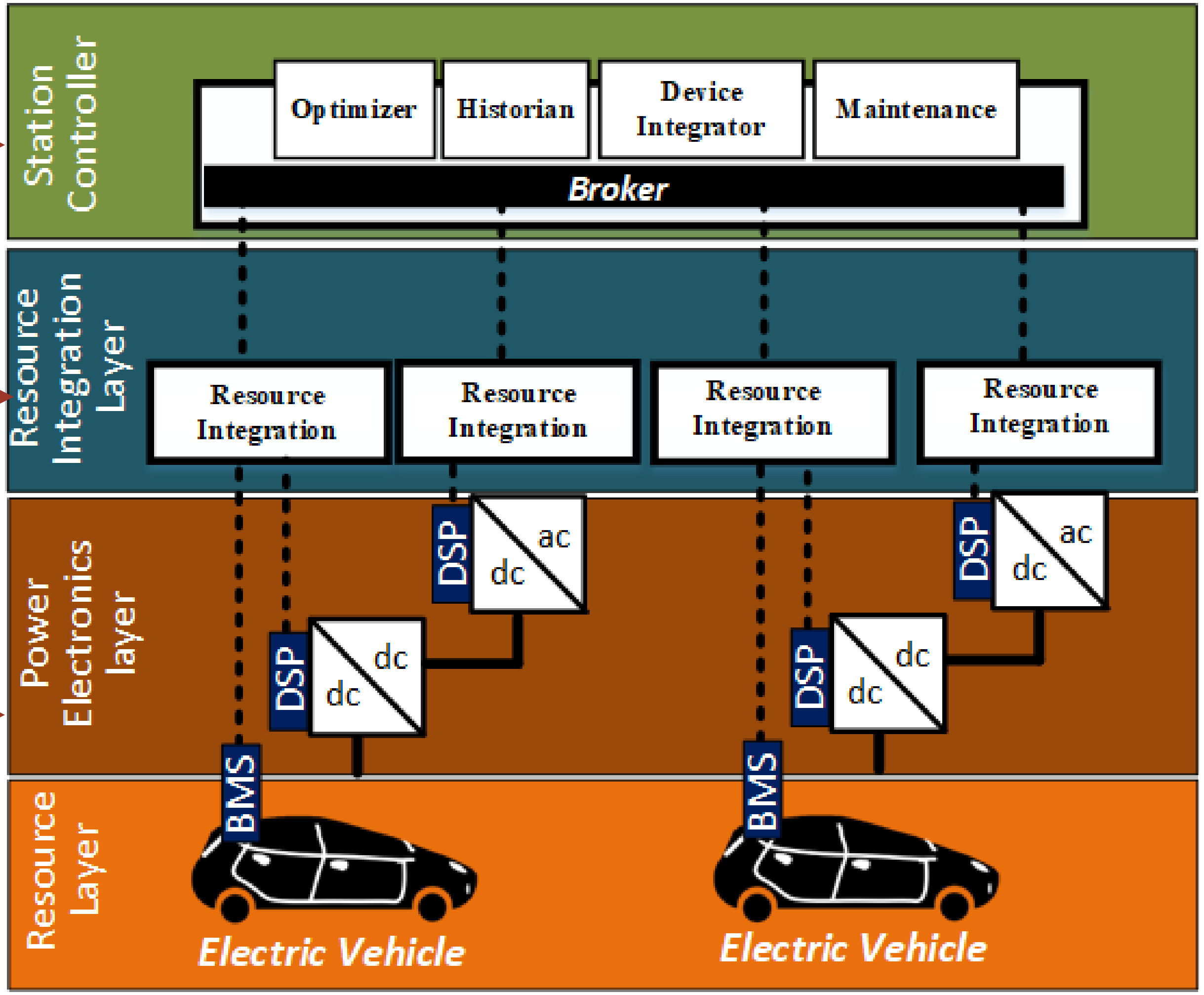
Control

Restore

Station Level:
Receives Warning and Includes Updates on Station Level Optimization

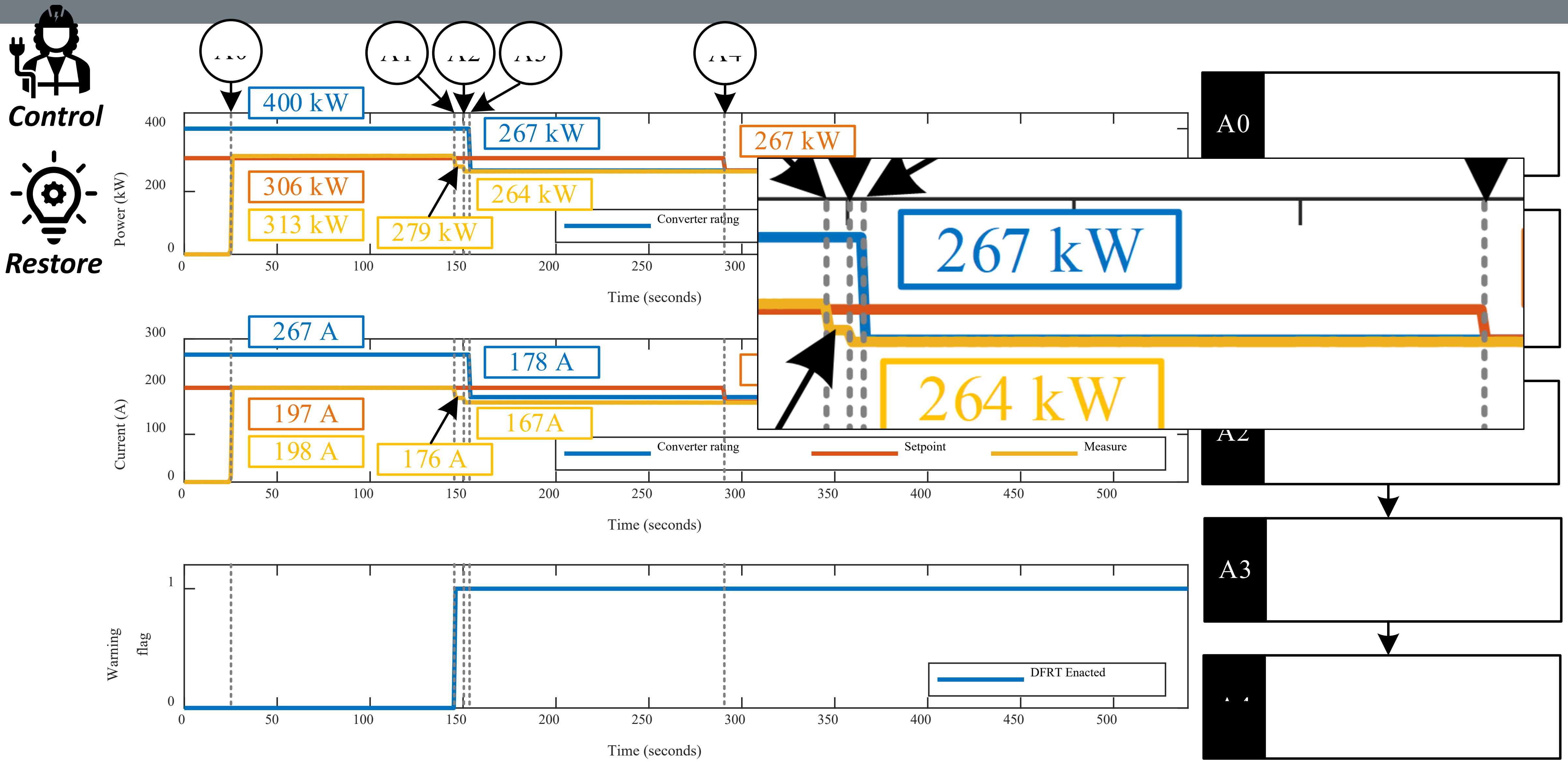
Integration Level:
Receives Warning and Reduced Capacity Warning. Reduces Capacity

Converter Level:
Device Fault, Converter controls enact immediate change in operations



N. Kim, M. Starke, B. Dean, "Improving EV Charging Resilience under a Device Fault Condition," ECCE 2023 (**Accepted**)

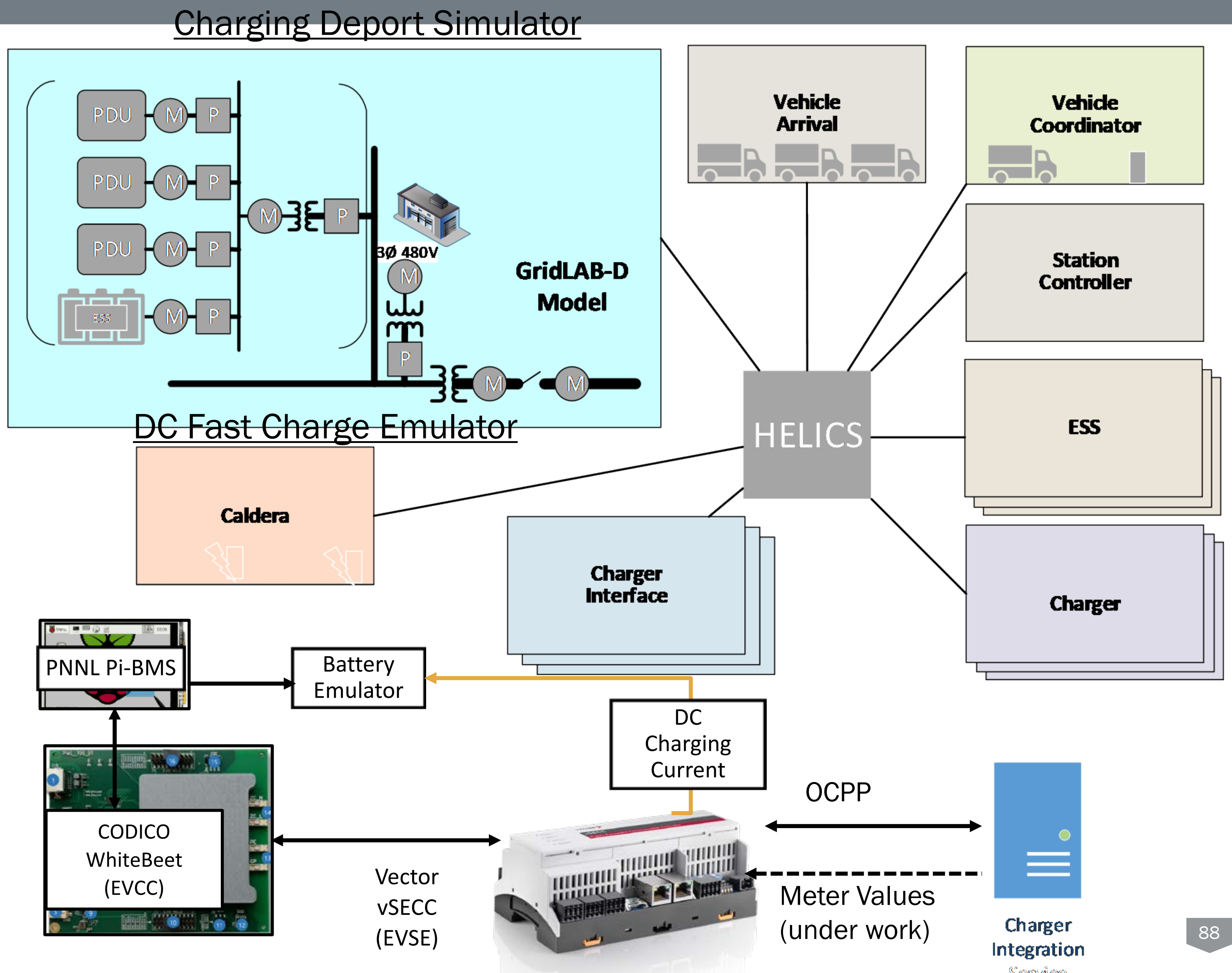
CHIL RT Simulation Results: Optimization



N. Kim, M. Starke, B. Dean, "Improving EV Charging Resilience under a Device Fault Condition," ECCE 2023 (**Accepted**)

Charger Simulation Integration

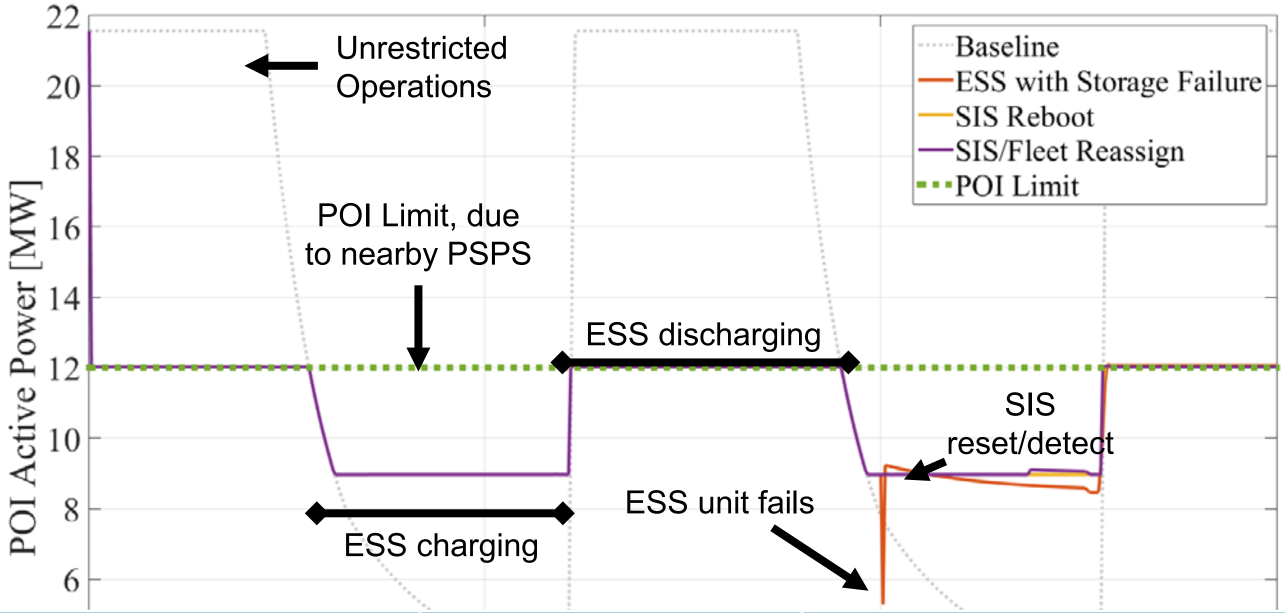
- DC Fast Charge Emulator models the essential communications and processes necessary for charging
- Charger Integration Service provides an interface to control and query chargers from the eVISION charging depot simulator
- Service can invoke programs that dispatch a sequence of OCPP requests, and whose logic is based on charger state and response to prior requests



Depot Resilience Simulations

- Grid constrained due to nearby PSPS event (POI limit)
- Additional charger port at each bank, held in reserve
- ESS Unit Fails – System redispatch to recover
- Charging pedestal fails
  - SIS detects and reboots
  - SIS detects, fleet management redirects vehicles

Charging impacted minimally, due to mix of resilient asset dispatch, fleet dispatch, and anomaly detection.



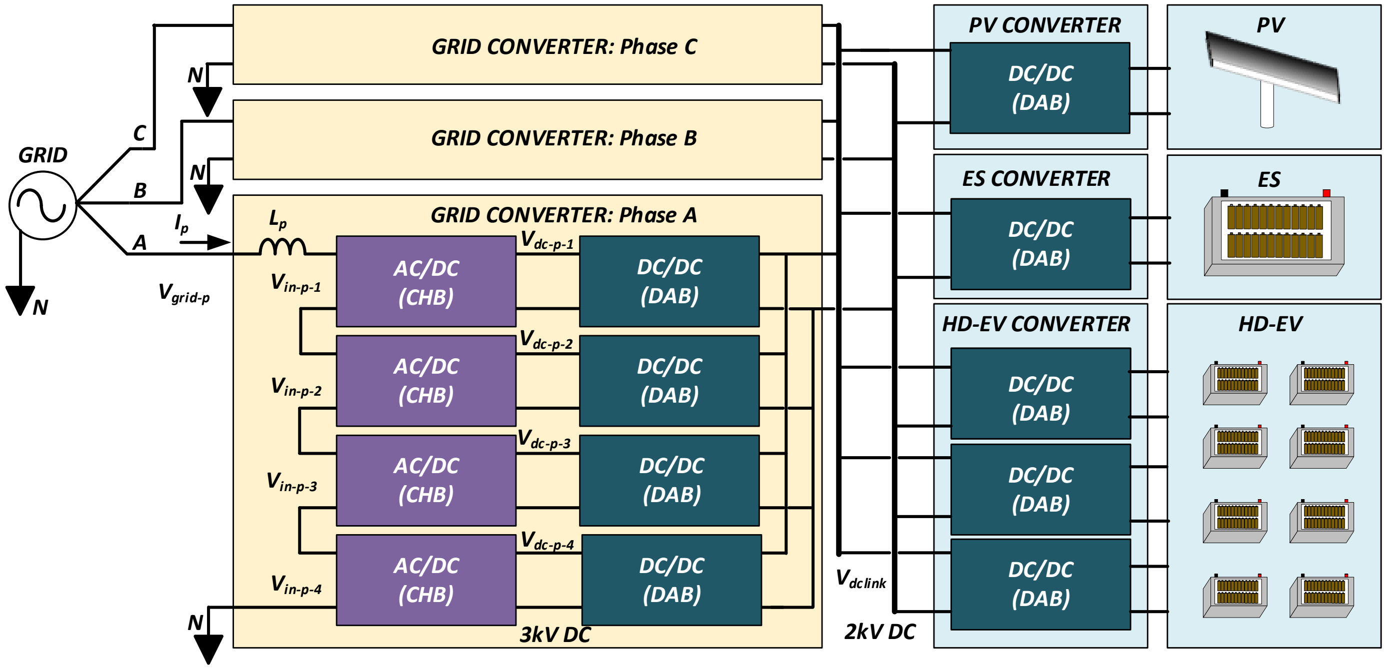
	Energy Transferred (MWh) [larger better]	Charging Sessions Completed (count) [larger better]
Baseline No POI Restriction	32.34	198
ESS Failure POI Restriction	31.41	180
Pedestal Failure SIS Reboot	32.32	180
Pedestal Failure SIS Detect/Fleet Redispatch	32.32	179

Final on Outcomes

- Publications
  - M. Starke, S. Bal, M. Chinthavali and N. Kim, "A Control Strategy for Improving Resiliency of an DC Fast Charging EV System," 2022 IEEE Transportation Electrification Conference & Expo (ITEC), 2022, pp. 947-952.
  - M. Starke, N. Kim, B. Dean, S. Campbell and M. Chinthavali, "Automated Controller Hardware-In-The-Loop Testbed for EV Charger Resilience Analysis," 2023 IEEE Transportation Electrification Conference & Expo (ITEC), Detroit, MI, USA, 2023, pp. 1-6.
  - M. Starke et al., “Supporting Resilience for Electric Vehicle Charging” IEEE Power and Energy Society General Meeting 2023. (Presented)
  - N. Kim, M. Starke, B. Dean, “Improving EV Charging Resilience under a Device Fault Condition,” ECCE 2023 (Accepted)
- Tools
  - Hardware Platform for Training and Evaluating Machine Learning and Physics Models
  - CHIL Automation Tool for Use Case Evaluations (ESA Tool)
  - Software & Simulation Platform for Evaluating Larger Use cases.

Going into Future Work (FY24)

- Expanding resiliency focus to mega-watt class charging systems.
- Examining architecture to support outage recovery and multi-converter system and fault recovery.
- Characterization of MCS cybersecurity vulnerabilities and loss of resiliency, development of detection methods, and ID of responses & preventions



M. Starke et al., "A MW scale charging architecture for supporting extreme fast charging of heavy-duty electric vehicles," 2022 IEEE Transportation Electrification Conference & Expo (ITEC), 2022, pp. 485-490.

R. S. K. Moorthy, M. Starke, B. Dean, A. Adib, S. Campbell and M. Chinthavali, "Megawatt Scale Charging System Architecture," 2022 IEEE Energy Conversion Congress and Exposition (ECCE), 2022, pp. 1-8.

Thank You!

Michael Starke, PhD

starkemr@ornl.gov

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U.S. Department of Energy

Lunchtime!

Welcome to adventure off-site or join at

Argonne Cafeteria – Building 213

Return 12:45pm

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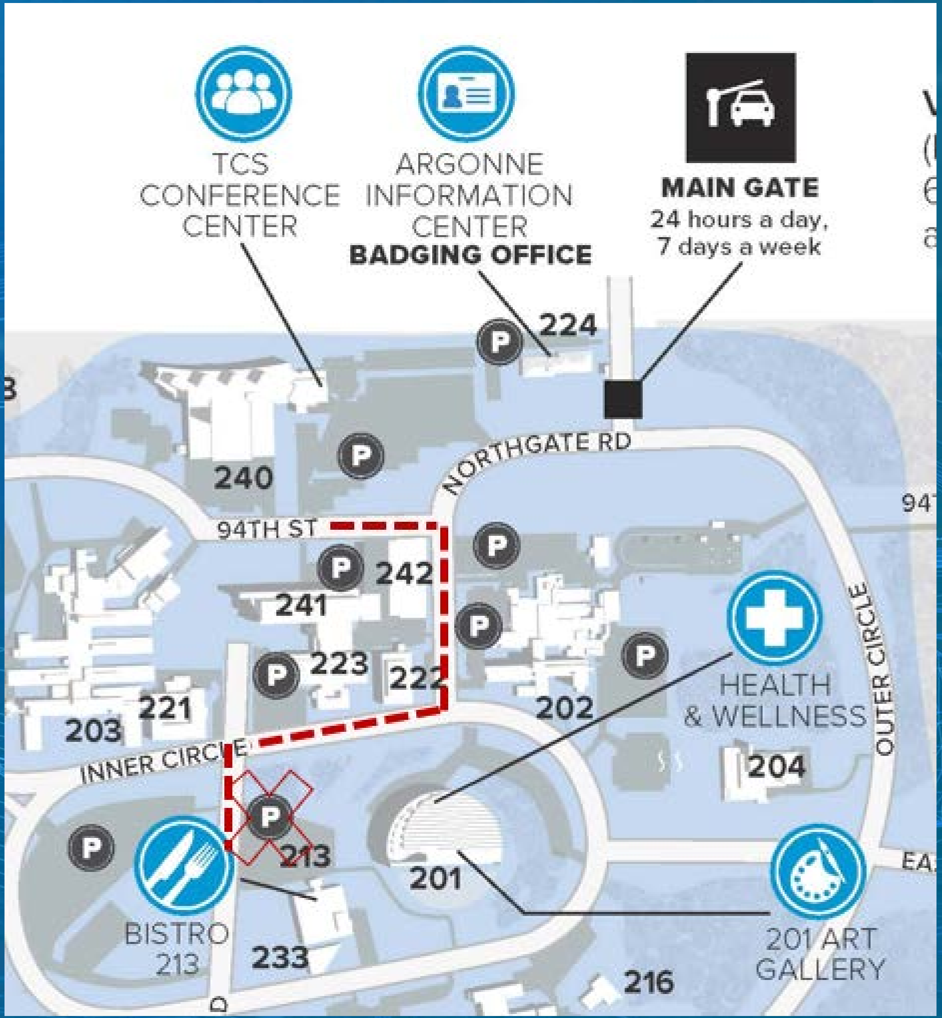

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Zero Trust Approach to Electric Vehicle Charging Infrastructure Security

Thomas E. Carroll, PNNL

September 27th, 2023

Cyber-Physical Security (CPS): Zero Trust Overview

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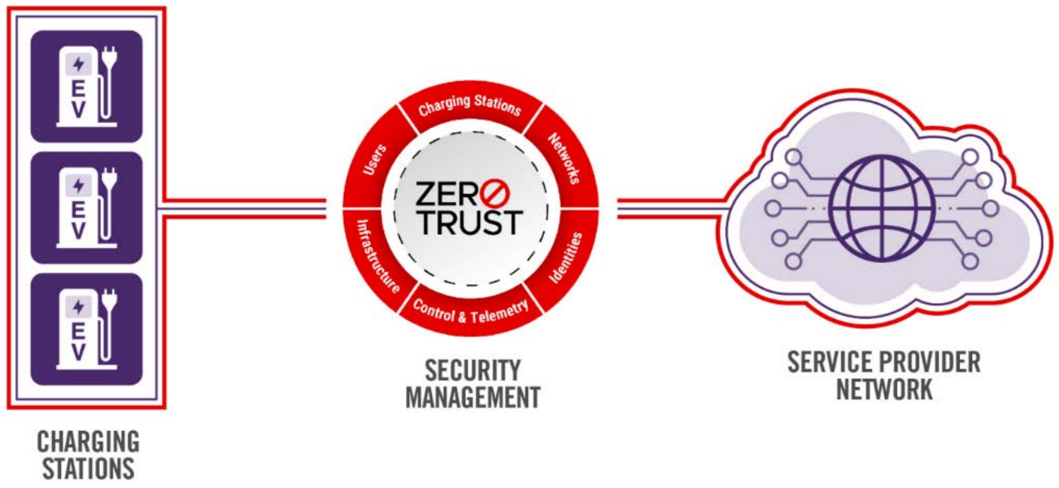
Objective: Develop, demonstrate, and evaluate Zero Trust approaches to bolster EV Infrastructure security by reducing the attack surface.



Outcomes:

- **Design architecture** for incremental deployment and infrastructure integration
- **Prototype architecture** in a testbed
- **Characterize and assess** prototypes to address vulnerabilities
- **Develop blueprint**

Industry Partners:

Talos, Cisco, NetFoundry, PLM Electric Power Engineering

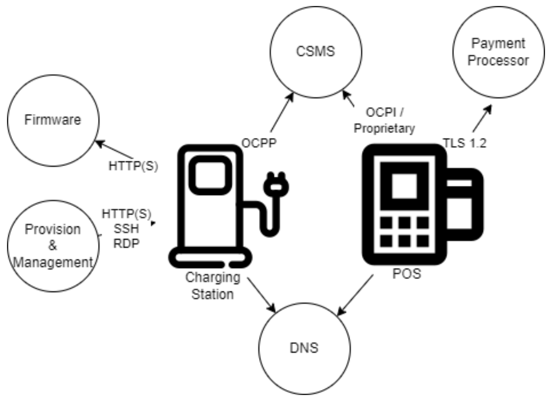
What is Zero Trust?

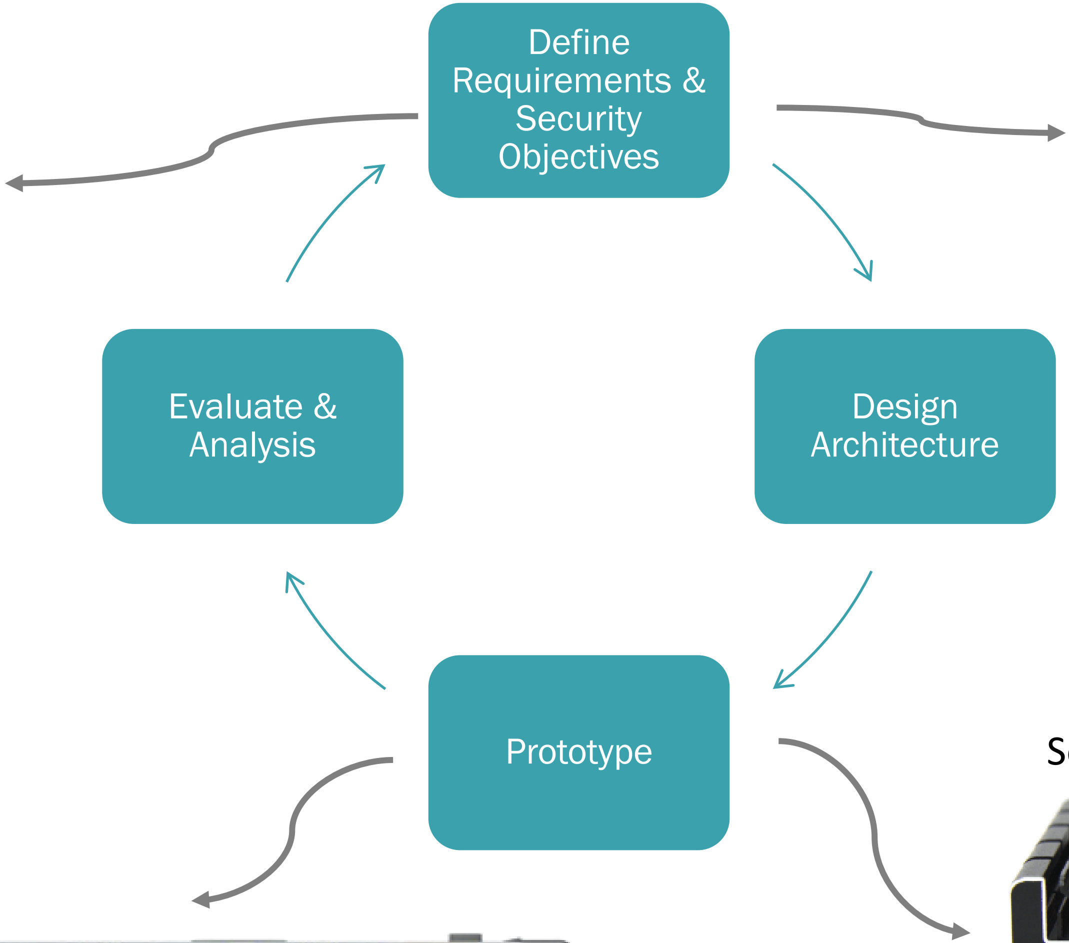
Zero Trust architecture implements network security approaches following the tenet “Never trust, verify everything”

- Zero Trust’s goal is to reduce implicit trust
  - Removal of implicit trust limits compromise scope
  - Increases adversary cost to exploit the system
- **Operationally Zero Trust:**
  - Independently considers each access request
  - Uses policy, identity and environment in each access request decision
  - Ensures adherence to “least privilege” and “separation of duties” principles

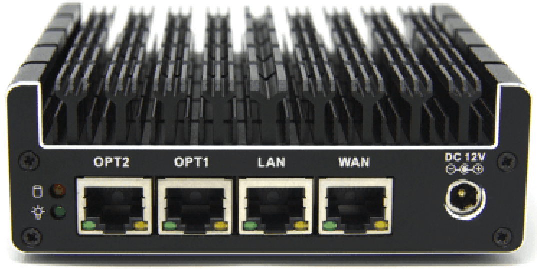
Implicit trust – a vulnerability resulting from limited verification | Least privilege – authorization level | Separation of duties – privileges limited based on role

Zero Trust Project Approach

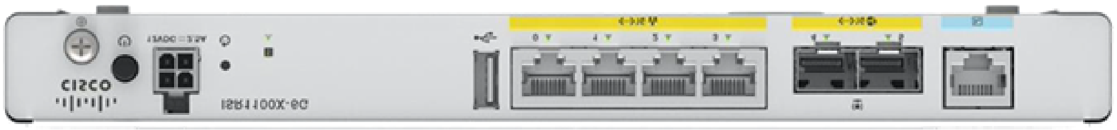




Focus on Charging Station Operator (CSO)



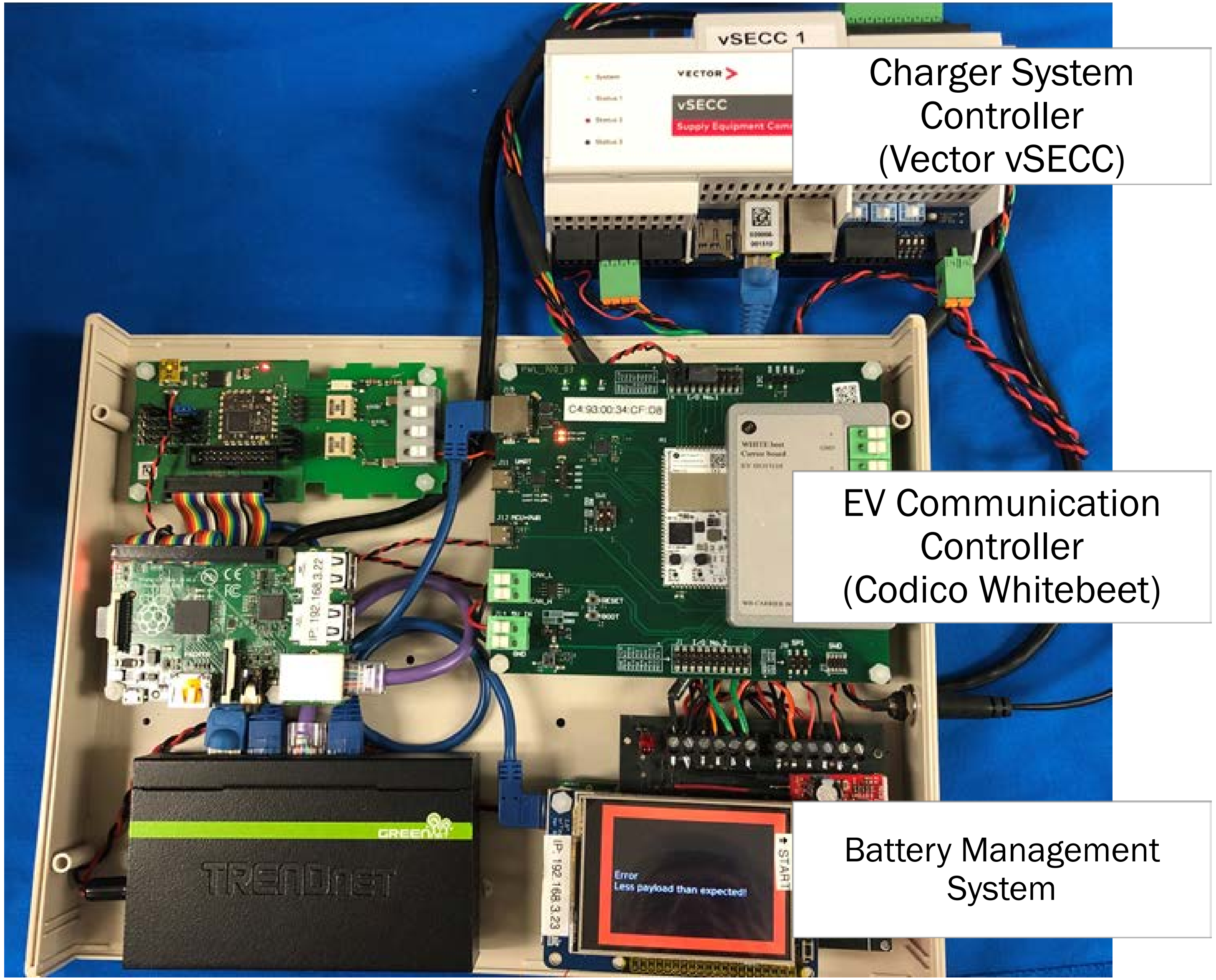
Security Service Edge Gateway



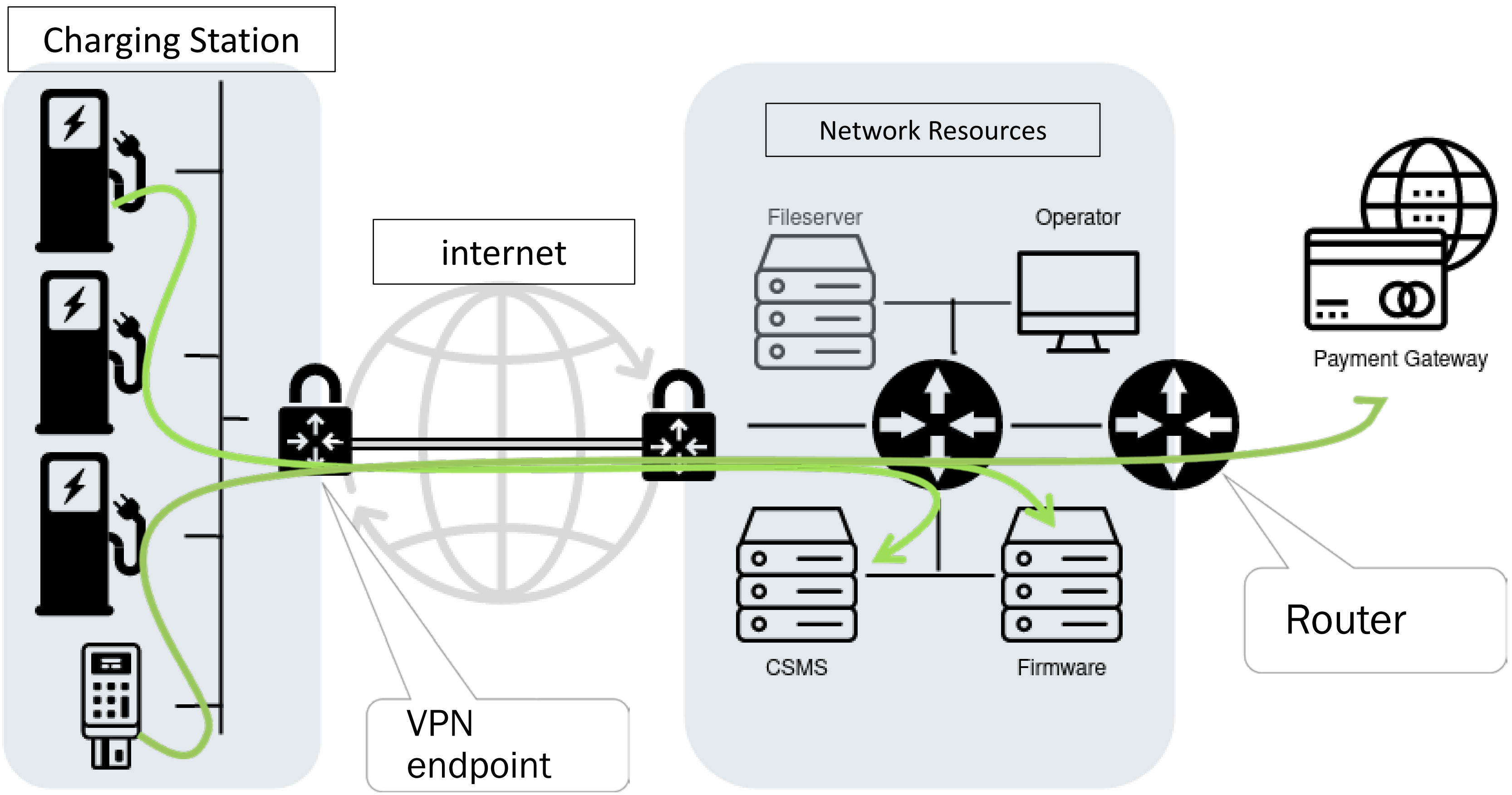
Cisco SDWAN

Charging Station Operator – entity responsible for the operation and maintenance of chargers and supporting equipment and facilities.

Prototype: DC Fast Charge Emulator Design

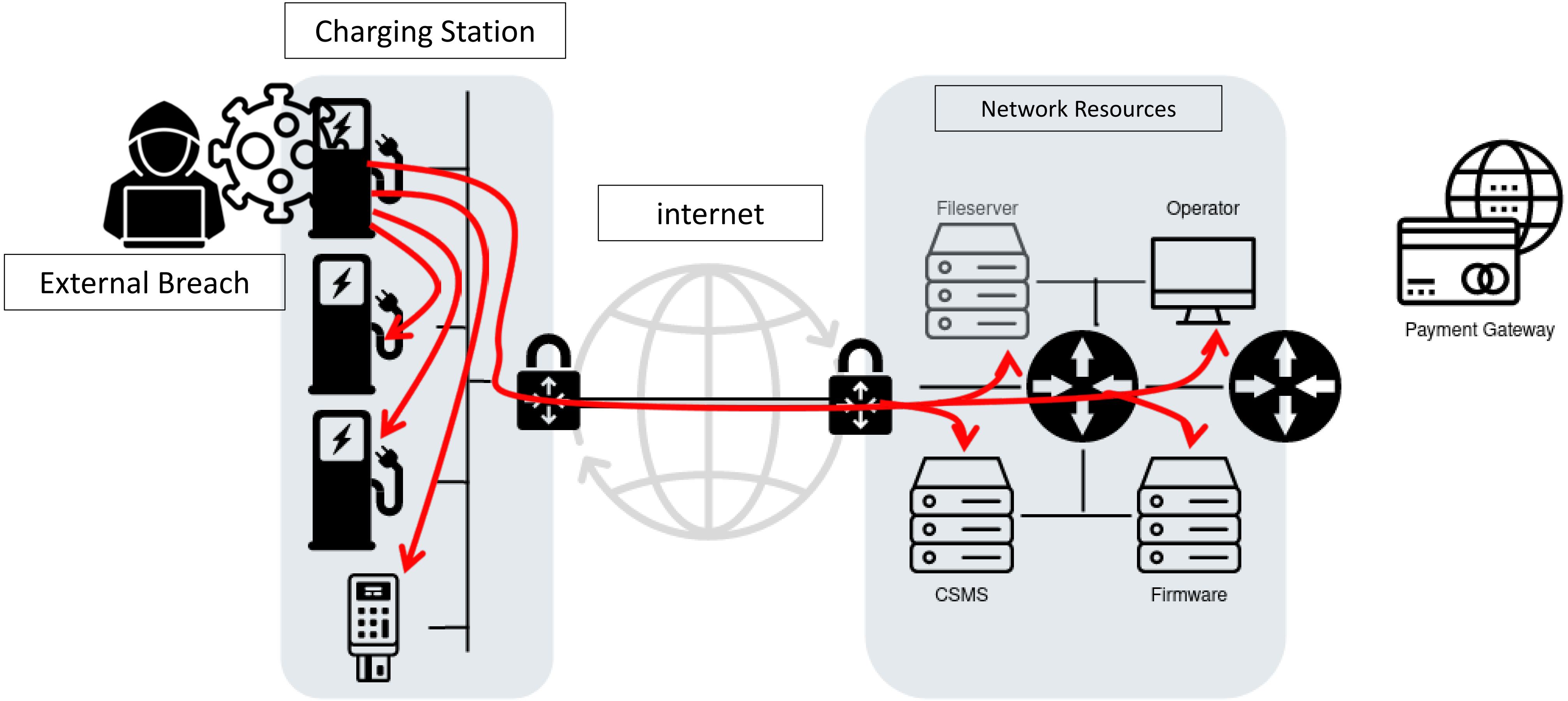


Conventional EV Service Provider + WAN

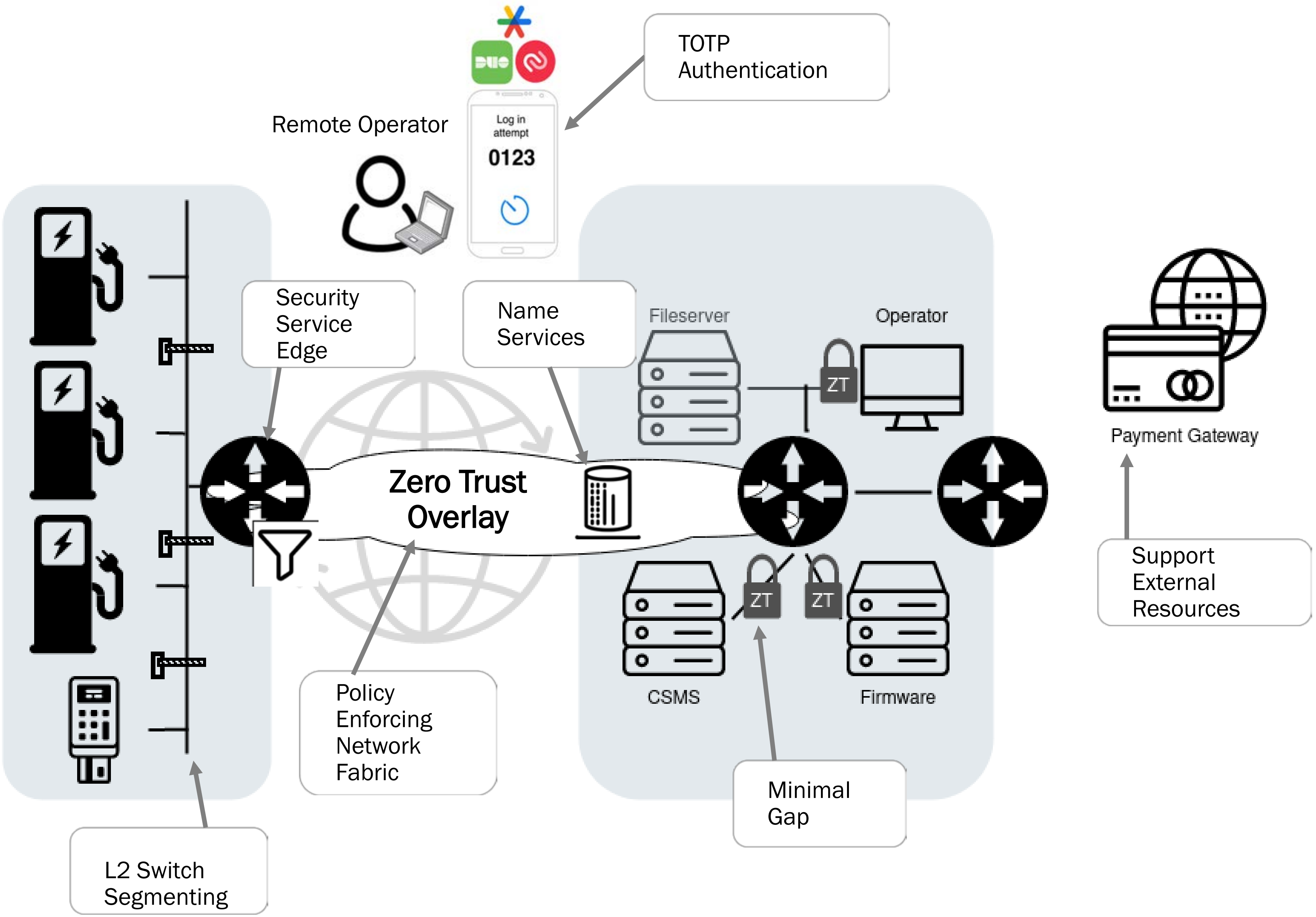


CSMS – Charging Station Management System - software for remote and real time charge point operation control (e.g., OCPP 2.0.1).

Breach to a Conventional EV Service Provider + WAN



Zero Trust Architecture for EV Service Provider



Zero Trust Architecture to Prevent Breach to a Conventional EV Service Provider

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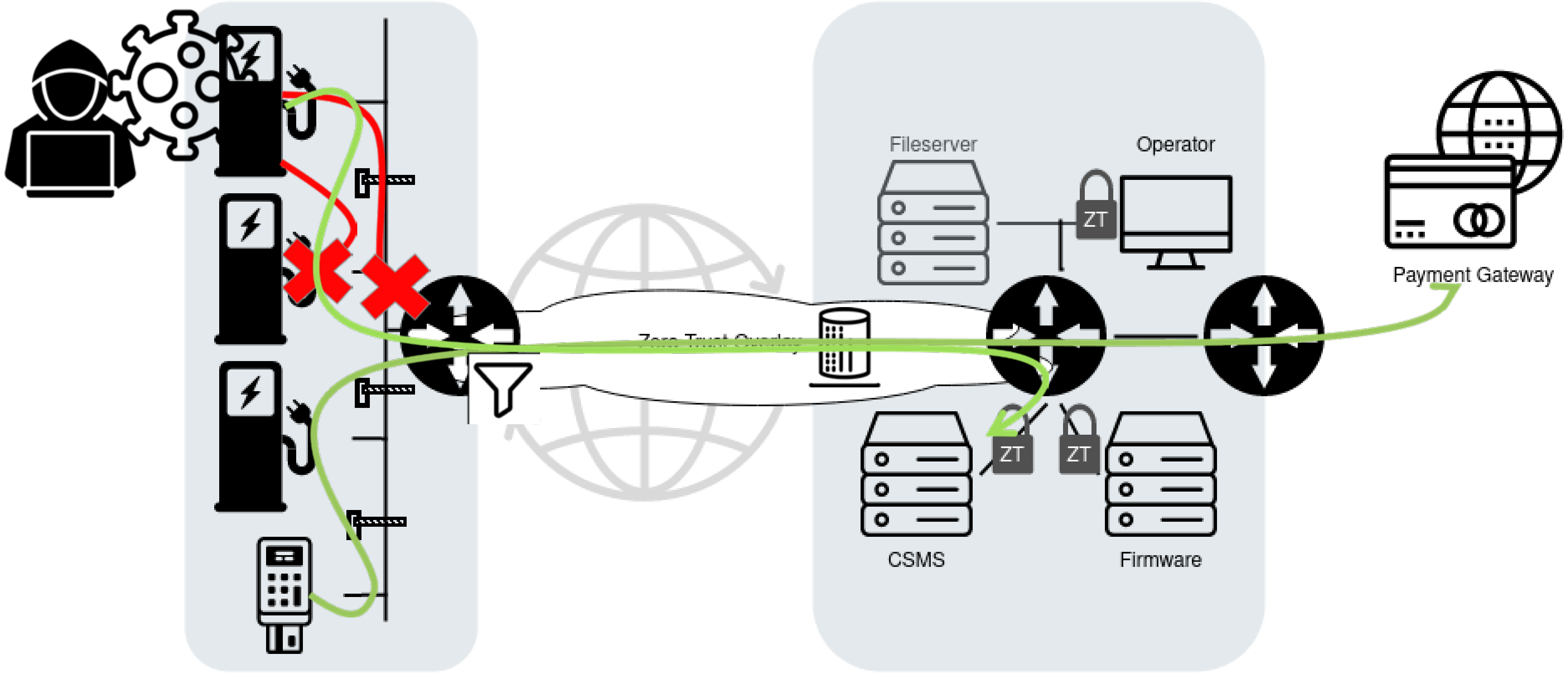
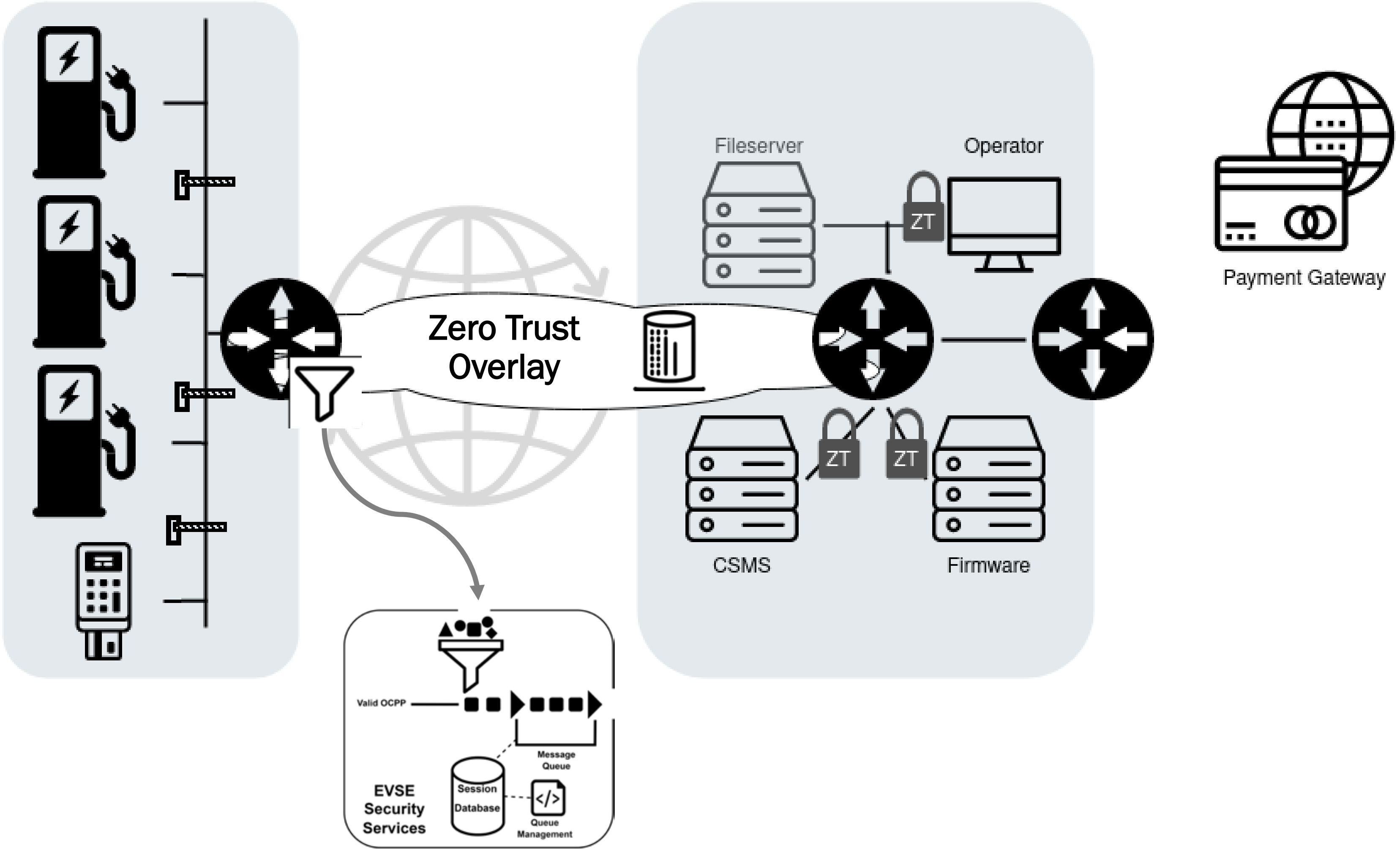
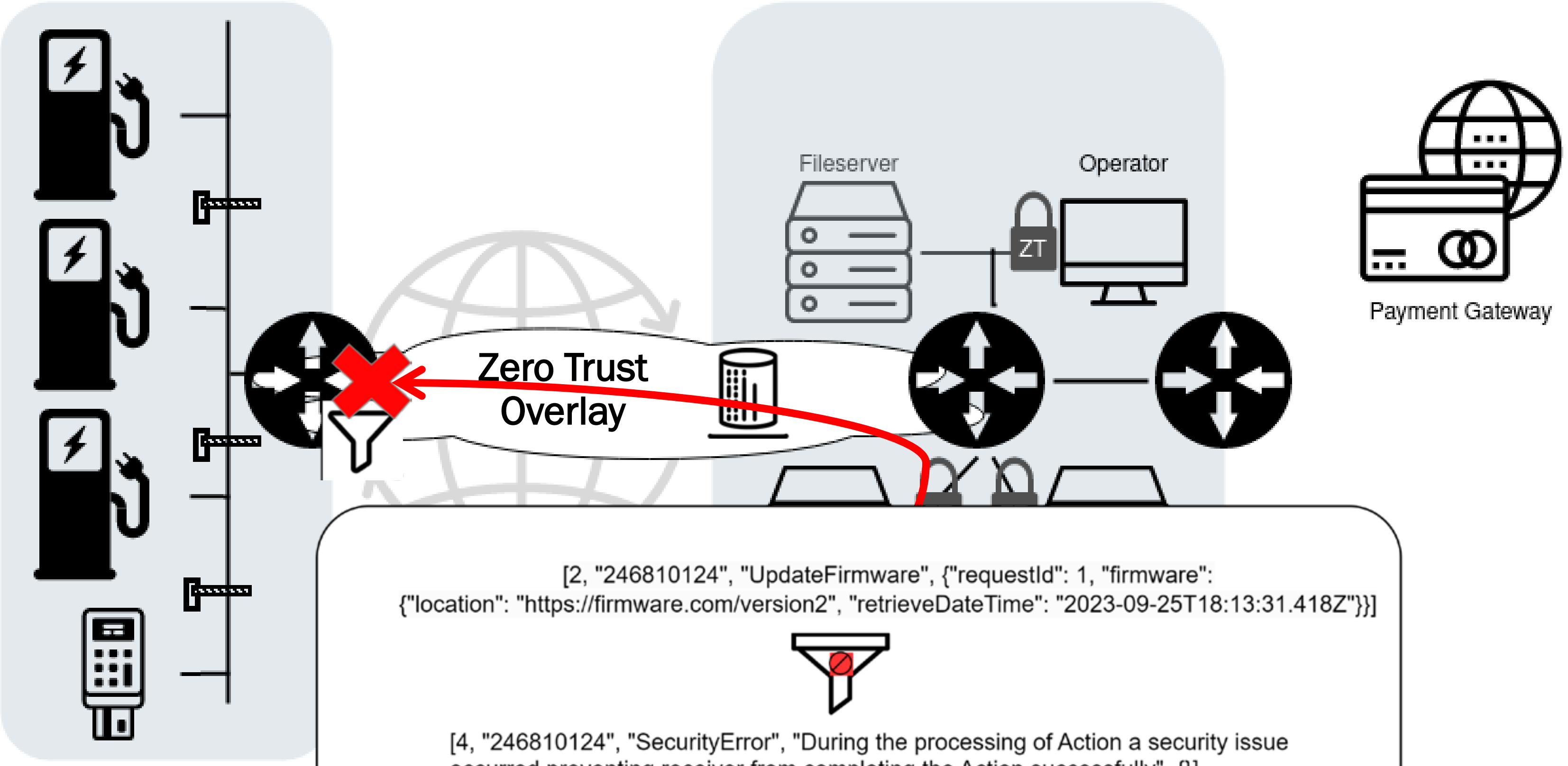


Zero Trust Architecture for EV Service Provider



Zero Trust Architecture for EV Service Provider



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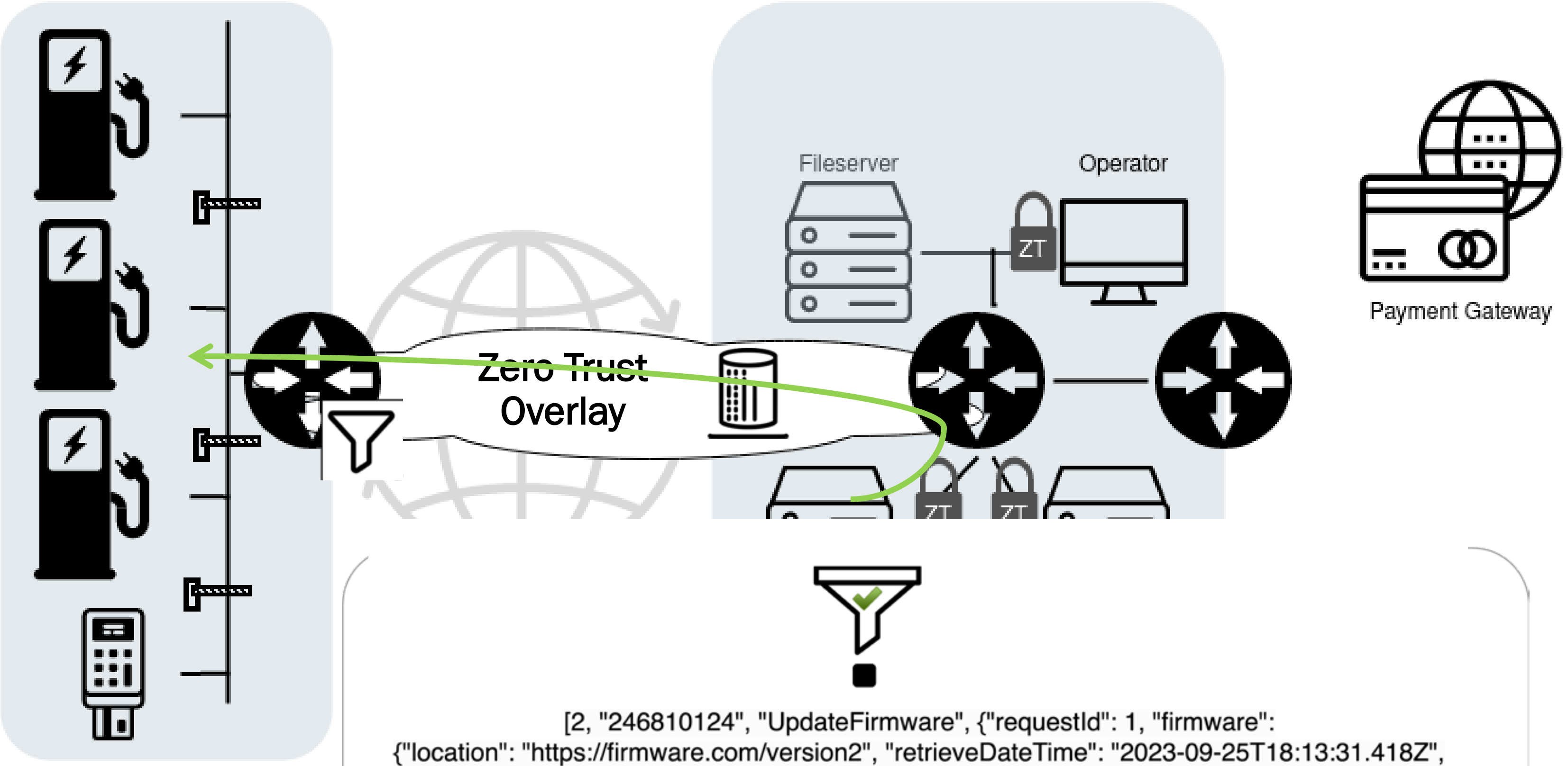
[4, "246810124", "SecurityError", "During the processing of Action a security issue occurred preventing receiver from completing the Action successfully", {}]

Zero Trust Architecture for EV Service Provider



[2, "246810124", "UpdateFirmware", {"requestId": 1, "firmware":
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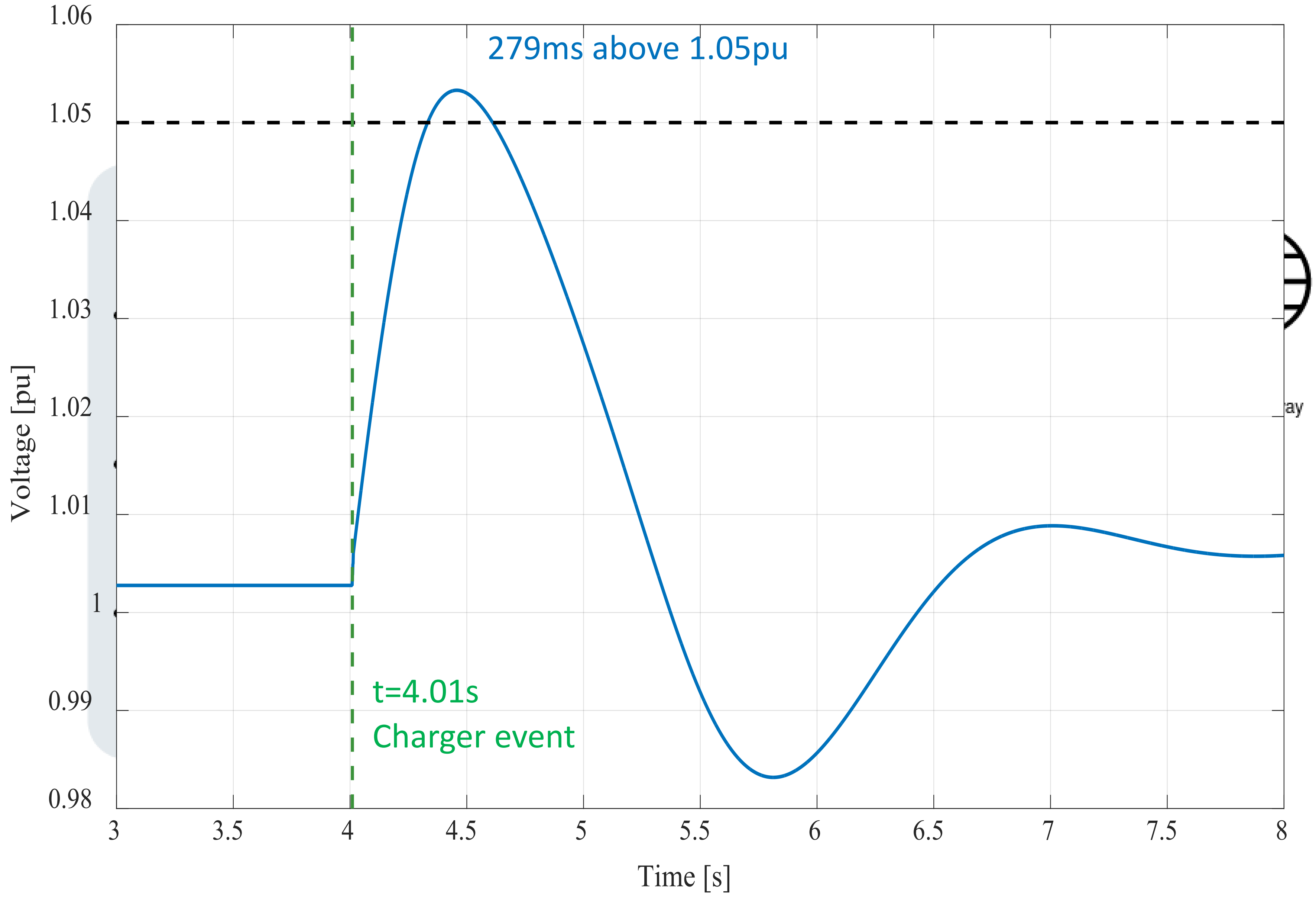
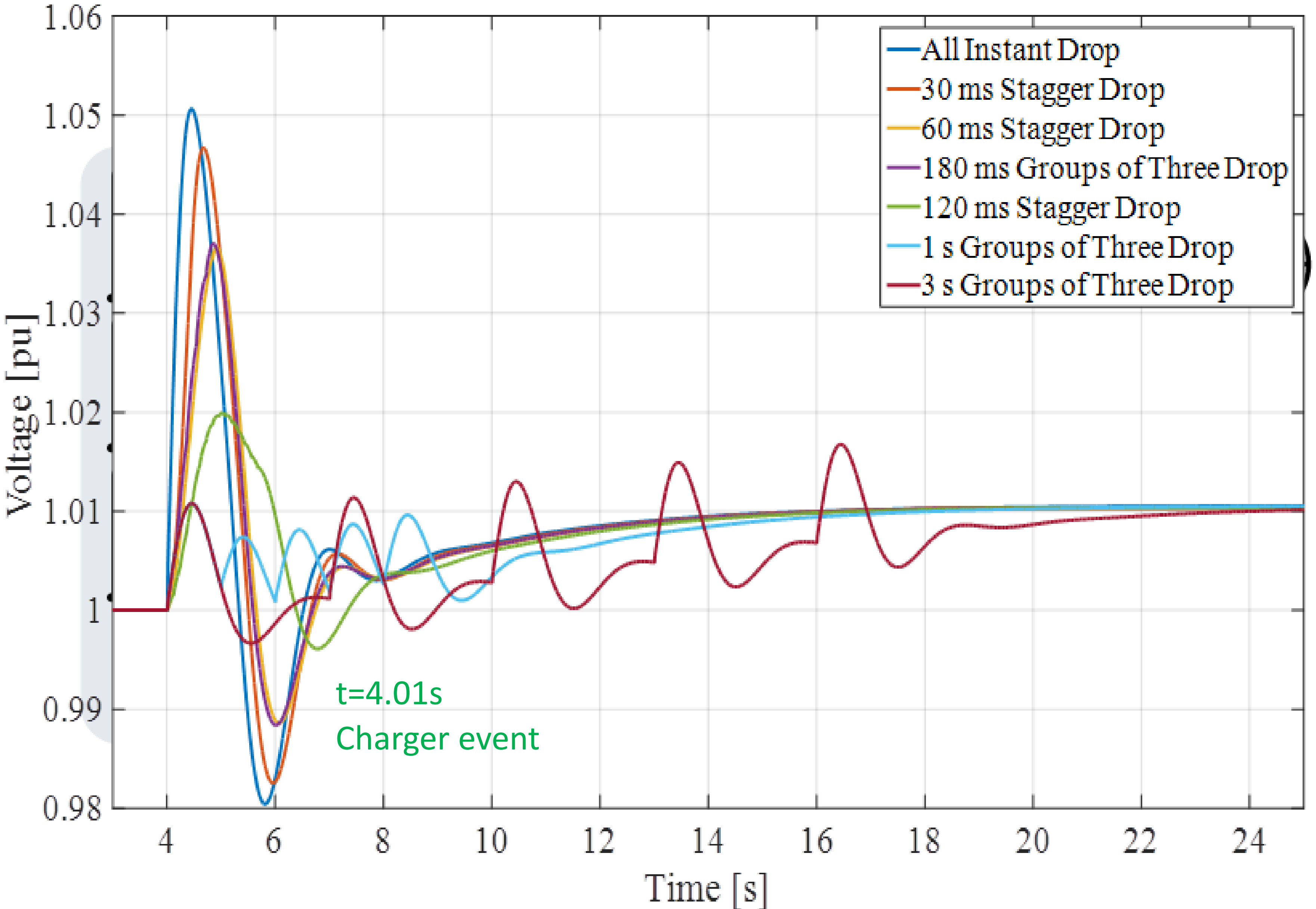
Zero Trust Architecture for EV Service Provider



Zero Trust Architecture for EV Service Provider



Zero Trust Conclusion and Next Steps

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Review

- Evolving test cases informing Zero Trust architecture design
- Test bed prototyping in AWS, using DC FC Charge Emulator
- Evaluated first prototype in context of a subset of test cases
- Cisco, NetFoundry and Talos relationships and mutual engagement deepening with each meeting
- Spun-off a university Senior Design Team

Next steps

- Continue to evolve the use cases, test cases, and evaluation criteria
- Complete third prototype based on Cisco SDWAN and Duo technology stack
- Engage and build relationships with stakeholders – Identify lab and field deployment partners

Post Quantum Cryptography (PQC) Overview

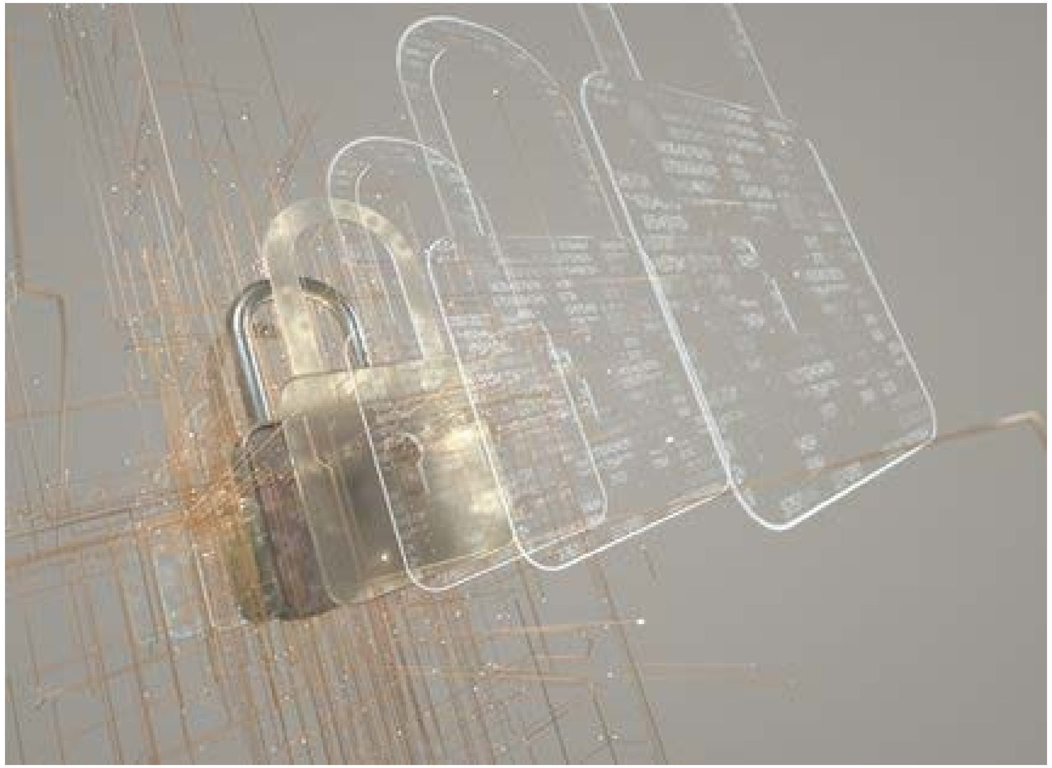
Objective: Study the impact of PQC and develop guidance for an orderly transition

Motivation:

– A Cryptanalytically-Relevant Quantum Computer (QRQC) will defeat traditional public-key cryptography in tens to hundreds of hours
– PQC transition is non-trivial

Outcomes:

– Identify traditional public-key cryptography applications
– Assess PQC impacts with a test-and-measure approach
– Identify challenges
– Develop guidance for an orderly PQC transition



Project Background

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- A QRQC will e… …ey exchange schemes
  → Trust, comm… …e
- PQC are cryptos… …l computers
- Why start now
  - Vehicles and i…
  - Publicly-truste…
  - Time to ratify,…
  - Others are doi…
  - US Gov't sugg…

TIMEFRAME	WHAT ONE MAY EXPECT BASED ON THE EXPERTS' OPINIONS
NEXT 5 YEARS	Most experts (27/40) judged that the threat to current public-key cryptosystems in the next 5 years is "<1% likely". About a quarter of them (9/40) judged it relatively unlikely ("<5% likely"). The rest selected "<30%" (3/40) or "about 50%" (1/40) likely. Overall, *there seems to be a non-negligible chance of an impactful surprise within what would certainly be considered a very short-term future.*
NEXT 10 YEARS	Moving from the previous timeframe to this timeframe corresponds to the largest average sentiment shift (see Figure 7). Within this timeframe, more than half of the respondents (20/40) judged the event is more than 5% likely, and almost a quarter (9/40) felt it was "about 50%" or ">70%" likely, suggesting *there is a significant chance that the quantum threat becomes concrete in this timeframe.*
NEXT 15 YEARS	More than half (22/40) of the respondents indicated "about 50%" likely or more likely, among whom 11 indicated a ">70%" likelihood or higher. *This time frame appears to be a tipping point, as the number of respondents estimating a likelihood of "about 50%" or larger become the majority.*
NEXT 20 YEARS	More than 90% (37/40) of respondents indicated "about 50%" or more likely, with 10/40 pointing to ">95%" or ">99%" likely. This indicates *there is a significant tendency toward viewing the realization of the quantum threat as substantially more likely than not within this timeframe.*
NEXT 30 YEARS	Thirty-five experts out of 40 indicated that the quantum threat has a likelihood of 70% or more this far into the future, with more than a quarter of the experts (11/40) indicating a likelihood greater than 99%. Thus, *there appears to be a relatively low expectation of any fundamental show-stoppers or other reasons that a cryptographically-relevant quantum computer would not be realized in the long run.*

Mosca, Michelle and Marco Piana (2022) "*Quantum Threat Timeline Report 2022*"

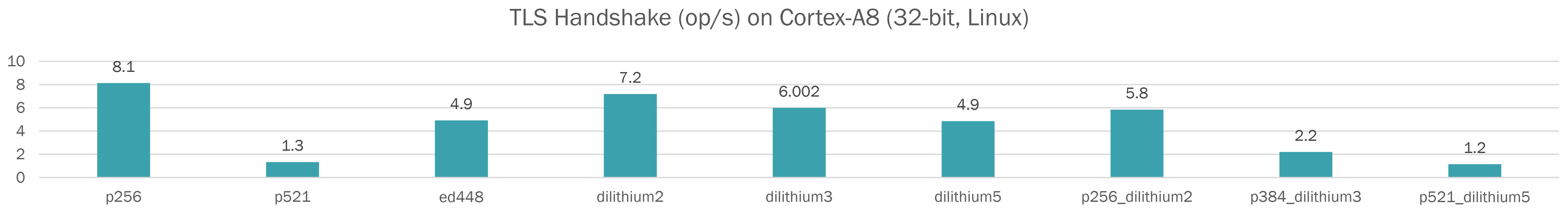
What is being done in this space?

- NIST is completing the process of standardizing Post Quantum Cryptography methods
- IETF actively working on specifying PQC elements for X.509 Certificates and TLS
- NIST releases draft SP 1800-38A "Migration to Post-Quantum Cryptography: Preparation for Considering the Implementation and Adoption of Quantum Safe Cryptography"
- PNNL-34843 "Where Public Key Cryptography is Used in Electric Vehicle Charging" inventories public key cryptography applications in the EV charging infrastructure and protocols

	Traditional			PQC			Hybrid		
	P-256	P-521	ED448	DILITHIUM2	DILITHIUM3	DILITHIUM5	P256+ DILITHIUM2	P-384+ DILITHIUM3	P-521+ DILITHIUM5
Traditional Security	128	256	256	128	192	256	128	192	256
Qubit Security	-	-	-	85	96	128	85	96	128
Security Level	-	-	-	2	3	5	2	3	5

PQC Test & Measure

		Traditional			PQC		
		P-256	P-521	Ed448	Dilithium2	Dilithium3	Dilithium5
Size (bytes)	Public Key	64	130	57	1312	1952	2592
	Private Key	32	65	57	2528	4000	4864
	Signature	64	130	114	2420	3293	4595



- **Dilithium keys and signatures are significantly larger than P-256 (20.50-40.5x and 37.81-71.8x)**
- **PQC are comparable with P-256, bests P-521 for all but P521+Dilithium5**

Preliminary Findings & Preparations

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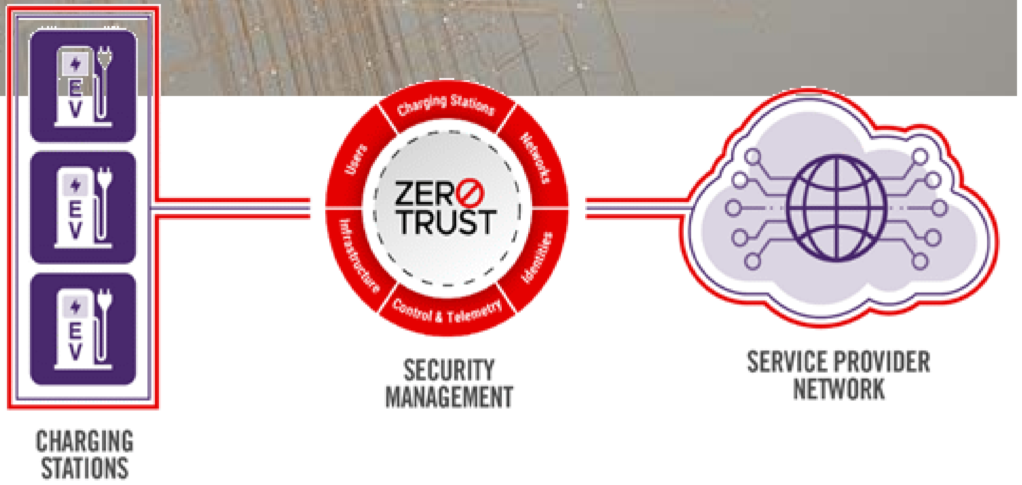
- Findings & Impacts
  - Dilithium & hybrids compute time & memory working set are larger, but not concerning for small devices
  - For TLS 1.3, cost is paid at connection setup. Once established, low-cost symmetric cryptography is activated (AEAD)
  - Larger data is not concerning for PLC, LTE, or Ethernet, but may delay connection setup, increase messaging latency
    - Messages may span TCP segments
- Preparations
  - Establish a development & testing Dilithium 3 / P-384+Dilithium3 V2G Root
  - Increase capacity of data structures conveying certificates and signatures
    - Also consider more efficient representation
  - EVSEs, CSMS, etc. are issued a certificate for each cryptosystem, chose certificate based on client preference

Zero Trust may speed PQC deployment

- Many Zero Trust strategies make extensive use of public key cryptography
- Zero Trust frameworks are characterized by a degree of crypto-agility, the capacity to switch out algorithms and parameters
- Transition the Zero Trust frameworks earlier, while solving challenges for public-trusted public key infrastructure



PQC Conclusion and Next Steps

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Review

- Completed inventory of traditional public-key cryptography applications in EV charging
- On-going resource assessment of compute, memory and storage
- Our testing indicates larger CRYSTALS-Dilithium / CRYSTALS-KYBER resources are of little concern for embedded devices, PLC, LTE
- Our testing indicates CRYSTALS-Dilithium resources are reasonable, especially when compared to P-521, and should be considered to secure EVCI, future 15118 standards

Next steps

- Complete resource assessment
- Report PQC impacts and challenges

Thank You!

Join us for the

Cyber-Physical Security Deep Dive on October 10th

Thomas.Carroll@pnnl.gov

EVs@Scale

U.S. Department of Energy

Backup slides with Supporting Data

Public, Private, Signature lengths / Absolute and Relative

	p256		p521		Ed448		Dilithium2		Dilithium5		Dilithium2_p256		Dilithium5_p521	
	Absolute Value	Relative Value	Absolute Value	Relative Value	Absolute Value	Relative Value	Absolute Value	Relative Value	Absolute Value	Relative Value	Absolute Value	Relative Value	Absolute Value	Relative Value
Public Key	64	1	130	2.03	57	0.89	1312	20.50	2592	40.5	1376	21.5	2722	42.53
Private Key	32	1	65	2.03	57	1.78	2528	79	4864	152	2560	80	4929	154.03
Signature	64	1	130	2.03	114	1.78	2420	37.81	4595	71.80	2484	38.81	4725	73.83

Timings on RPi3 (A53)

		p256	p521	ed448	dilithium2	dilithium3	dilithium5	p256_dilithium2	p384_dilithium3	p521_dilithium5
Absolute Time (op/s)	Time to Create Signature	5765	59.9	456.2	1053.9	682.2	531.5	880.9	120.7	53.4
	Time to Verify Signature	1937	78.6	319.5	3206.6	1936.5	1120.9	1189.7	166.7	72.5
	Time to TLS "Hello"	108.2	5.29	23.077	104.109	74.688	51.619	55.149	9.694	4.307
	Total TLS Handshake Time	10.8	3.669	7.5	9.833	9.309	8.696	8.827	5.061	3.063
Relative Time	Time to Create Signature	1	0.01	0.079	0.183	0.118	0.092	0.153	0.021	0.009
	Time to Verify Signature	1	0.041	0.165	1.655	1	0.579	0.614	0.086	0.037
	Time to TLS "Hello"	1	0.049	0.213	0.962	0.69	0.477	0.509	0.09	0.04
	Total TLS Handshake Time	1	0.34	0.695	0.911	0.862	0.805	0.818	0.469	0.284

Timings on ARM Cortex-a8 (32-bit, Linux)

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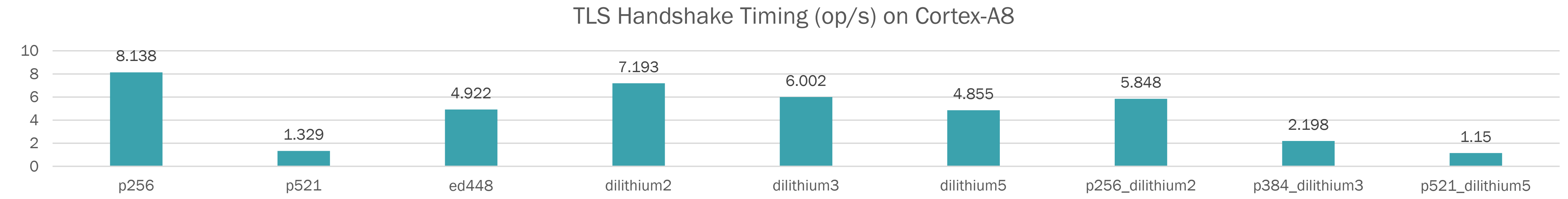
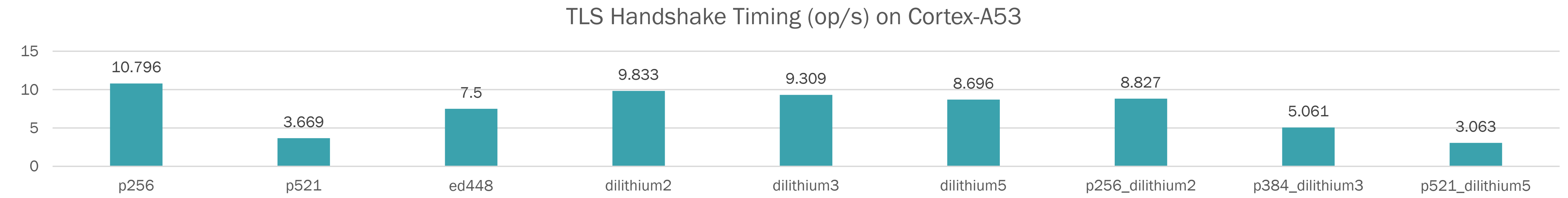
		p256	p521	ed448	dilithium2	dilithium3	dilithium5	p256_dilithium2	p384_dilithium3	p521_dilithium5
Absolute Time (op/s)	Time to Create Signature	1440	16.6	257.5	111.9	69.3	49.8	94.6	23.8	12.4
	Time to Verify Signature	489.8	22.9	102.5	337.8	200.3	114.7	174	40	18.5
	Time to TLS "Hello"	29.65	1.506	8.705	19.788	12.816	8.518	12.142	2.73	1.28
	Total TLS Handshake Time	8.138	1.329	4.922	7.193	6.002	4.855	5.848	2.198	1.15
Relative Time	Time to Create Signature	1	0.012	0.179	0.078	0.048	0.035	0.066	0.017	0.009
	Time to Verify Signature	1	0.047	0.209	0.69	0.409	0.234	0.355	0.082	0.038
	Time to TLS "Hello"	1	0.051	0.294	0.667	0.432	0.287	0.41	0.092	0.043
	Total TLS Handshake Time	1	0.163	0.605	0.884	0.738	0.597	0.719	0.27	0.141

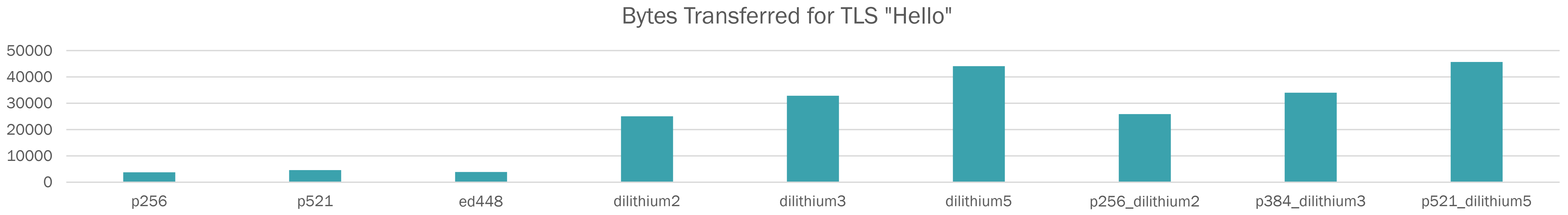
Transfer Bytes

		p256	p521	ed448	dilithium2	dilithium3	dilithium5	p256_dilithium2	p384_dilithium3	p521_dilithium5
Bytes Transferred for TLS "Hello"	Absolute Value	3774	4586	3879	25047	32845	44103	25901	34022	45705
	Relative Value	1	1.215	1.028	6.637	8.703	11.686	6.863	9.015	12.11

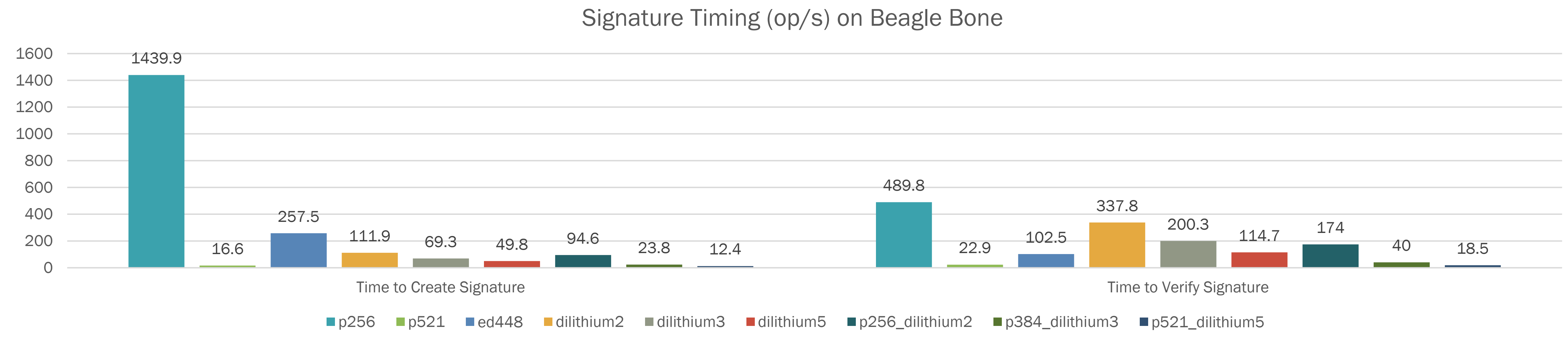
Comparison: TLS Timing & Transferred Bytes

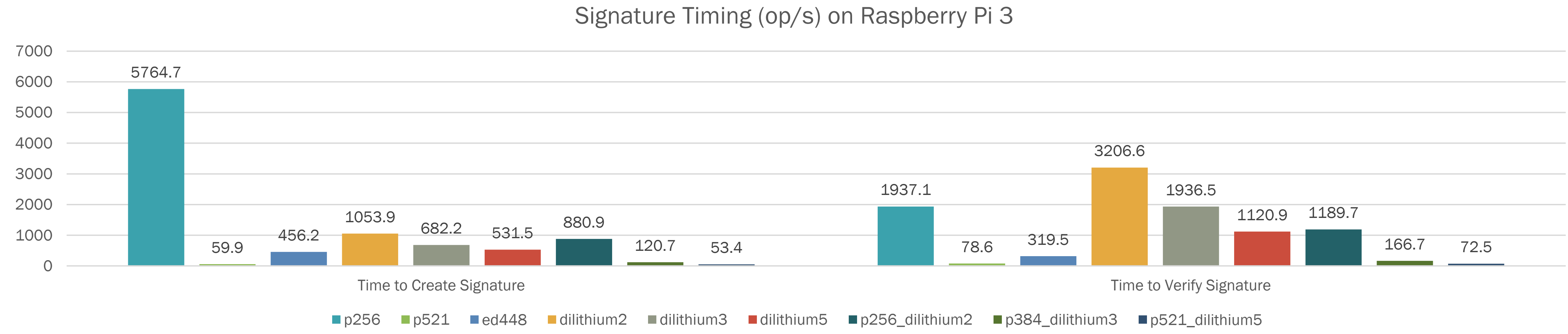






Comparison: Signature





PQC Keys and Digital Signatures are Larger

		Traditional			PQC		Hybrid	
		P-256	P-521	Ed448	Dilithium2	Dilithium5	P256+Dilithium2	P521+Dilithium5
Size (bytes)	Public Key	64	130	57	1312	2592	1376	2722
	Private Key	32	65	57	2528	4864	2560	4929
	Signature	64	130	114	2420	4595	2484	4725
Relative Size	Public Key	1	2.03	0.89	20.50	40.5	22	43
	Private Key	1	2.03	1.78	79.00	152	80	154
	Signature	1	2.03	1.78	37.81	71.8	39	74

EVs @ Scale
U.S. Department of Energy

Flexible charging to Unify the grid and transportation Sectors for EVs at scale (FUSE)

Jesse Bennett

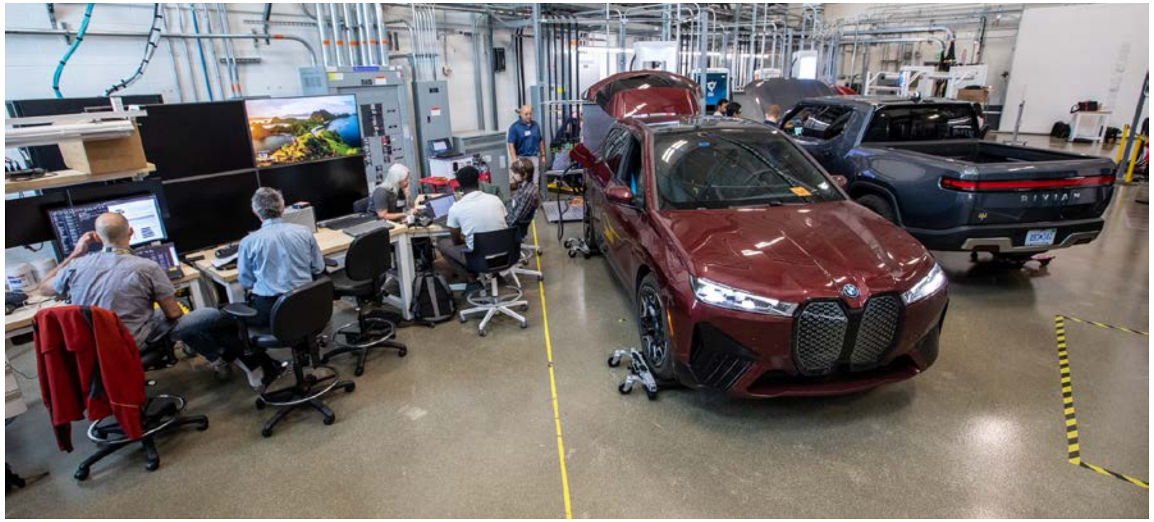
September 27, 2023

EVs@Scale FUSE - Overview

EVs@Scale U.S. Department of Energy

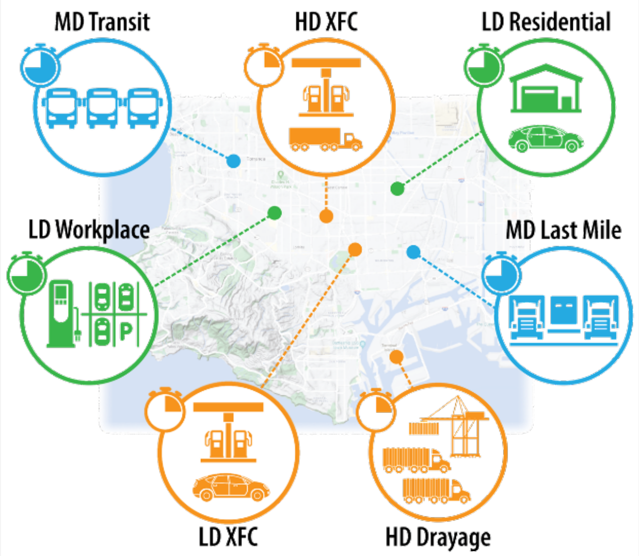
Objective:

- Develop an adaptive ecosystem of smart charge management (SCM) and vehicle grid integration (VGI) strategies and tools relevant to assess and reduce barriers to electrification throughout a wide geographic area and across numerous vocations



Outcomes:

- **Broadly identify limitations and gaps** in the existing VGI and SCM strategies to strategically shift PEV charging in time across a wide range of conditions
- **Develop enabling technologies** and demonstrate VGI approaches to reduce grid impacts throughout the entirety of the **LD, MD, and HD on-road electric fleet** while accounting for vehicle operational and energy requirements.
- **Determine SCM and VGI benefits** for consumers and utilities for EVs@Scale across the range of conditions (geographies and seasons) found in the US



EVs@Scale FUSE - Team and Partners

EVs@Scale
U.S. Department of Energy

Team:

- **National Renewable Energy Laboratory (NREL)**
  - Vehicle Charging, Grid Impact Analysis, SCM/VGI Development and Demonstration
- **Argonne National Laboratory (ANL)**
  - SCM/VGI Development and Demonstration
- **Idaho National Laboratory (INL)**
  - Vehicle Charging Analysis, SCM/VGI Development
- **Sandia National Laboratories (Sandia)**
  - Grid impact Analysis

Industry Partners/Data Sources:

- **Electric Distribution Utilities**
  - Dominion Energy (100+ distribution feeder models throughout VA)
- **Vehicle Travel Data**
  - Wejo (~400 million LDV trips in VA for Sept. '21 and Feb. '22)
  - GeoTab Altitude API Access MD/HD vehicle operations)

NREL Transforming ENERGY

Jesse Bennett
Matt Bruchon
Shibani Ghosh
Yi He
Zhaocai Liu
Nadia Panossian
Priti Paudyal
Emin Ucer
Wenbo Wang
Mingzhi Zhang

INL Idaho National Laboratory

Manoj Sundarrajan
Jean Chu
Tim Pennington
Steven Schmidt

Argonne NATIONAL LABORATORY

Jason Harper
Dan Dobrzynski
Bryan Nystrom

Sandia National Laboratories

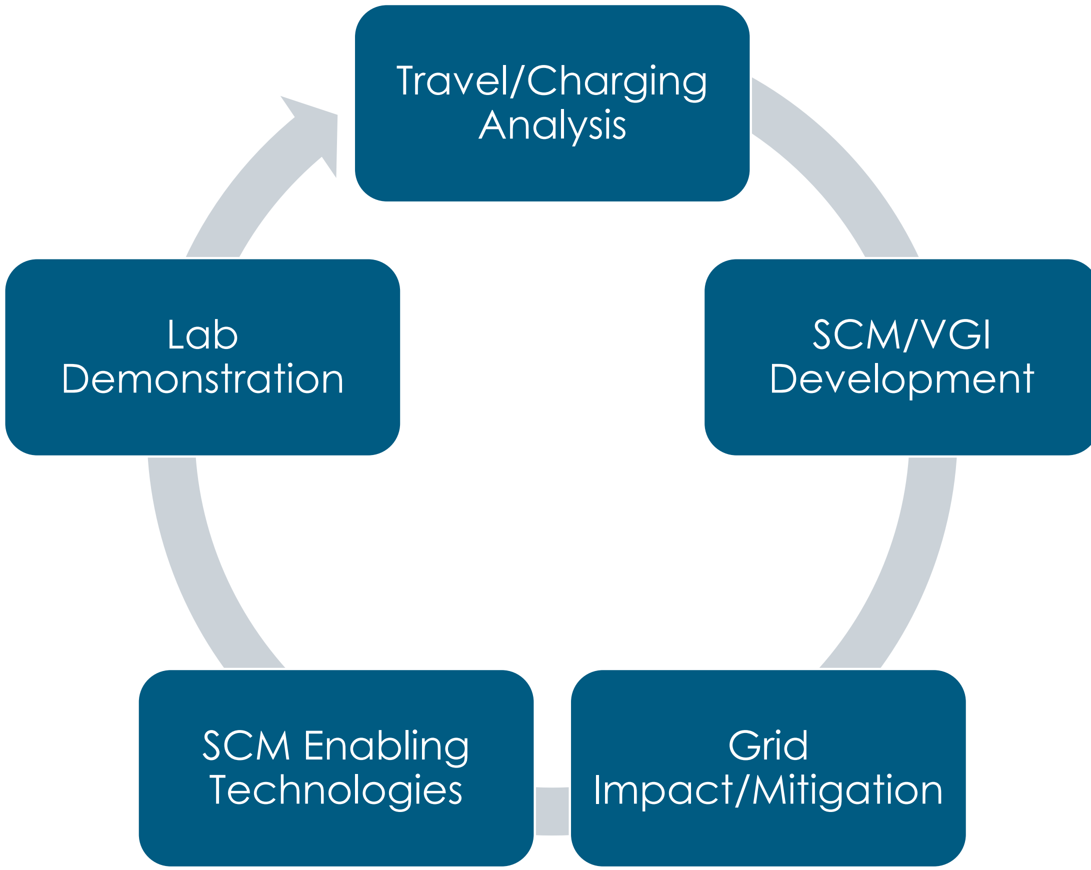
Jeewon Choi
Matt Lave
Andrea Mammoli
Emily Moog
Will Vining

EVs@Scale FUSE - Approach and Outcomes

- **This project will analyze and demonstrate SCM and VGI approaches to reduce grid impacts from EVs@Scale as a result of the charging needs of the LD, MD, and HD on-road electrified fleet.**

- **SCM/VGI Analysis**
  - Assess the potential charging demand for EVs@Scale and determine the uncontrolled charging grid impacts.
  - Develop and analyze the effectiveness of various VGI and SCM strategies at mitigating the grid impacts of charging EVs@Scale

- **SCM/VGI Demonstration**
  - Expand on existing SCM/VGI strategies to adapt to the evolving needs EVs@Scale throughout a wide range of vehicles and vocations.
  - Develop enabling technologies to demonstrate the potential for new and existing SCM and VGI in a laboratory and real-world environment.
  - Coordinate with Codes and Standards Pillar to determine the potential of existing technologies and need for future developments.



EVrest: EV Reservation System

ANL Deployment

EVs@Scale U.S. Department of Energy

- EV Charge Reservation Mobile App
  - iOS and Android
- Allows EV Drivers the Ability to Reserve a Specific Port/Station for Future Use
- Integrates with ANL's OCPP CSMS Platform to Enable Future Smart Charging Algorithm
- Development and EV Charging Behavior Research
- Deployed at Smart Energy Plaza for use with Argonne Employees

OptiQ: Smart L2 EVSE

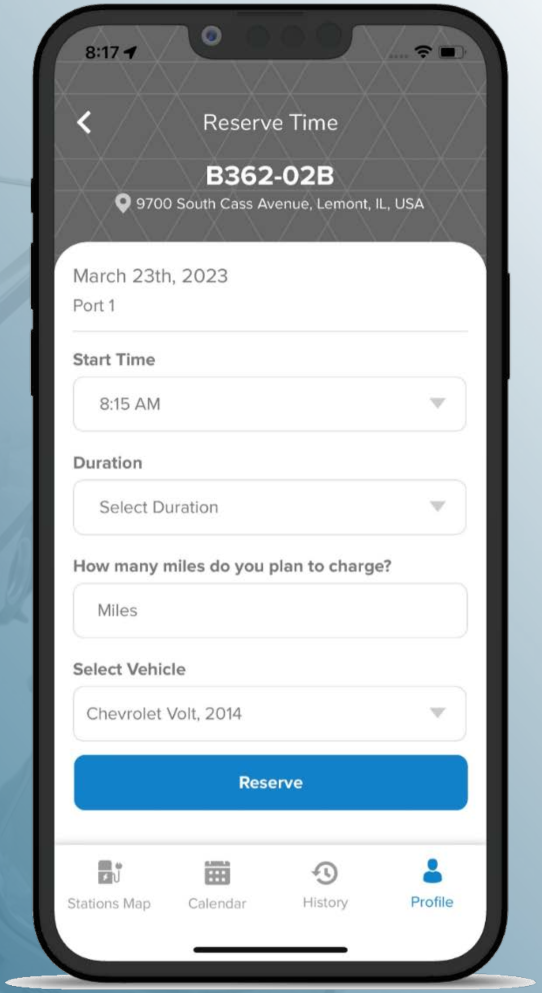
Development and Deployment

- Deploys 4 Protocols
  - J1772 (PWM)
  - Tesla SWCAN
  - ISO-15118 (-2, -20 WIP)
  - DIN Spoofing
- Revenue Grade AC Submeter
- OCPP 1.6J to CSMS (2.0.1 WIP)
- Enables Smart Charge Scheduling
- Charge Scheduler Bridge Application developed to Enable non-ISO 15118 vehicles to participate in Charge Scheduling

Available for Licensing: https://www.anl.gov/partnerships/optiq-a-smart-l2-charge-station

Charge Scheduler Bridge

- Middleware Application that Integrates with EVrest and the ISO 15118 Charge Scheduler to Schedule EV Charging on Behalf of non-ISO 15118 EV/EVSE
- Needed to enable optimized charge scheduling for non-ISO 15118 EV/EVSE



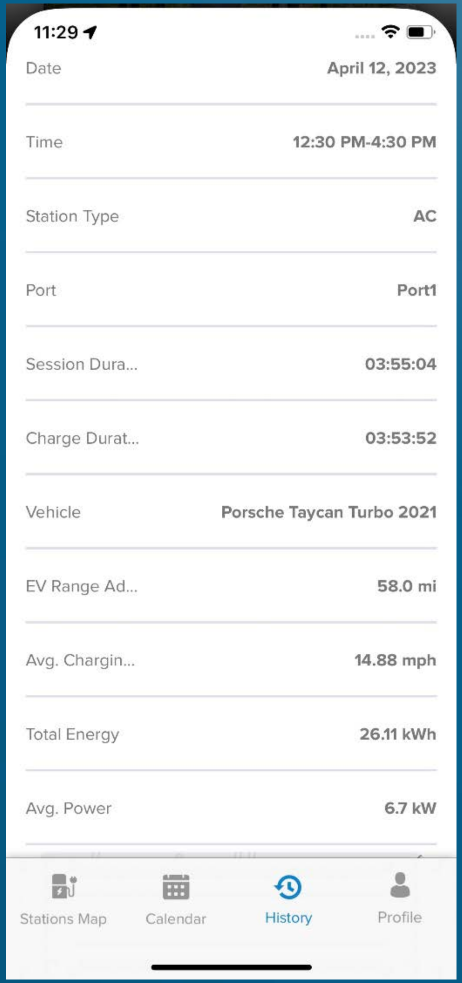
Goal

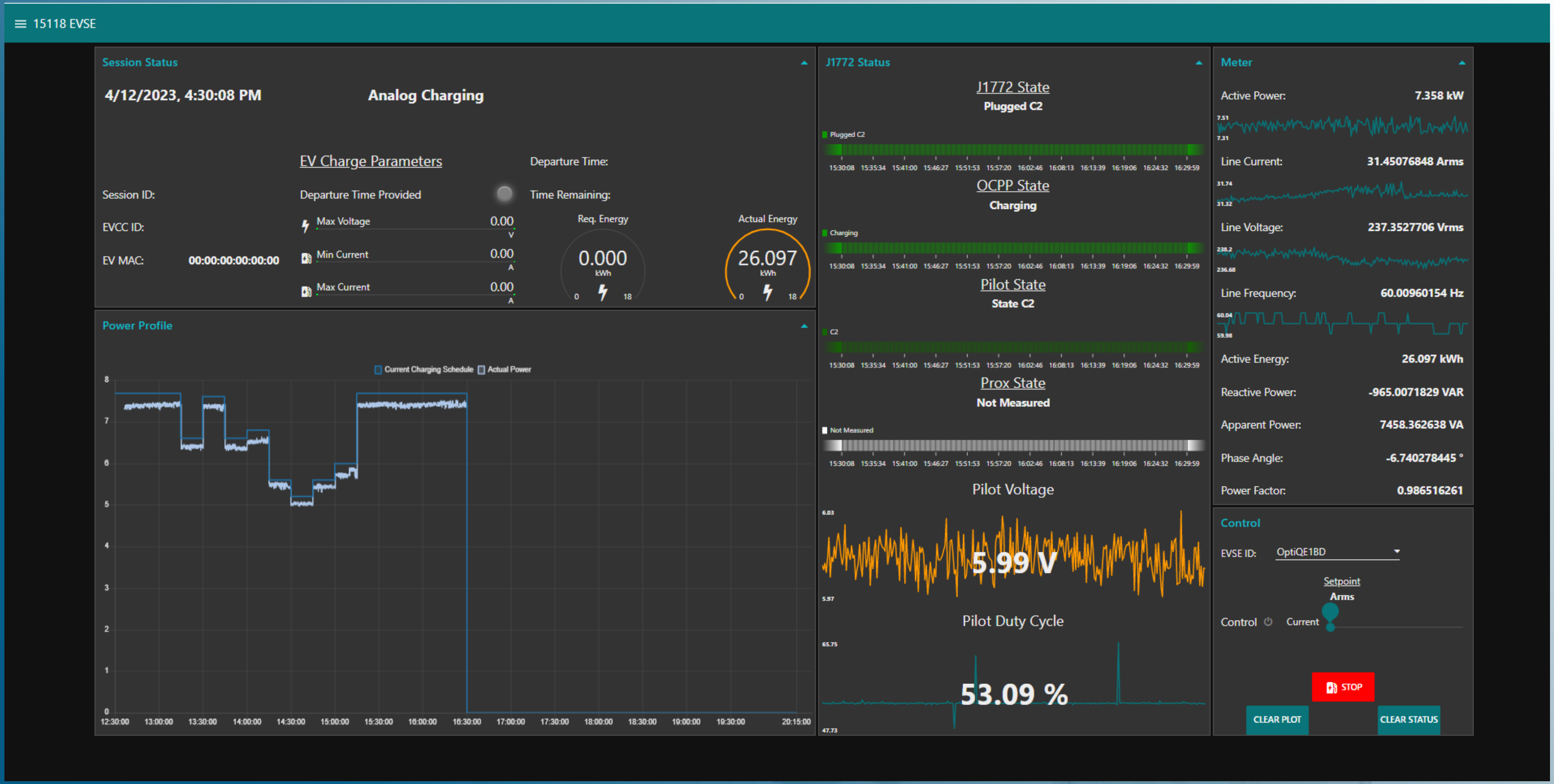
- Work with any OCPP 1.6J station (integrated in EVrest)
- Work with any AC J1772 EV

Key Elements of a Charge Schedule:
- Charge Start Time
- Charge End Time
- Requested Energy (kWH)
- Max Rate of Charge (kW)

2021 Porsche Taycan

Scheduler Bridge Demo





Although Taycan capable of ISO-15118 Charge Scheduling, Charge Scheduler Bridge was utilized to schedule this charge session.

OCPP Performance Testing and SCM Demonstrations

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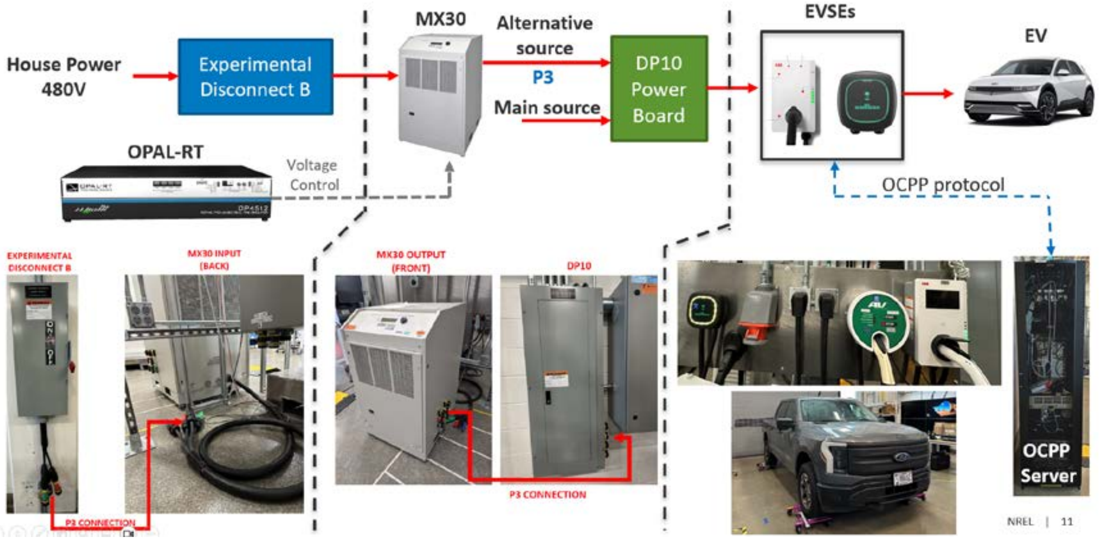
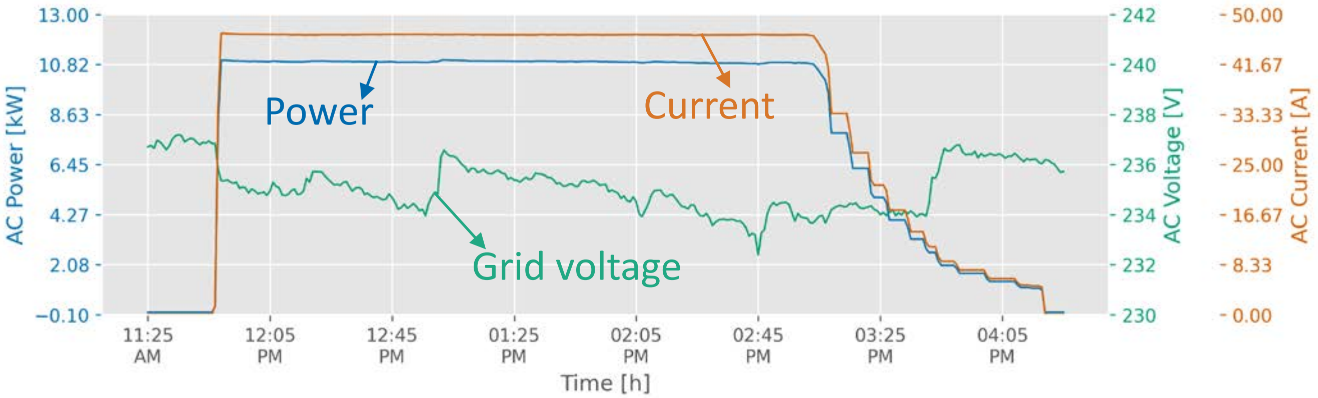
Experimental Testbed



Some initial charging test results (F150 65%-100%)



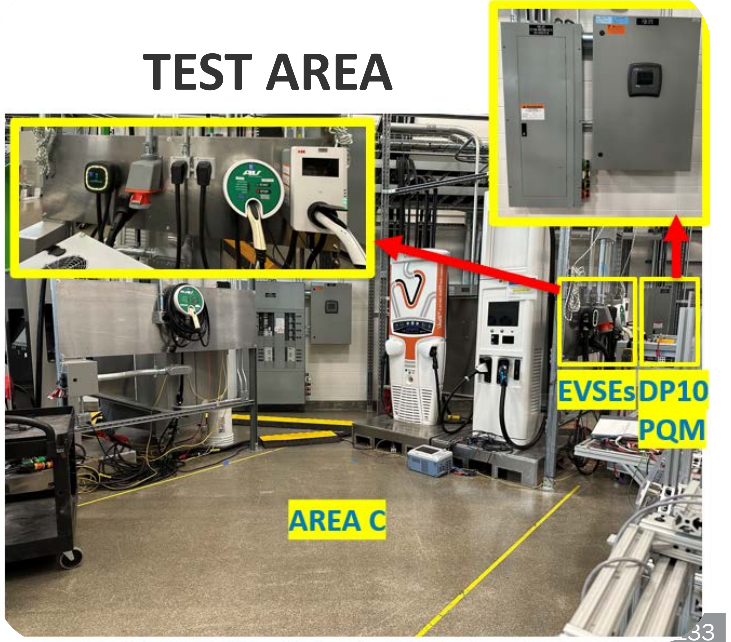
Completion of installation: 8/2/2023
Testing began: 8/11/2023

OCPP Performance testing plans

- Response time measurements
- Accuracy, precision and frequency characterization
- EVSE and EV response to grid-related events
- Testing and verification of SCM capabilities

EVSEs

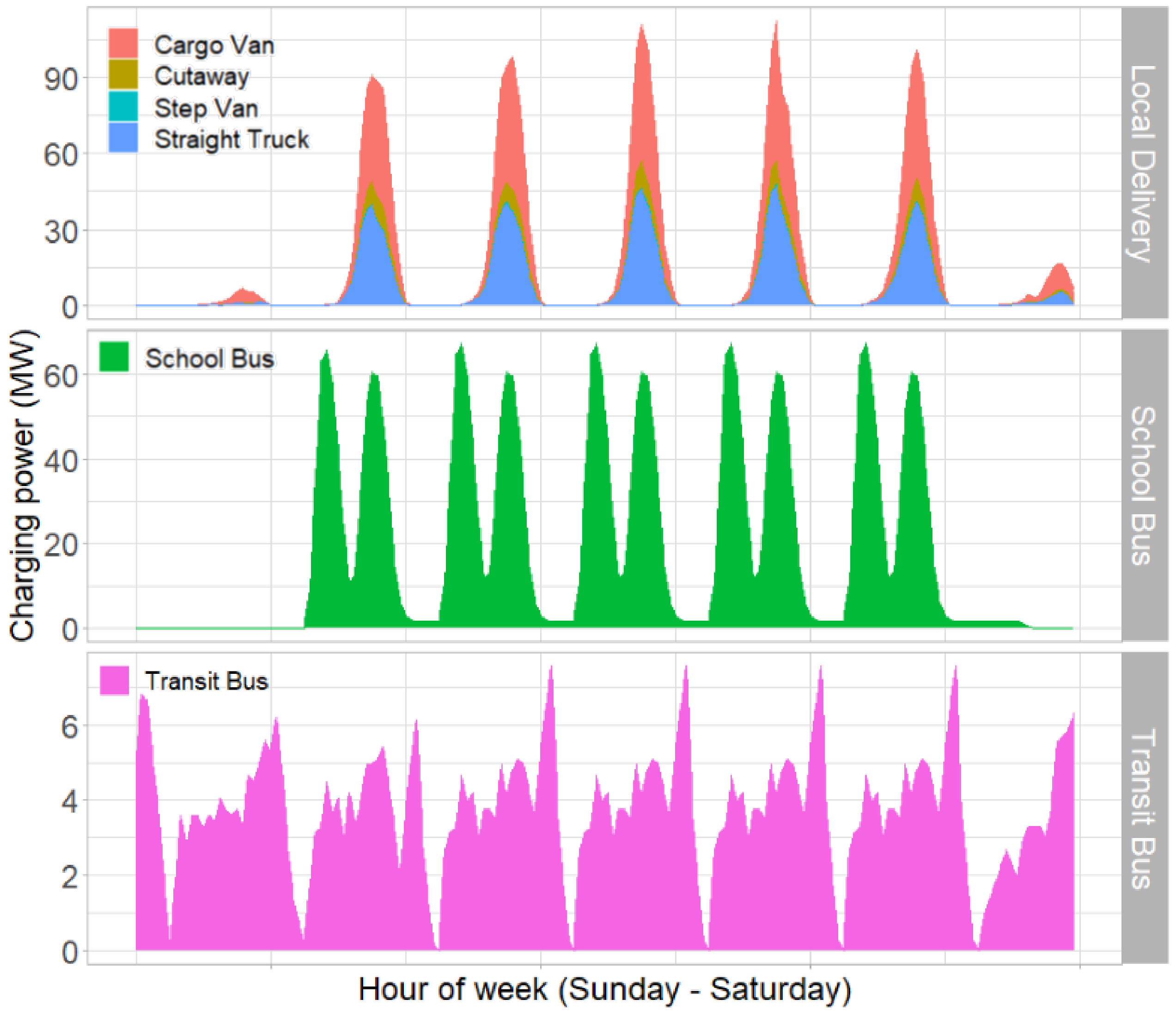
TEST AREA



Transportation Loads: Medium/Heavy Duty Vehicle Modeling

- Long-dwell, domicile-centric vocations were prioritized for the first set of M/HDV analyses
- Weekly synthetic charging itineraries for Newport News & Richmond were created and delivered to grid modeling team:
  - Local delivery vehicles (Class 2b-6) using Geotab Altitude API data
  - School buses using FleetDNA data
  - Transit buses using General Transit Feed Specification (GTFS) data
- The next stage of analysis will shift focus to regional freight (including drayage trucks) and long-haul freight

Weekly load profiles for initial M/HDV vocations

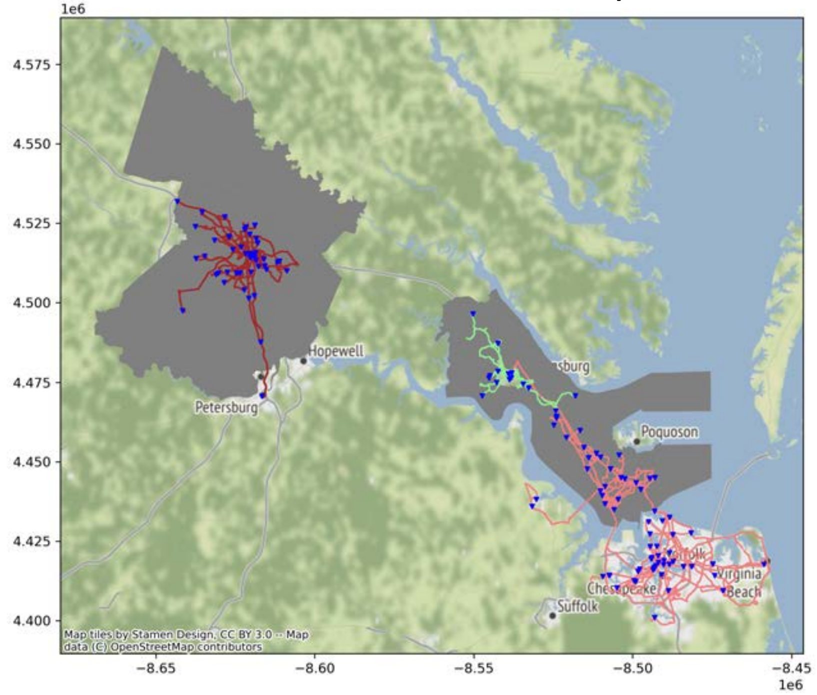


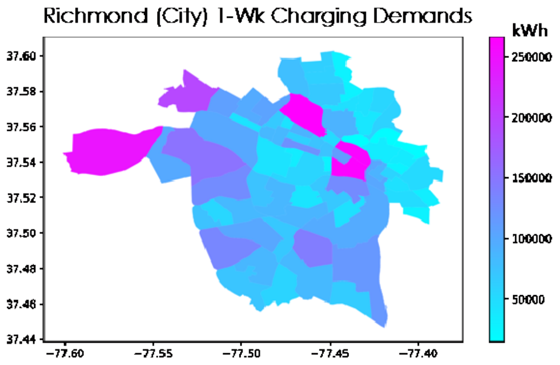
Transportation Loads: Additional Updates

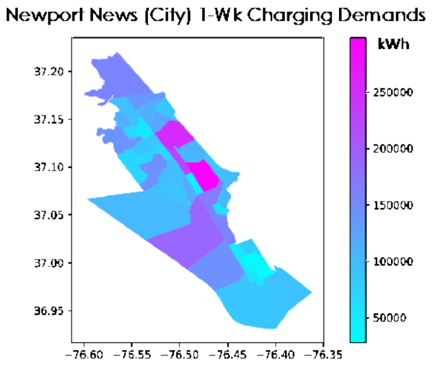
EVs@Scale
U.S. Department of Energy

- **Light Duty Vehicle (LDV) analysis refinements:**
  - Generated results for February 2022
  - Refined assignment of vehicles to parcels, and of home charging accessibility, to ensure consistency across September and February
  - Augmented charging events data to include full activity charging and trips (discharging) and lat-long coordinates
  - Investigated the probability of concurrent charging events at shared sites
  - Facilitating use of passenger EV charging data sets (shared with NREL grid team and INL charging analysis team)
- **Publication and presentations:**
  - Presented FUSE LDV analysis at the 2023 DICE conference
  - Drafted a conference paper for 2023 ECCE conference and will present the FUSE LDV analysis in October
  - Drafted a journal paper that is being reviewed by Transportation Research Part D
  - Planning to draft a journal paper focused on first three Medium/Heavy Duty Vehicle vocations (long dwell)

GTFS Data for Richmond & Newport News







Mid-route charging analysis

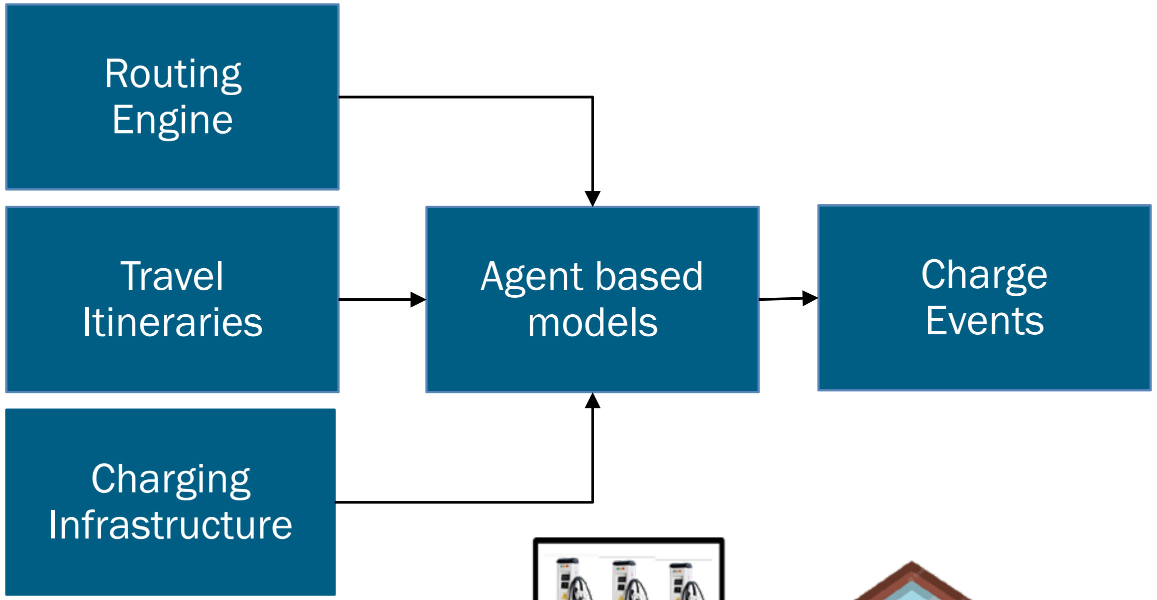
Steps completed:

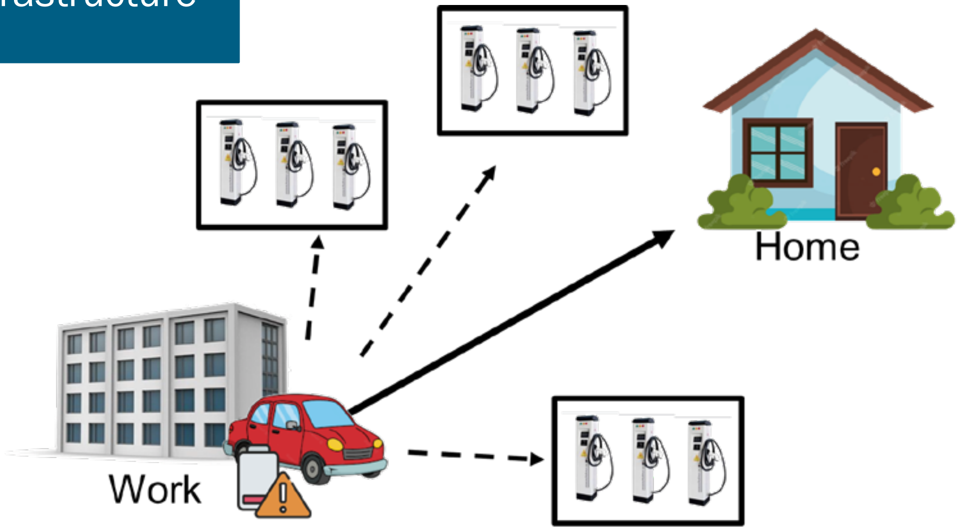
- Developed an agent-based EV charge event modelling platform – Caldera Charging Decision Model (CDM).
- Ran preliminary simulations modelling mid–route charging with itineraries from Richmond and Newport News.

Next steps:

- Fine tune and improve the agent based simulations in Virginia.
- Develop XFC price incentive SCM with Stationary Energy Storage (SES) for temporal and spatial XFC controls.

Caldera CDM block diagram

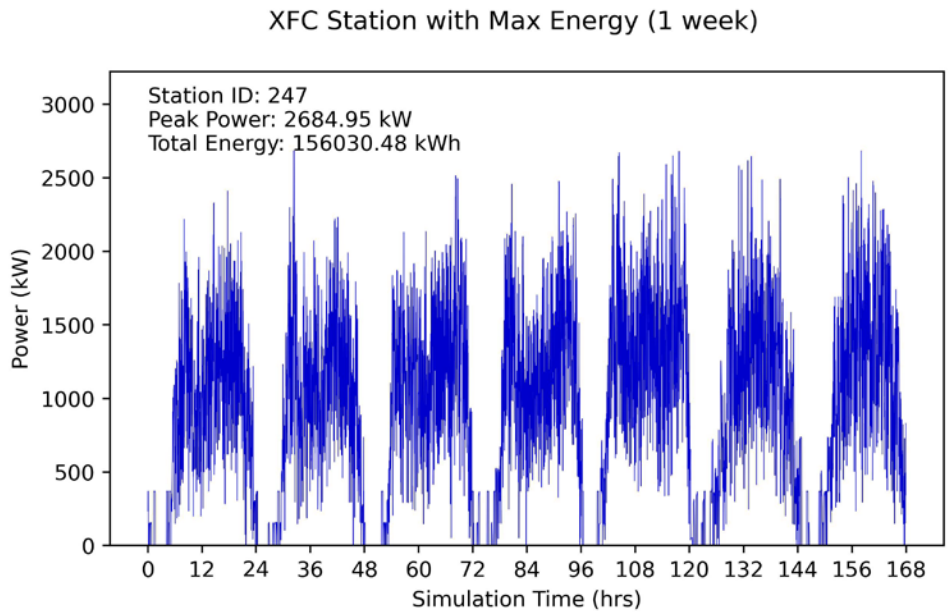


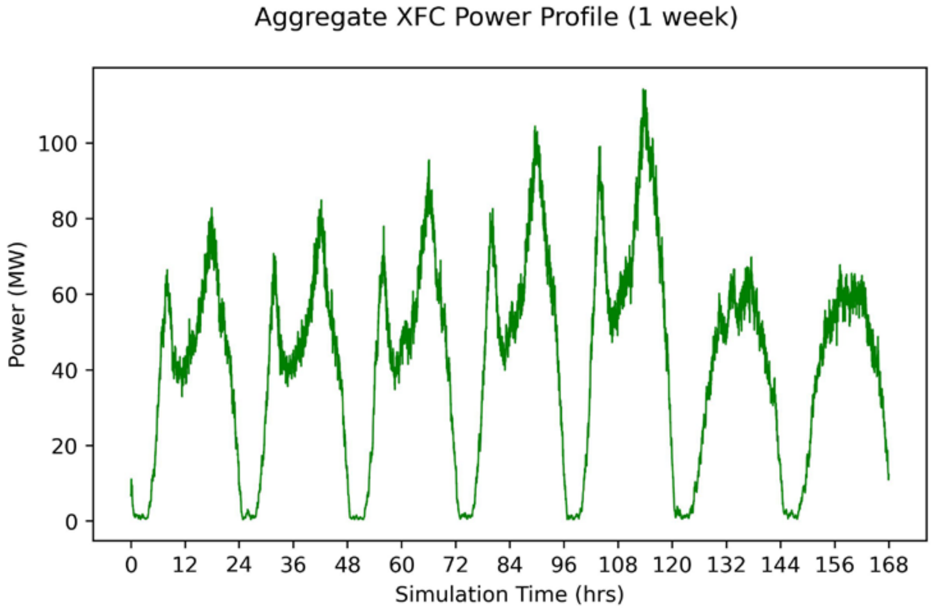


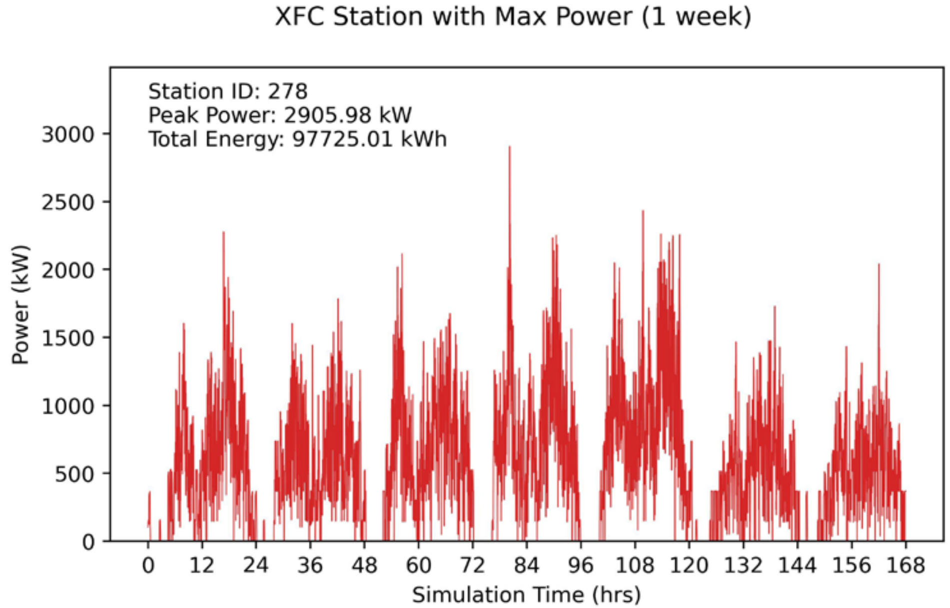
EV dynamically seeking mid-route XFC charging on way from work to home.

Mid-route charging preliminary results

- **Location:** Richmond, VA and Newport News, VA
- **Number of Cars:** 500,000
- **Number of charging stations:** 131, each with eight 350kW chargers
- 50% charging needs covered with public XFC
- Uncontrolled charging (drive up to the station without reservation)

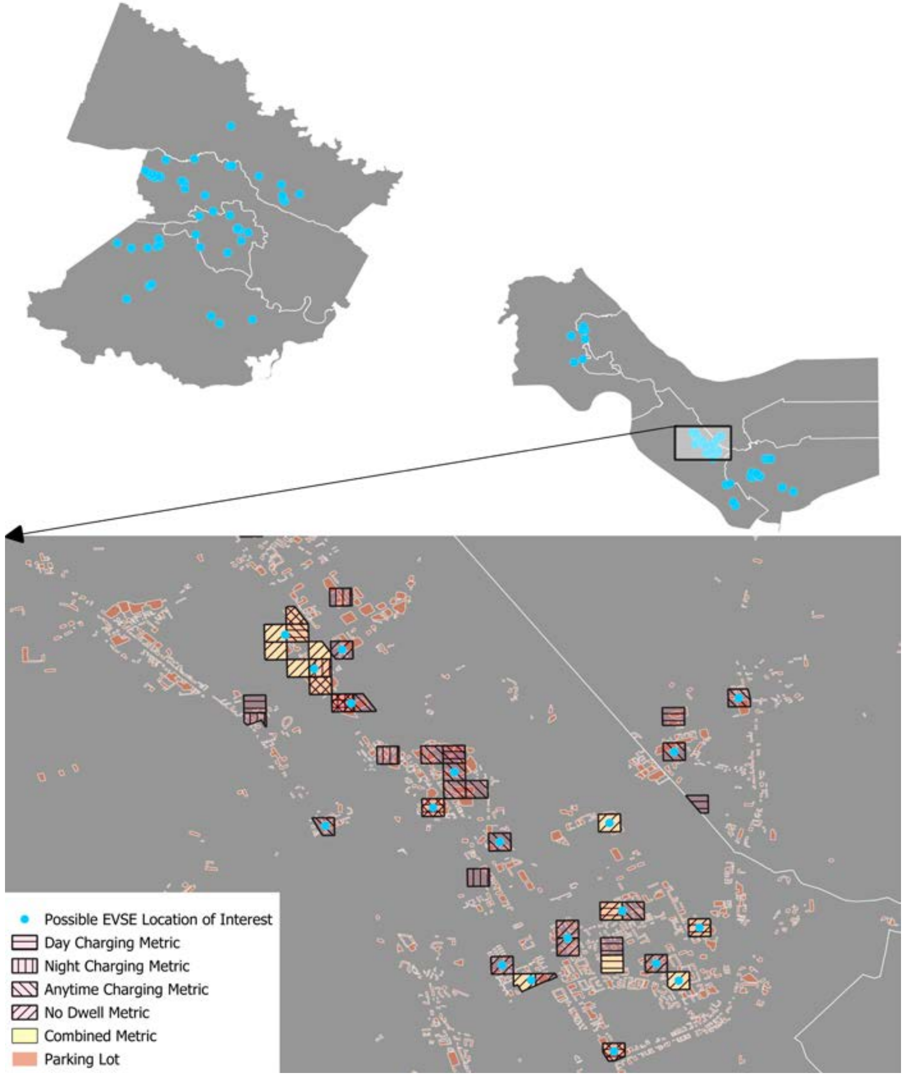






Concentrated EVSE to serve emerging needs

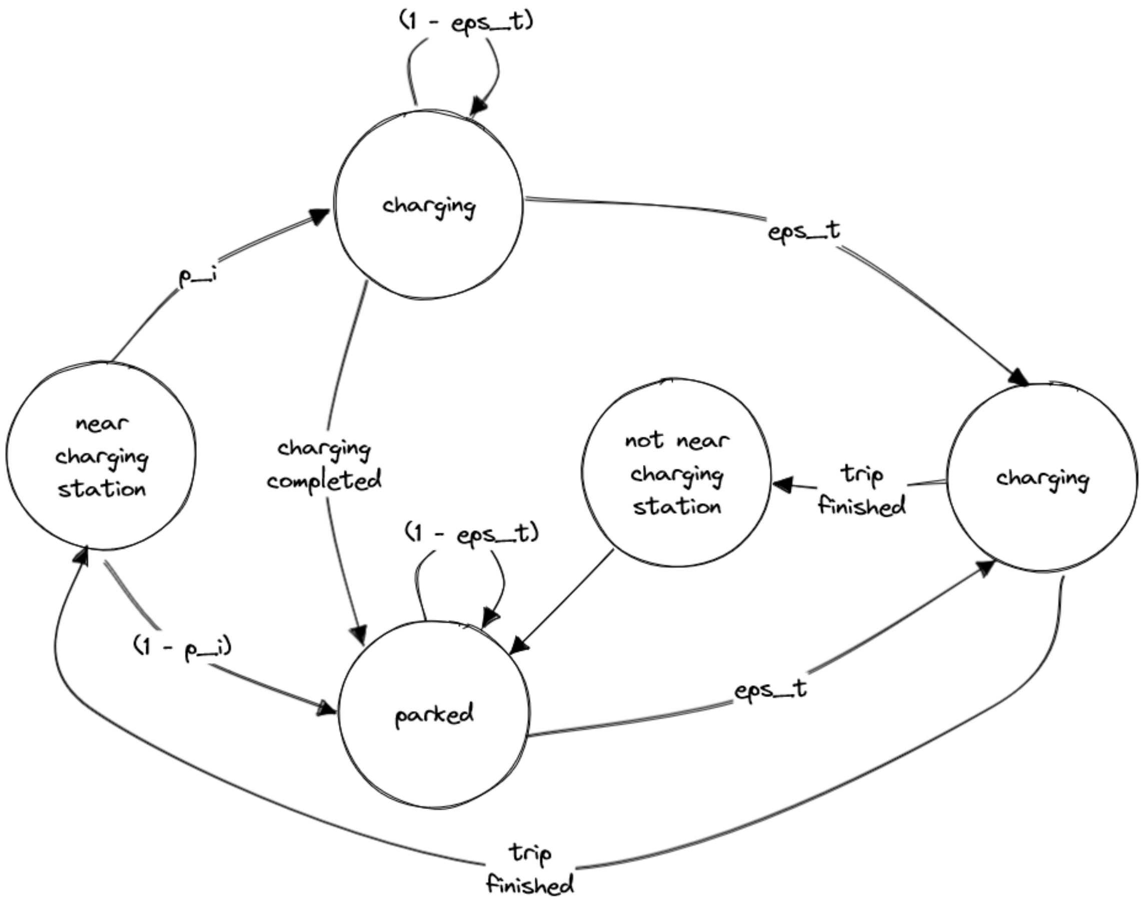
- **EV public charging feeder prioritization**
  - Assume public charging primarily used by those without access to home charging or who need to charge quickly (en route charging)
    - This population may otherwise be slow to adopt due to limited extant EVSE
    - EVSE availability may be critical to mass adoption
  - Looked at:
    - Dwell times and locations at different times of day
    - Multi-unit housing proportion
    - Renter population and car ownership
    - Available parking and parking lots
    - Location of other points of interest
  - Determine areas with relatively high demand for public charging and ensure feeder selection covers those areas



How we model charging behavior

- EV charging if home charging not available
  - At the workplace (L2)
  - At locations close to home, overnight or after work (L2)
  - En-route when necessary (L3)
- What influences charging decisions
  - Sufficient charge to reach destination(s)
  - Range anxiety
  - Charging/electricity prices
  - Congestion on route
  - Time of day
  - Availability of charging at destination
- Modeling techniques
  - Adapt Markov model:

    Z. Fotouhi, M. R. Hashemi, H. Narimani, and I. S. Bayram, “A General Model for EV Drivers’ Charging Behavior,” IEEE Trans. Veh. Technol., vol. 68, no. 8, pp. 7368–7382, Aug. 2019, doi: 10.1109/TVT.2019.2923260.
  - Adjust SoC probability assumptions
  - Adjust charging decision factors

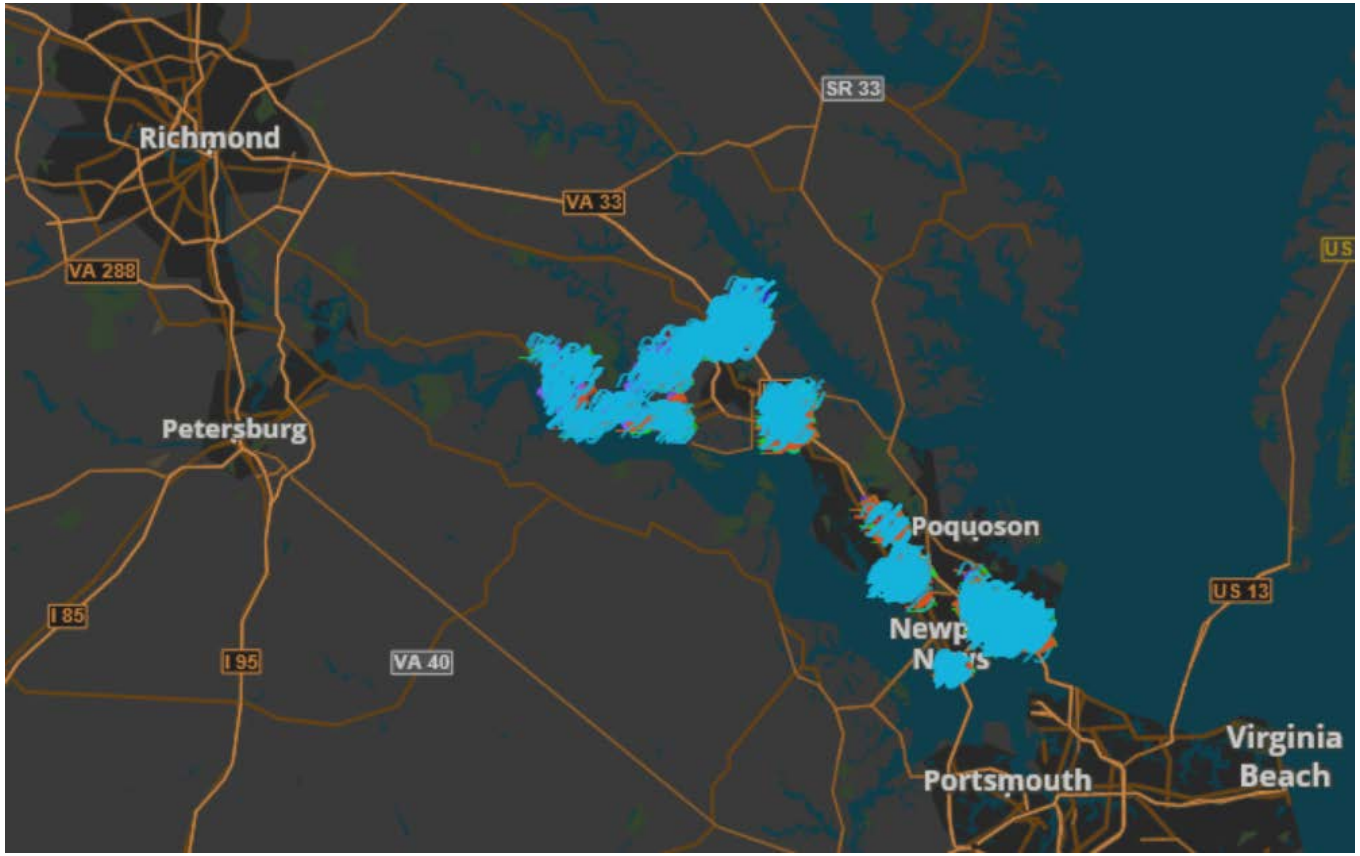


Where we go from here + impact on grid

- **Varying model parameters**
  - Range anxiety + charging decisions may be dependent on (imperfect) knowledge of local charging stations and therefore spatially dependent
- **Charging decision uncertainties**
  - Relative importance of co-location of charging and desirable activities?
  - Behavior effects of TOU / price surges at charging stations not well-studied in practice
    - Charging stations' pricing models may not be easy to compare
- **Effects of charging on distribution infrastructure**
  - Spatial availability of electrical capacity for charging may affect nearby business development
- **Modeling growth of EVs**
  - Spatial and built environment differences in adoption

Photo by Michael Fousert at Unsplash

Distribution Feeders of Interest



- Received 29 distribution feeders throughout Newport News
  – Williamsburg (10), and Peninsula (19)
- Additional 31 distribution feeders throughout Richmond under review
- Final set of 40 feeders will reflect MHDV needs

Factors considered for the final selection of feeders

– Concentrated amount of charging,
– High number of DERs
– Proximity to important infrastructure
– High-traffic areas
– Wide spread for the peak loads, rates, PEVs, and population

Distribution Feeder Hosting Capacity

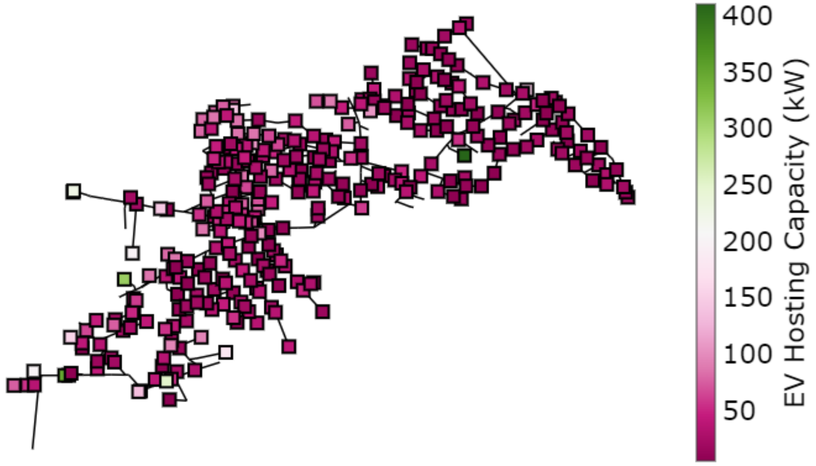
Assess grid capacity to support additional EV charging loads

Nodal Hosting capacity is assessed and determined by

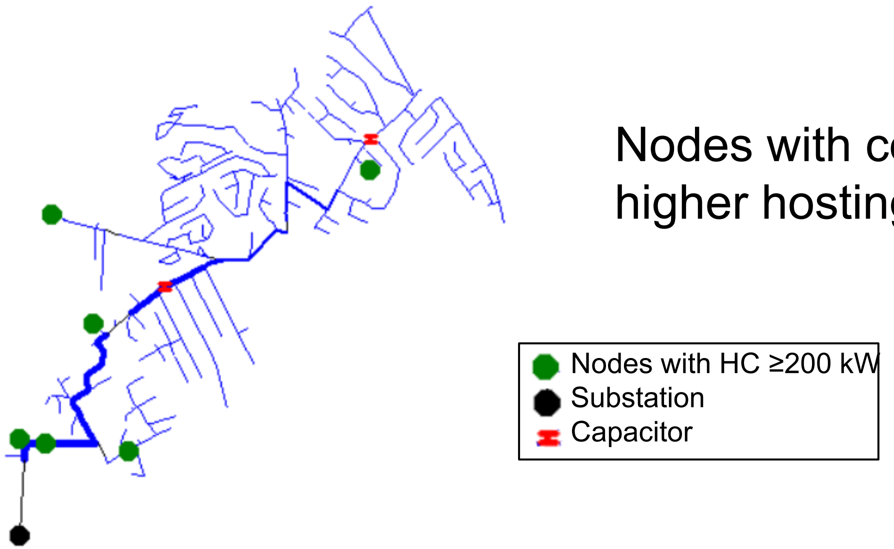
- Thermal violations
  - Typically due to transformer or conductor capacity
  - Violations occur beyond 100% rated capacity
- Voltage violations
  - Service voltage is outside desired range
  - Violations occur below 0.95 p.u. or above 1.05 p.u.

Next Steps

- EV Charging Co-Simulation
  - Uncontrolled and controlled charging simulations
  - Assessment of thermal and voltage violations with and without SCM solutions

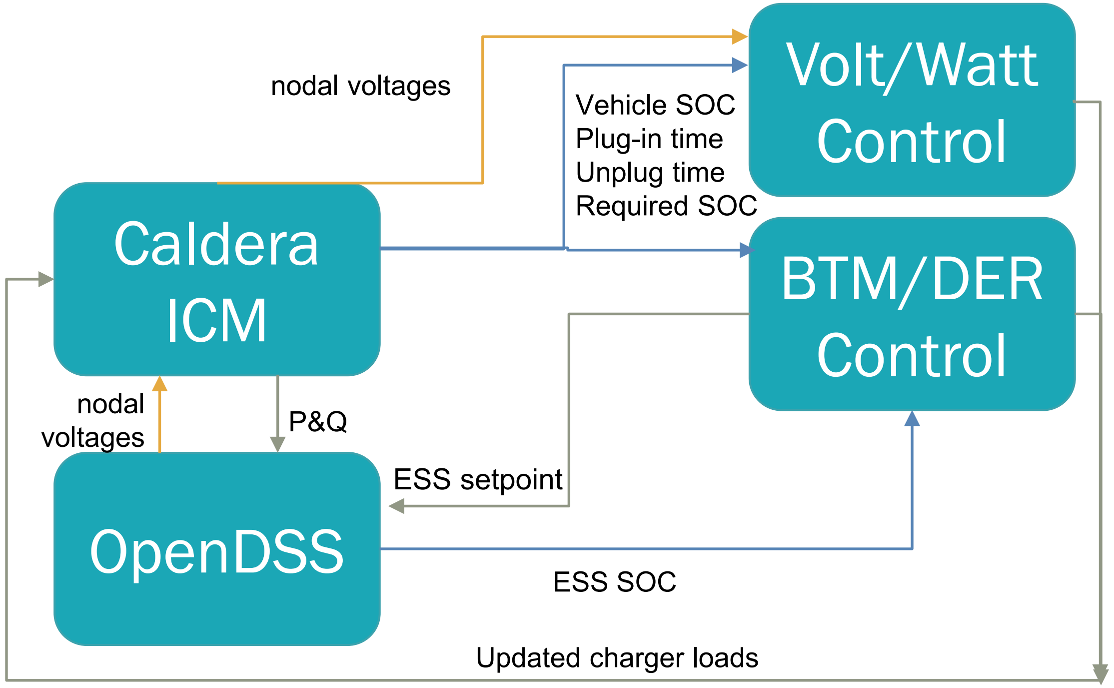


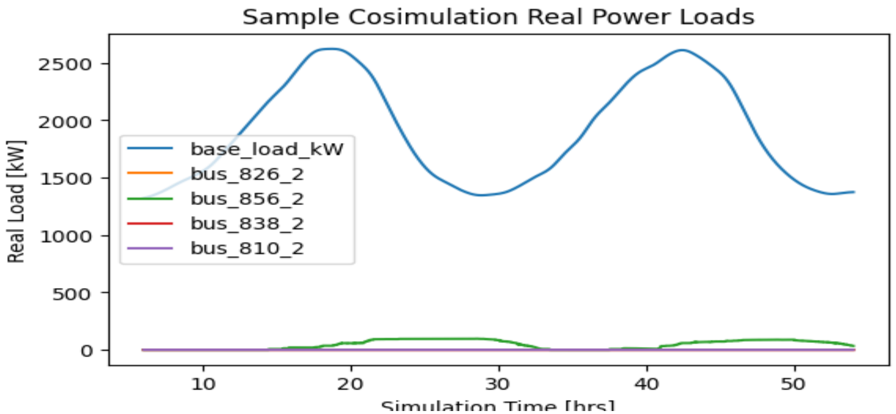
EV Hosting capacity range between 5 kW to 400 kW



Nodes with comparatively higher hosting capacity

HELICS Co-Simulation





Steps Completed

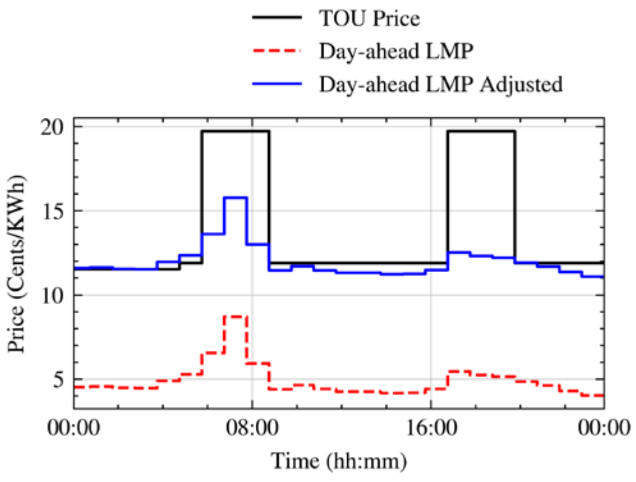
- Co-Simulation Connections Established
  - Multi-day co-simulation tested
  - 1, 5, and 15-minute timesteps used for different blocks
- Script for format conversion of travel data to compatible Caldera input format created

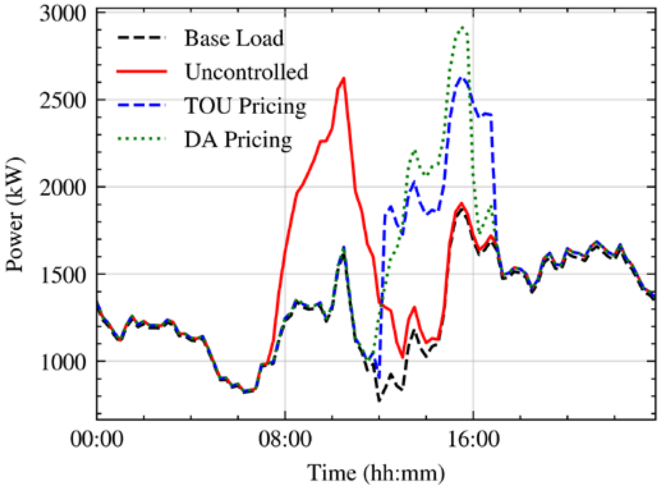
Next steps

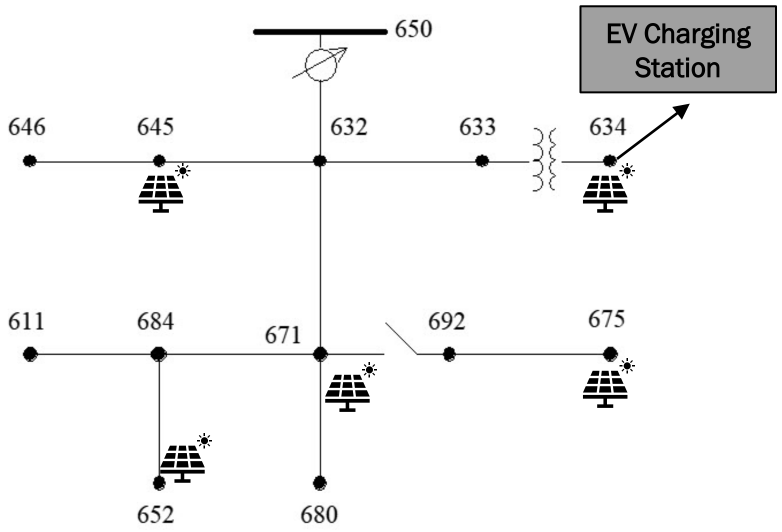
- Integrate Real OpenDSS feeders
- Integrate updated travel events
- Tune BTM/DER Control
- Scale cosimulation to support full Dominion territory analyzed

Day-Ahead Pricing based SCM

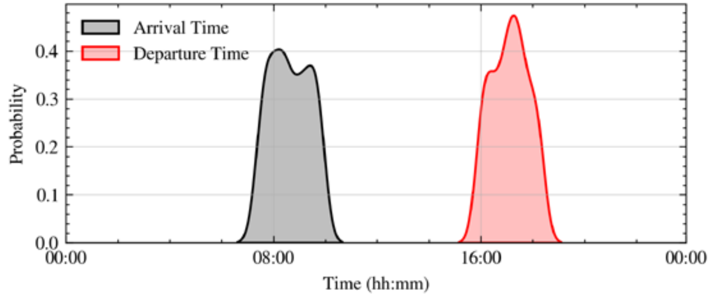
- **SCM objective**: Meet the energy needs of EVs prior departure and minimize the total charging cost under the *time-of-use (TOU)* and *Day-ahead Pricing* scheme.
- The day-ahead pricing signal is updated daily to more accurately reflect short-term power supply and demand conditions compared to the seasonal variated time-of-use (TOU) scheme. The fleet and charging station operator can utilize this price variation to decrease operational costs.
- The day-ahead price is determined by the day-ahead LMP of PJM. The value is adjusted to be equal to the average values of TOU. The customers are billed on the real-time hourly LMP price, not the day-ahead market price.







Case setup:
- 100 EVs with different arrival and departure time.
- Each EV has a random initial SOC (20%-60%).
- EV battery size: 60 KWh.
- Maximum charging power: 9.6 KW.
- Total PV installment capacity: 1000 KW.



TOU (Uncontrolled)	TOU (Smart Charging)	Day-ahead LMP	Real-time LMP
480.59$	432.37$	409.86$	390.96$

Renewable-based SCM

Steps Completed:

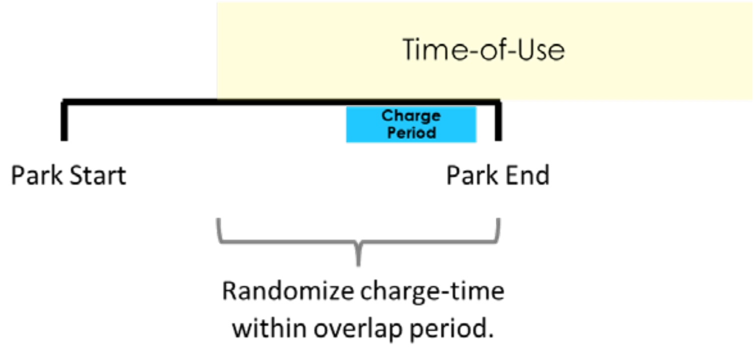
- Implemented the solar-based renewable following controls in Caldera Grid co-simulation environment.
- Modeled the controls on LD Home, Work and Destination charging in El Paso Electric service territory and Vermont state.

Next Steps:

- Implement a wind-based renewable following control in Caldera Grid co-sim environment.
- Develop vocation-specific control strategy for MD/HD short dwell vocations.
- Study region-specific scenarios with vocation-specific control strategies.

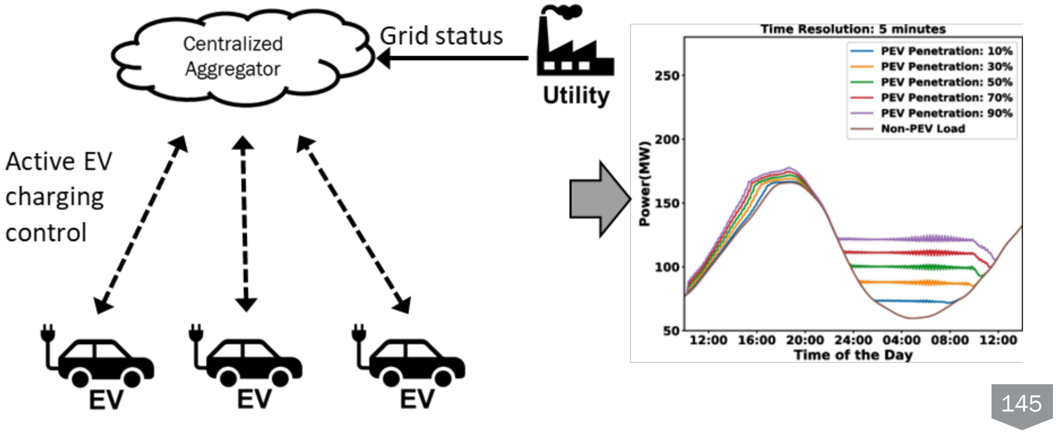
Solar TOU-Random:

EVs prefer to randomly distribute charging in the TOU window during solar duration.



Solar Centralized Aggregator:

Centralized strategy shifts EV charging based on grid conditions and solar objectives within vehicle dwell to minimize feeder peak



Broad regional analysis

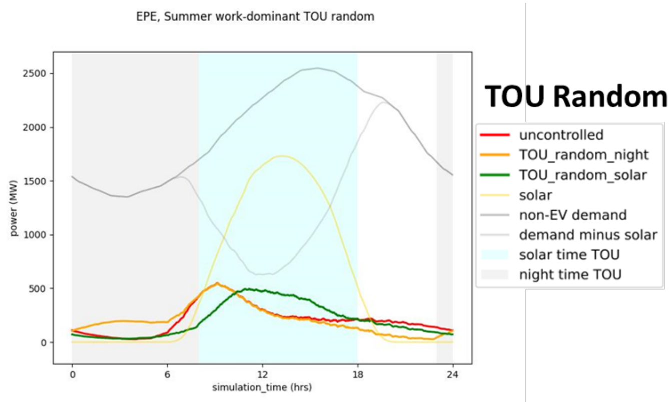
Analyze EV charging across a range of geographic and seasonal conditions.

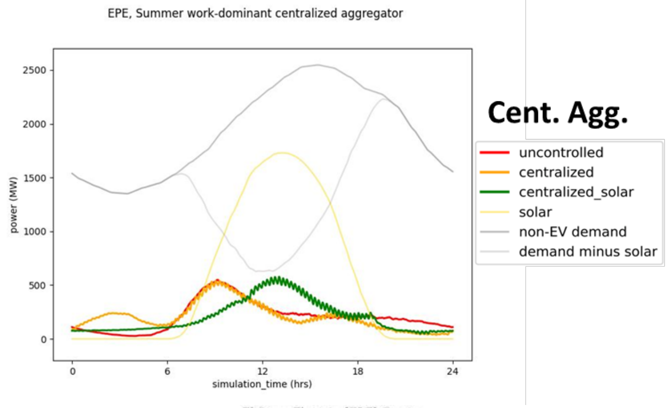
Steps completed:

- Completed LD EV charging at Home and Work in locations with different grid characteristics El Paso (Summer Peaking) and Vermont (Winter Peaking).
- Evaluated solar following SCM controls in El Paso and Vermont.

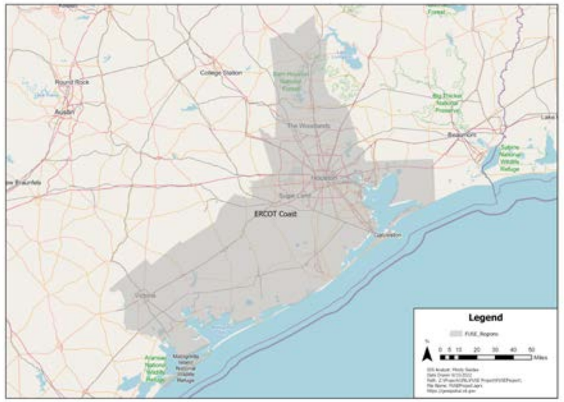
Next steps:

- EV charging analysis in other regions with renewable mix characteristics and transportation mix characteristics.
- Extend solar following control to include wind.
- Evaluate vocation specific SCM controls across different scenarios.

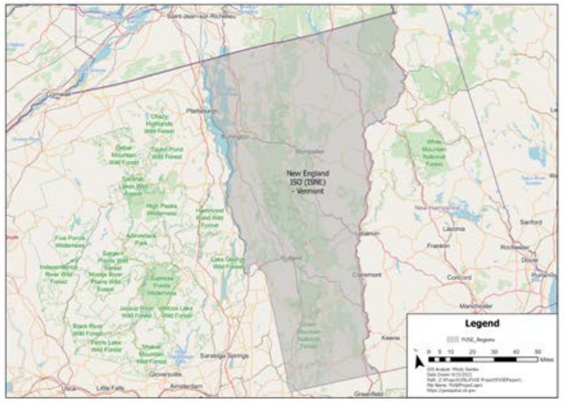




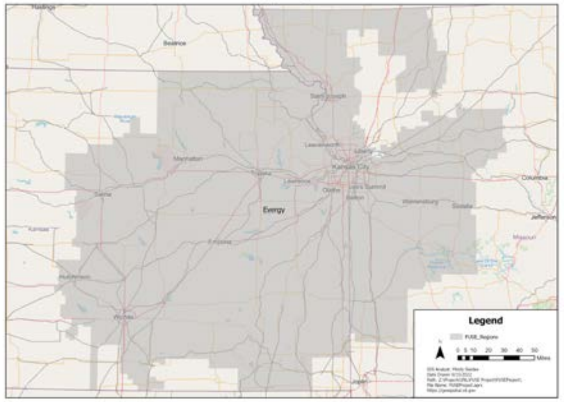
ERCOT Coast Region



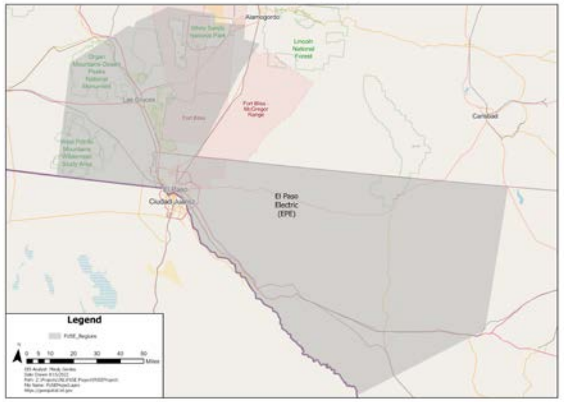
New England ISO (ISNE) - Vermont Region



Evergy Region



El Paso Electric (EPE) Region



EVs@Scale

U.S. Department of Energy

Thank You

Join us for the

SCM/VGI Deep Dive

Thursday October 26th

Additional Details to Follow

Breaktime!

Panel presentations resume at…

EVs @ Scale
U.S. Department of Energy

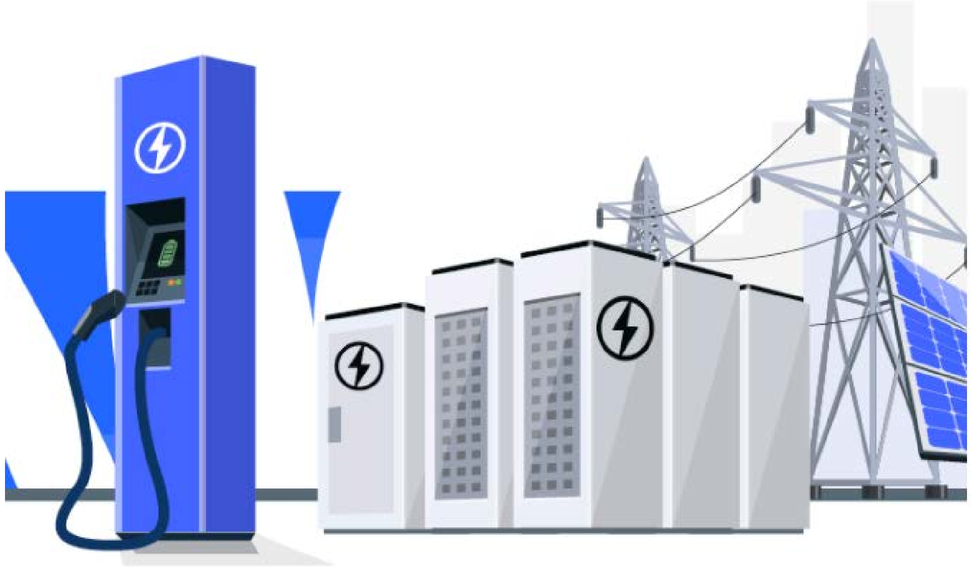
LION ELECTRIC

What is V2G?


AC PROPULSION
ELECTRIC VEHICLE TECHNOLOGIES

What is V2G?

- Vehicle-to-grid (V2G/V2X) is smart, bidirectional charging technology that draws unused power from the electric vehicle back onto the power grids.
- Provides vehicle owners with a source of revenue from the energy being sold back to the grid.
- To enable V2G, charging stations must be equipped with software that comunicates to the central grid to perform demand response.
- Bidirectional charging enables the battery capacity of the EV to be used 10x more efficiently than uni-directional smart charging.



What is V2G?

Advantages	Challenges
✓ Expands capacity for renewable energy storage and provides demand response and grid services	✓ Grid not designed for bidirectional power flow, will need to adopt communication standards, grid interconnection standards etc.
✓ Reduces costs and price volatility through energy arbitrage and frequency response	✓ Limited to DC chargers, no inverter for AC at this point in time
✓ Eases strain on the energy grid by making the power distribution more efficient	✓ No consistent set of regulations for vehicle-grid integration
✓ Provides reliable power source during times of peak demand & extreme weather	

V2G at Lion Energy

- Currently, Lion is running 4 V2G projects, with 3 in the United States (Florida, California and New York) and 1 in Canada (PEI)
- The primary bus model used for V2G deployment is the LionC (avg 44 KW discharge), but can be used with any of our models.
- We work with established market players that provide chargers and V2G software, who boast known and reputable brands with sufficient experience and knowledge

Past pilot projects in the U.S.

<u>White Plains New York</u>

- Partnership between White Plains School District in New York state, Lion, Nuuve and National Express
- Project spanned from 2018 to 2021 to test the functionality of V2G in providing peak shavings to grid (demand response)
- Tested the charging and discharging of 5 Lion school buses
- Con Edison successfully transmitted energy from the electric school buses in White Plains back into the grid & distributed to customers

Current pilot projects in the U.S.

<u>Cajon Valley Union School District</u>

- 5-year collaboration between SDG&E, the Cajon Valley Union School District (CVUSD), Nuuve
- 8 school buses that connect to 60KW bidirectional DC fast chargers
- Reduce costs due to cheaper rate of electricity vs fuel as well as lower maintenance
- Participating in California's SDG&E's Emergency Load Reduction Program (ELRP) which generates revenue of up to $2/kWh

<u>Florida Power & Light</u>

- 10-year collaboration between the City of West Palm Beach Parks & Recreation Department and Florida Power & Light
- 5 school buses that connect to 60 KW bidirectional DC fast chargers
- FPL will own and maintain the charging statons and batteries, while the city will own the buses

Current pilot project in Canada

<u>North Rustico, Prince Edward Island</u>

- First project in Canada to test electric school buses as mobile emergency batteries

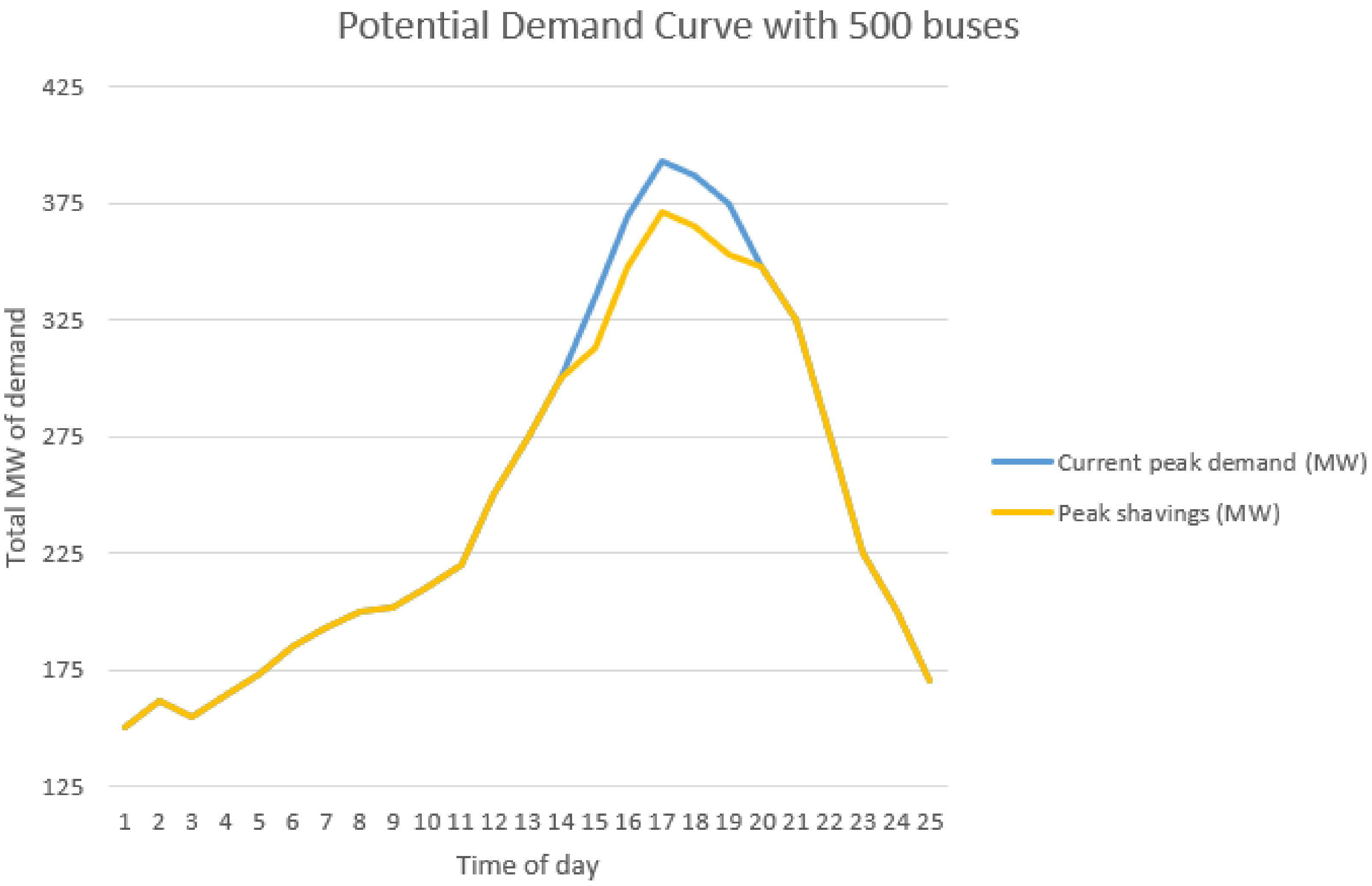
- Province has total of 82 LionC electric buses which can be used as emergency energy source for community disaster relief

- Buses will store renewable energy from P.E.I.'s wind and solar generation resources during periods of low demand (i.e. overnight)

- Project will contribute significantly to P.E.I.'s target of achieving net zero by 2040

P.E.I. potential V2G demand curve

Note that the current generation of the LionC can output 44kW onto the grid. However, newer iterations will have higher outputs.
This graph represents the potential demand curve with the utilization of V2G for 500 LionC buses.



The bright move

LION ELECTRIC

VGI approaches: *cater for client*

Harald W. Scholz and Federico Ferretti
European Commission - Joint Research Centre

EVs@Scale Semiannual Meeting, Sept 27th, 2023

JRC sites

Headquarters in **Brussels** and research facilities located in **5 EU Countries:**

- Belgium (Geel)
- Germany (Karlsruhe)
- Italy (Ispra)
- The Netherlands (Petten)
- Spain (Seville)

our Project SMART ENERGY SYSTEMS and SOLUTIONS (SMARTEN) team runs the...

European Interoperability Centre for EVs, Smart Grids and Smart Homes

We test & study: On	InterOp & Protocols	Cold / Warm Tests -30°C…+50°C	Energy Efficiency (converters / EVs)	EMC: radiated emiss. conducted emiss. Immunity	Smart Charging & VGI	Workplace Charging behavioral items
EVs						
EVSEs AC & DC						
EVSEs to Grid						
WPT						

European Commission

We test & study: On	InterOp & Protocols	Cold / Warm Tests -30°C…+50°C	Energy Efficiency (converters / EVs)	EMC: radiated emiss. conducted emiss. Immunity	Smart Charging & VGI	Workplace Charging behavioral items
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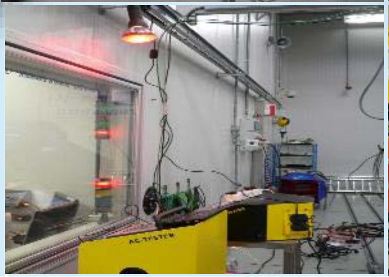
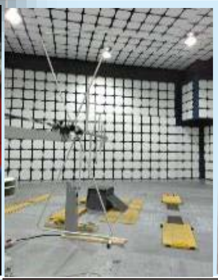
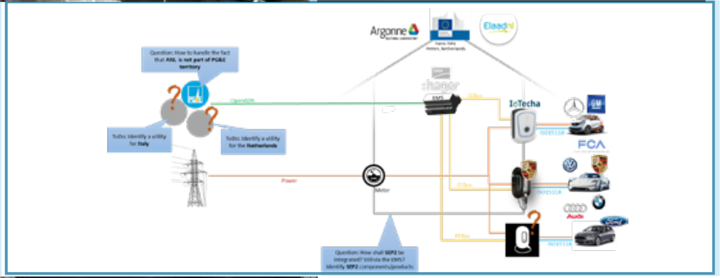
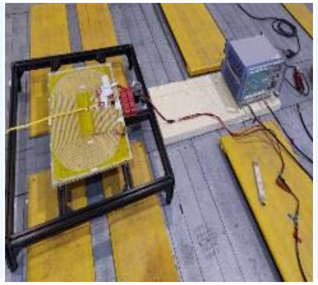
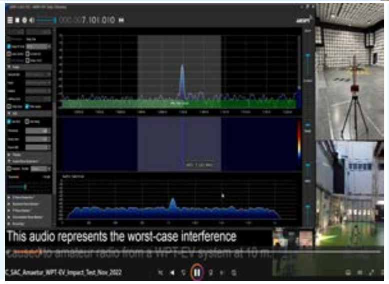
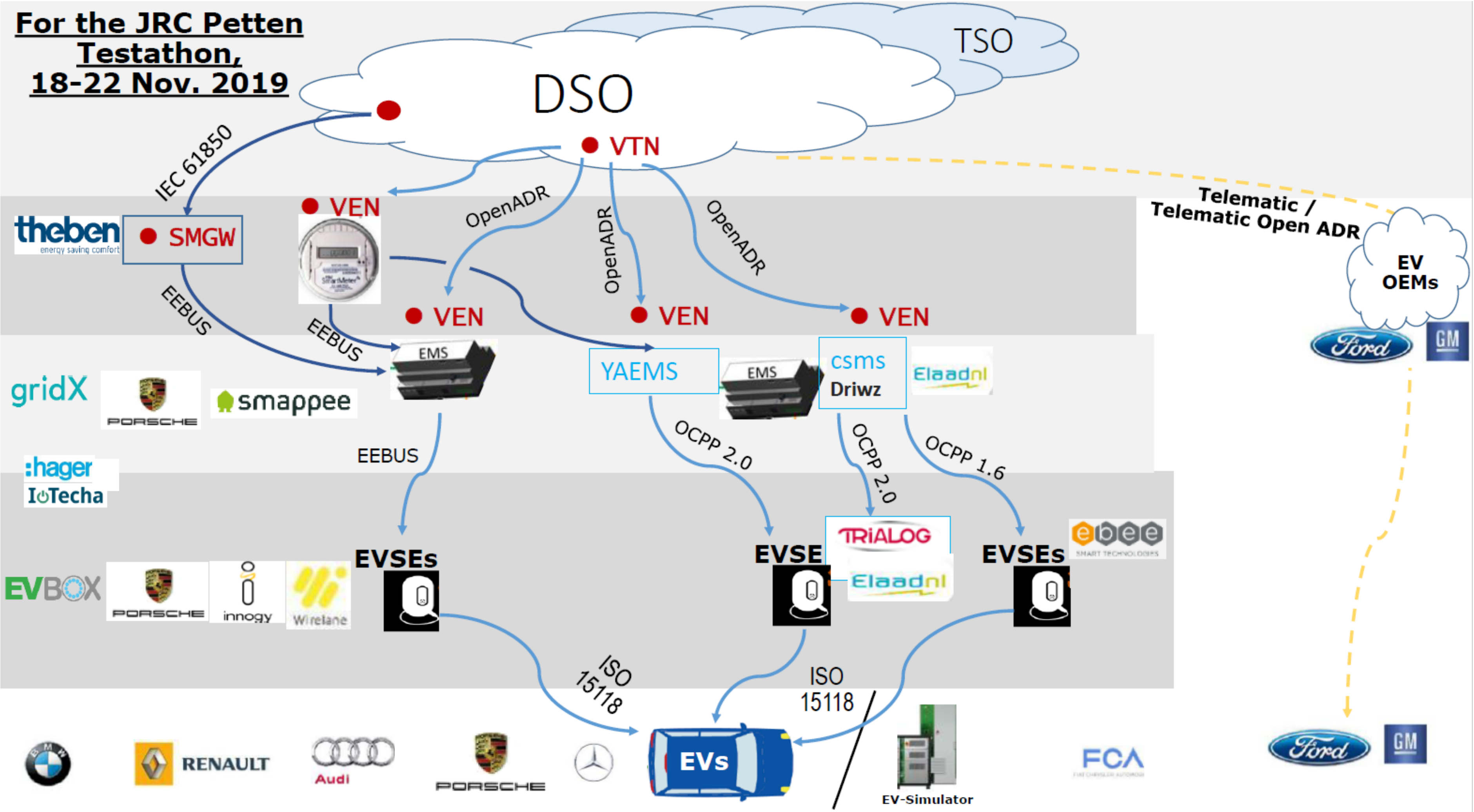
EVSEs to Grid				 		
WPT						

Will different architectures for VGI coexist?
(*Policy needs to know*)



European Commission

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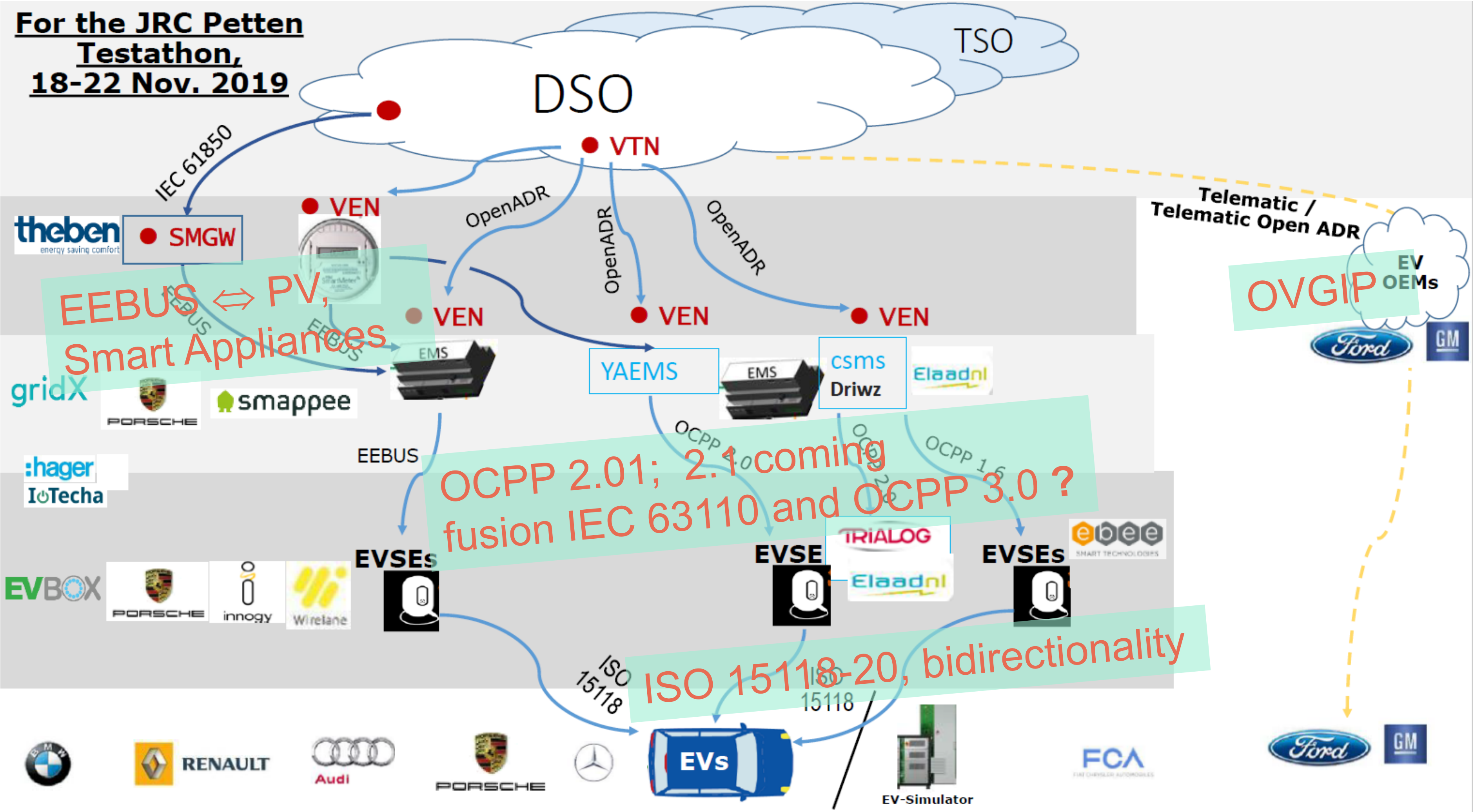
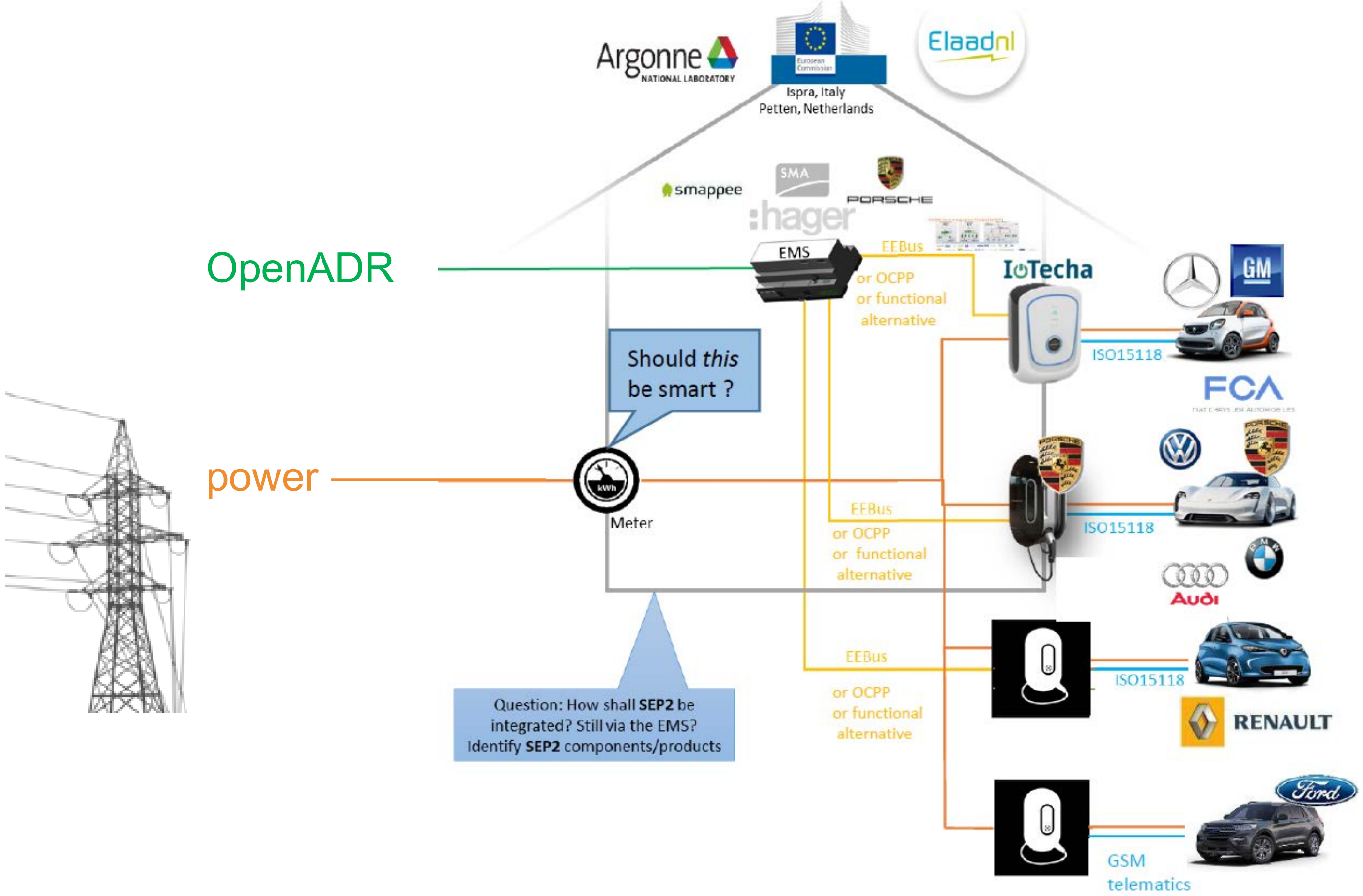


Every commercial interest group develops further its own idea

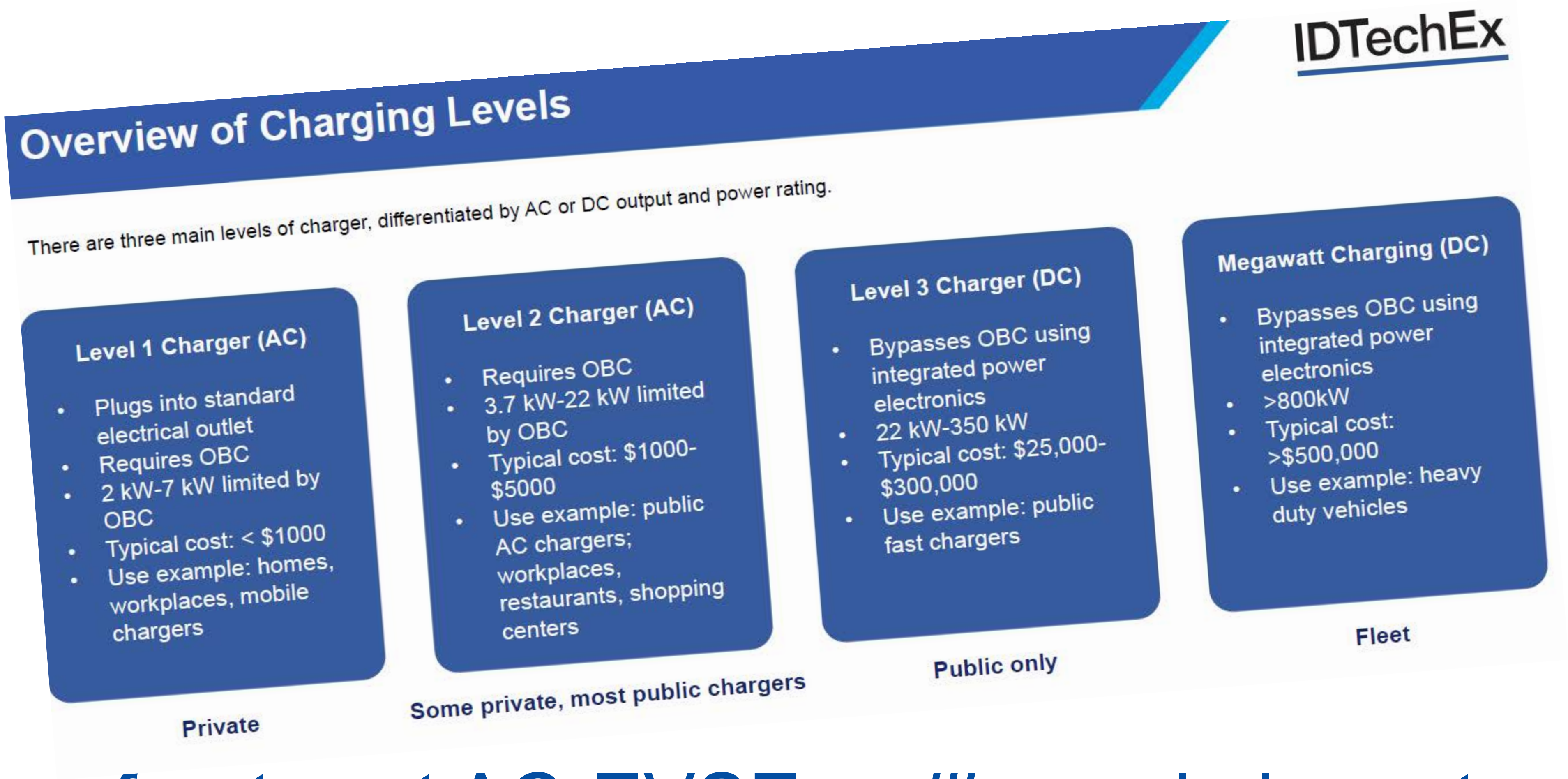
European Commission

Maybe we shall have no time for the perfect system



DSM will generate gains where people charge for hours

(Smart) DC is still *same factor* more expensive than AC



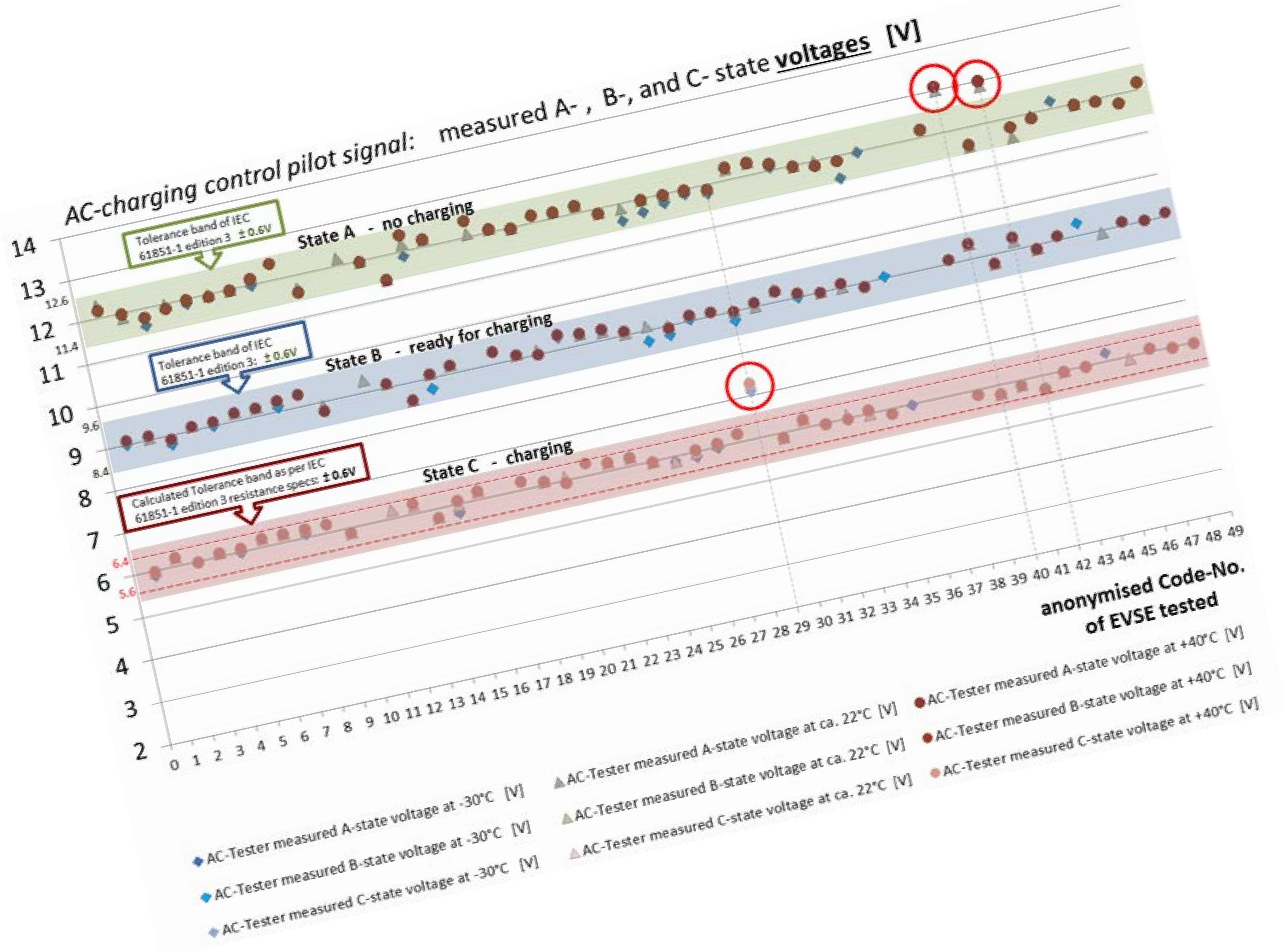
low up-front cost AC-EVSEs *will* remain important

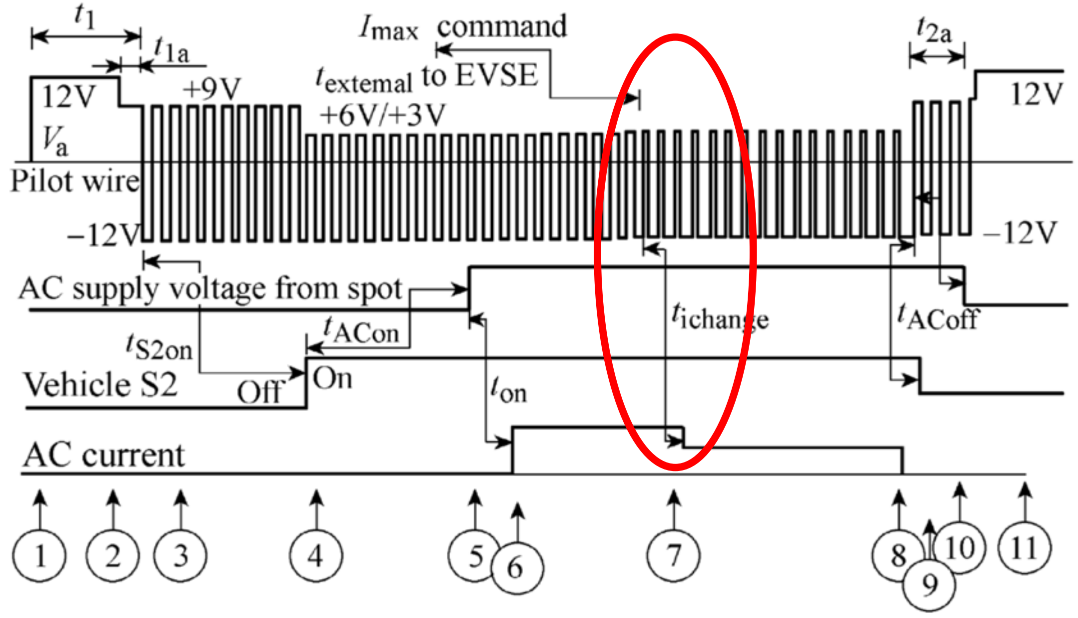
(Smart) DC is still *same factor* more expensive than AC

low up-front cost AC-EVSEs *will* remain important

In our early interop work on AC...

… we were told to not worry about **EV onboard charger “reaction patterns”**



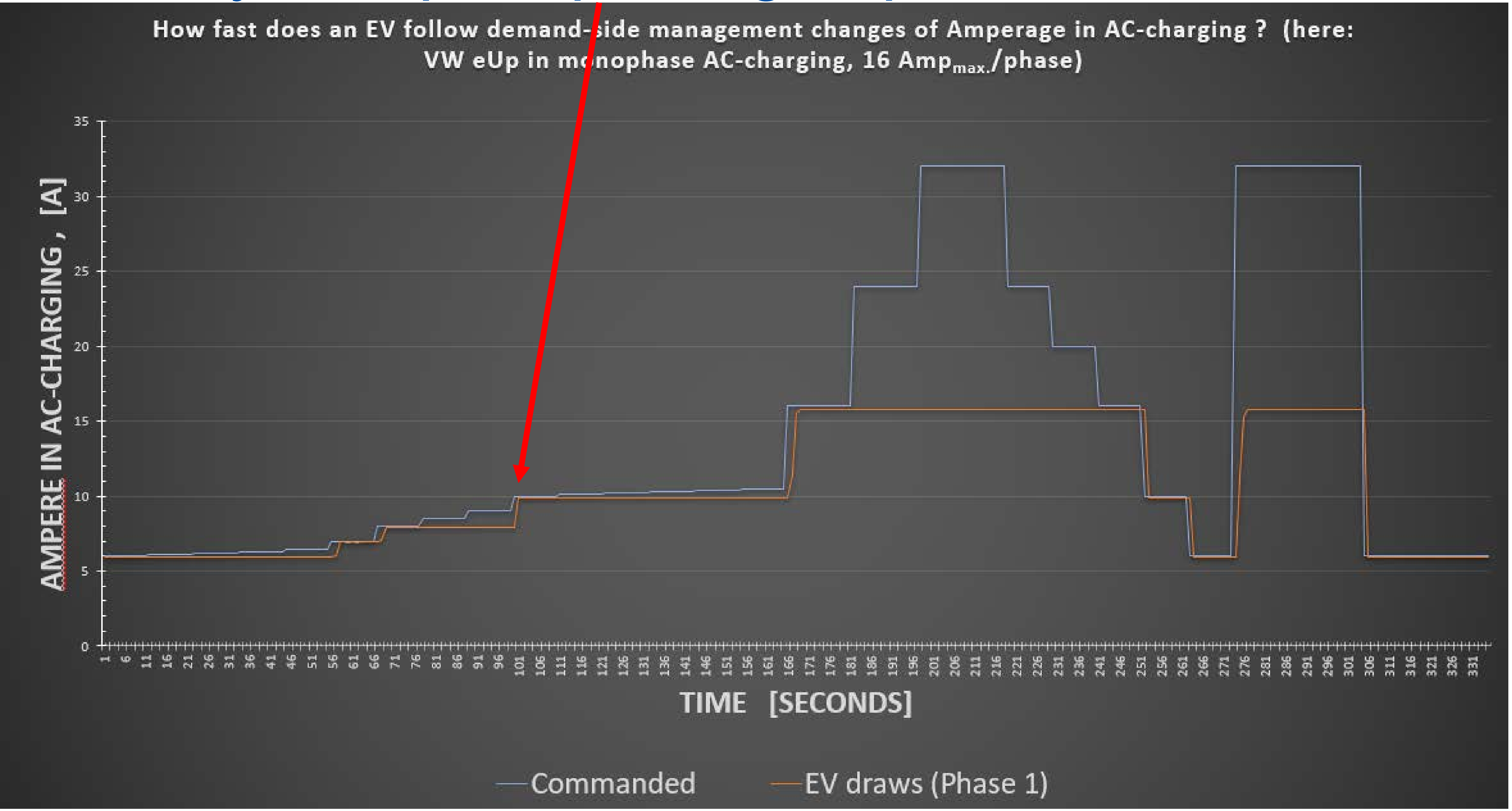


(b) Timing sequence

Fig.3 Control function of EVSE at different conditions[16]

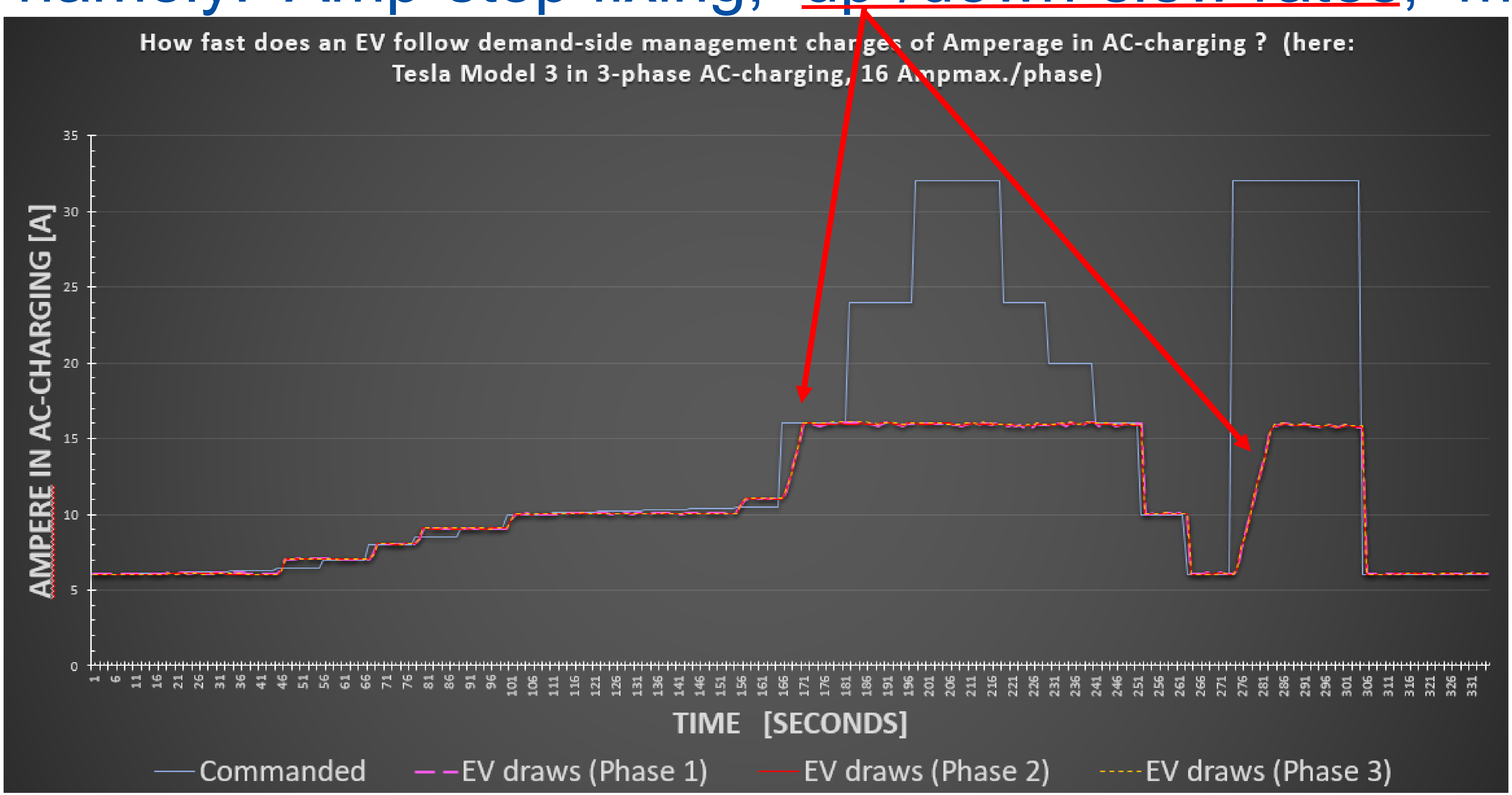
European Commission

namely: Amp-step fixing, up-/down-slew rates, max Amp

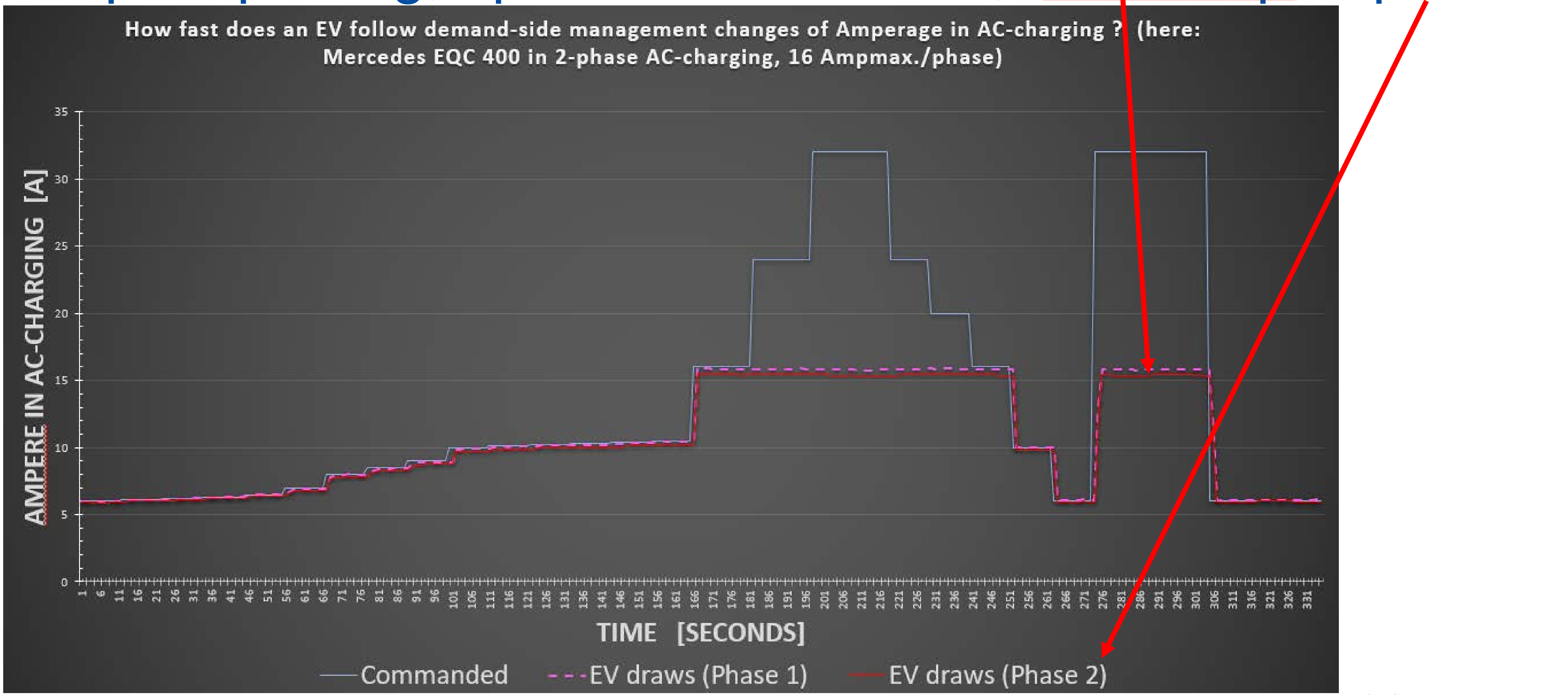


European Commission

namely: Amp-step fixing, up-/down-slew rates, max Amp

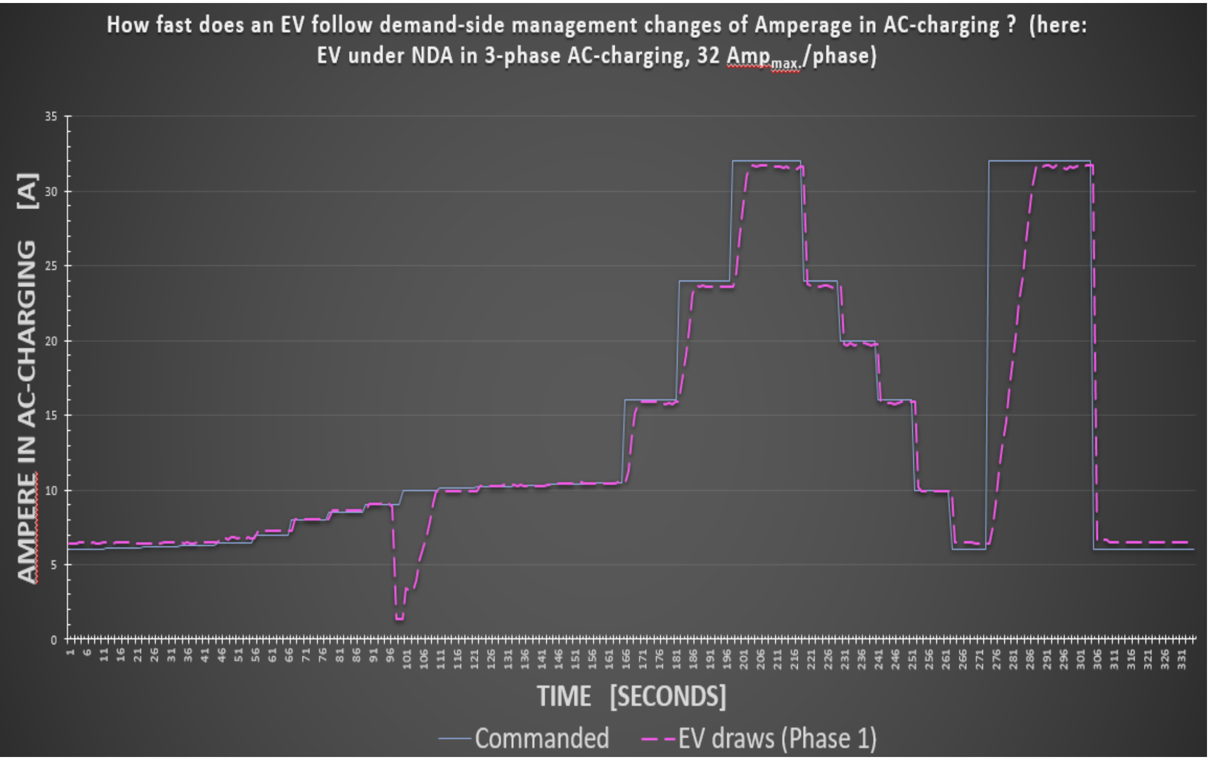


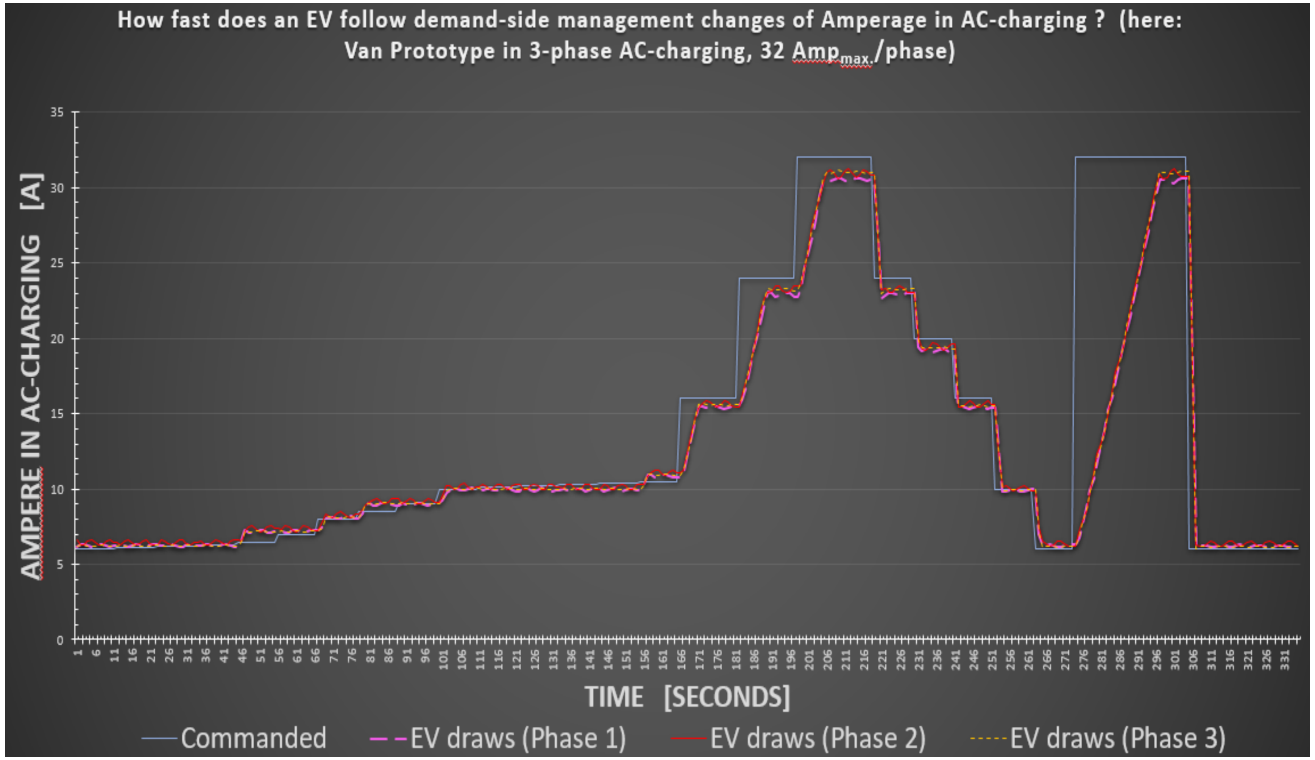
namely:
Amp-step fixing, up-/down-slew rates, max Amp, # phases



European Commission

We spooled through *many* different EV-types… and found:

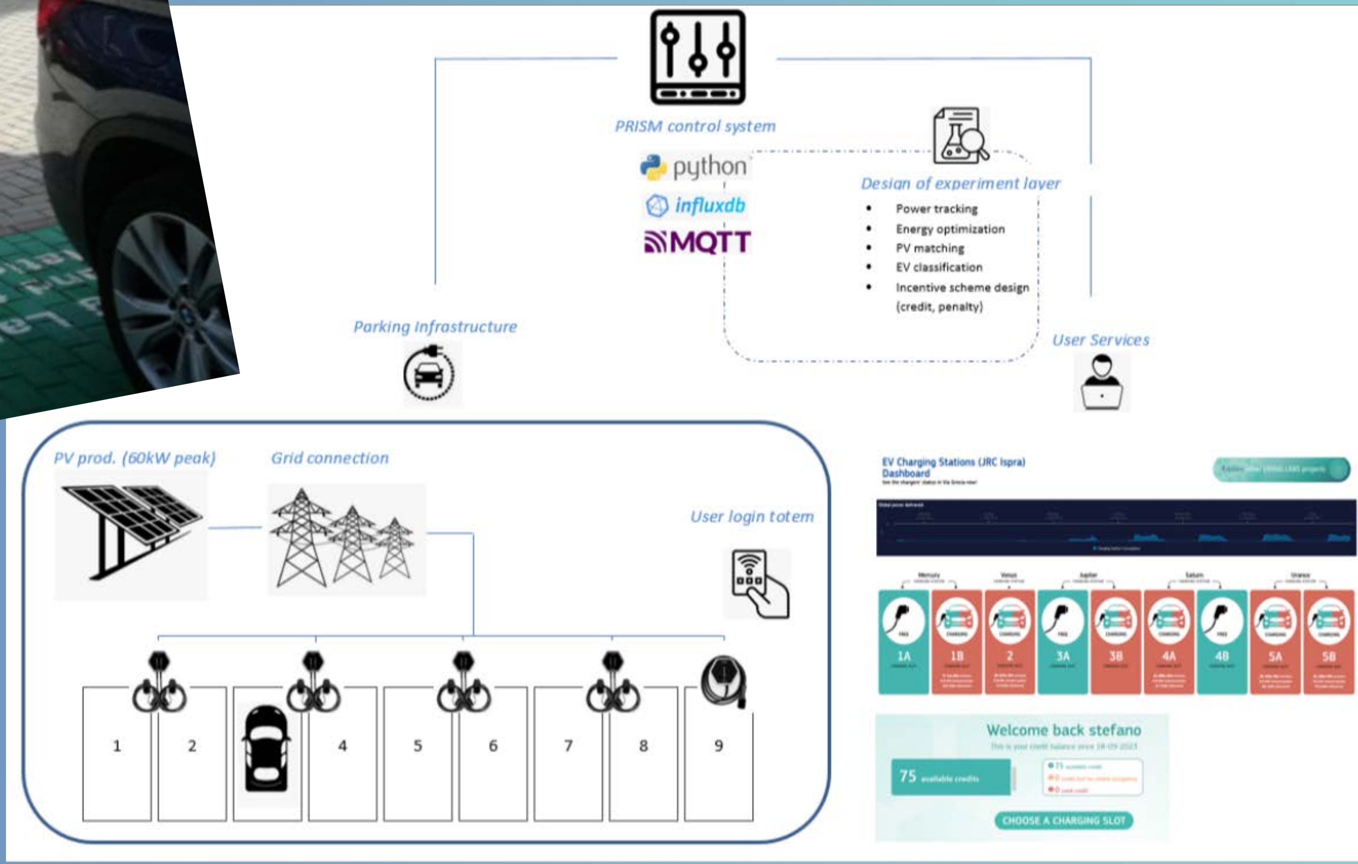




⇒ an EV gives its **finger-print** at any variable AC-charge

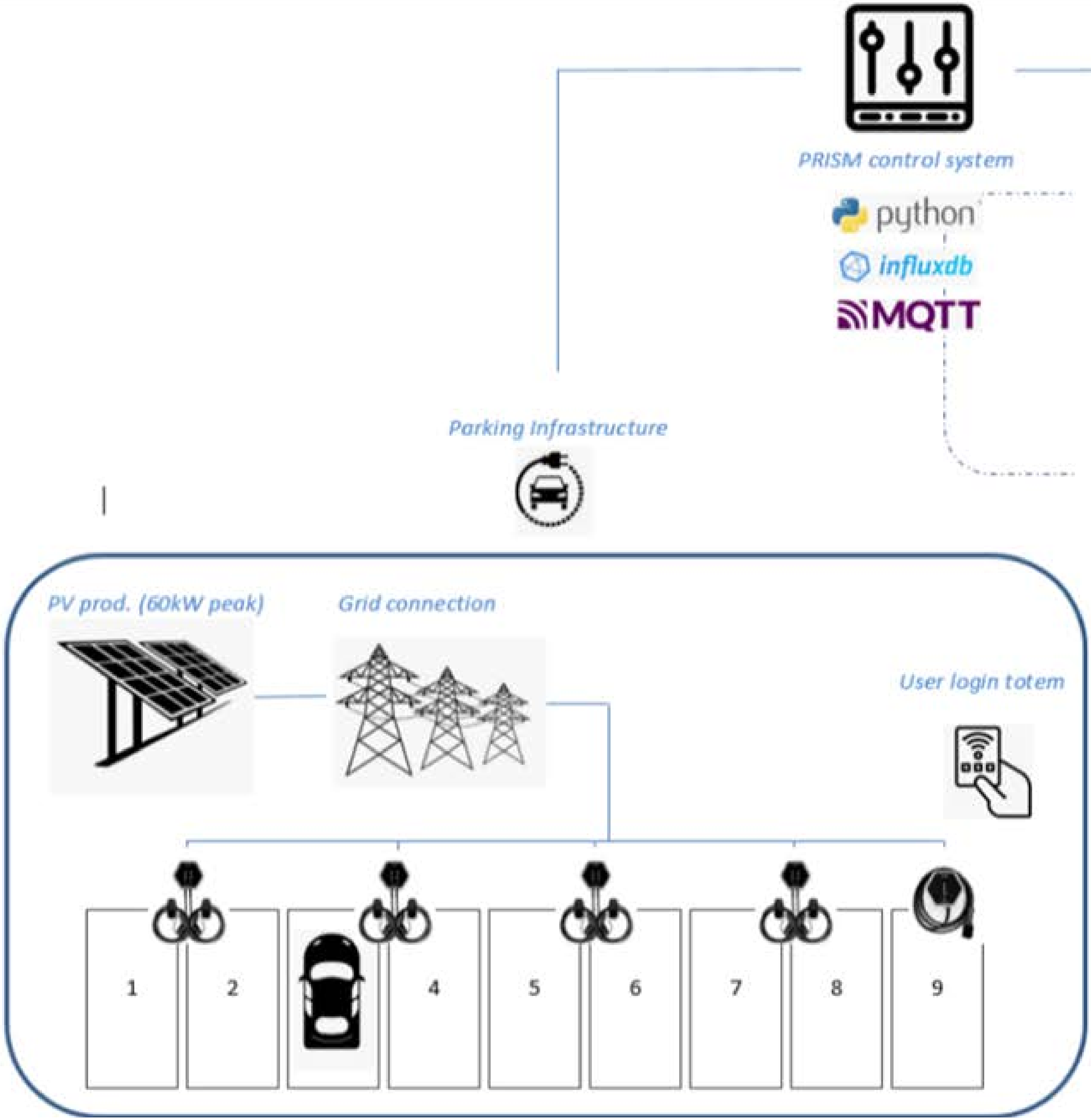
European Commission

In JRC, at our small AC staff charge-park…



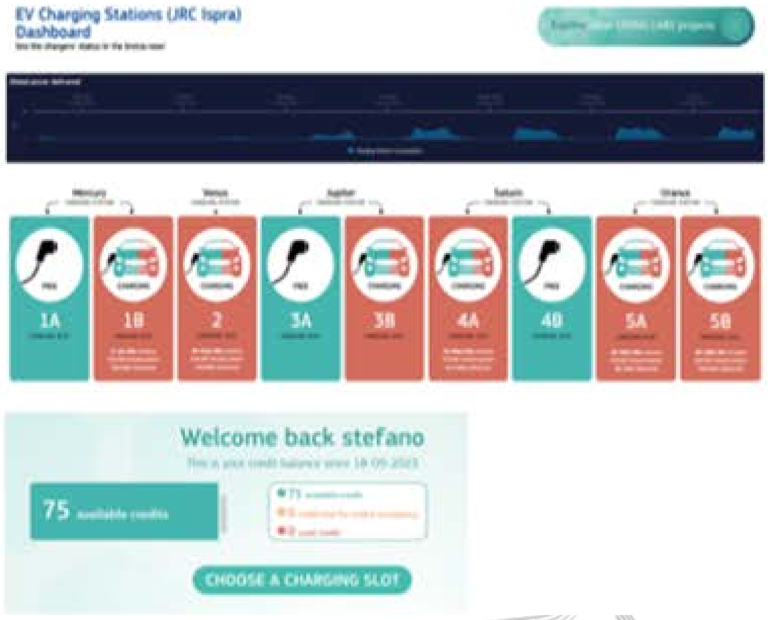
https://energylab.jrc.cec.eu.int/prism

European Commission

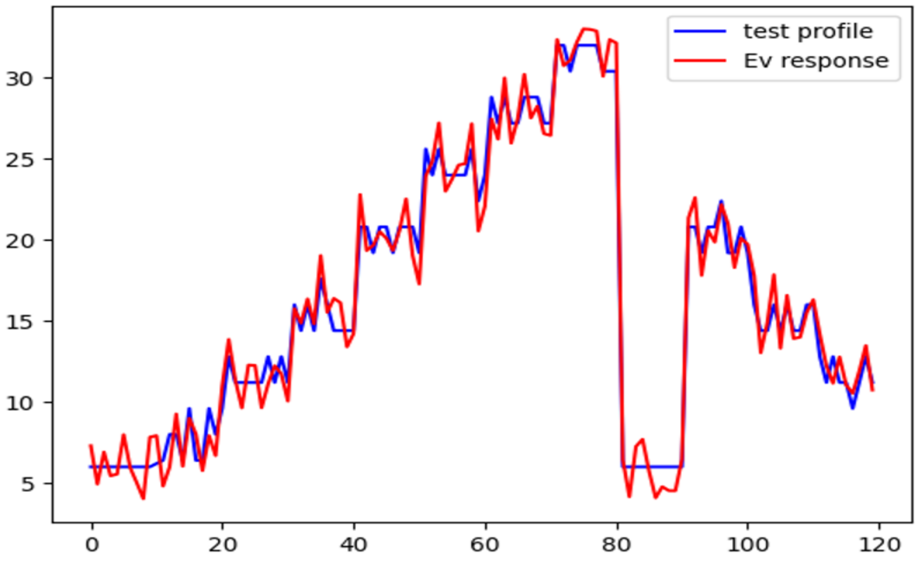


Experimental strands:

total / single power tracking
energy optimization
PV matching
EV identification
Incentive Scheme try-outs (credits, penalties…)



Method for EV-type identification without HLC



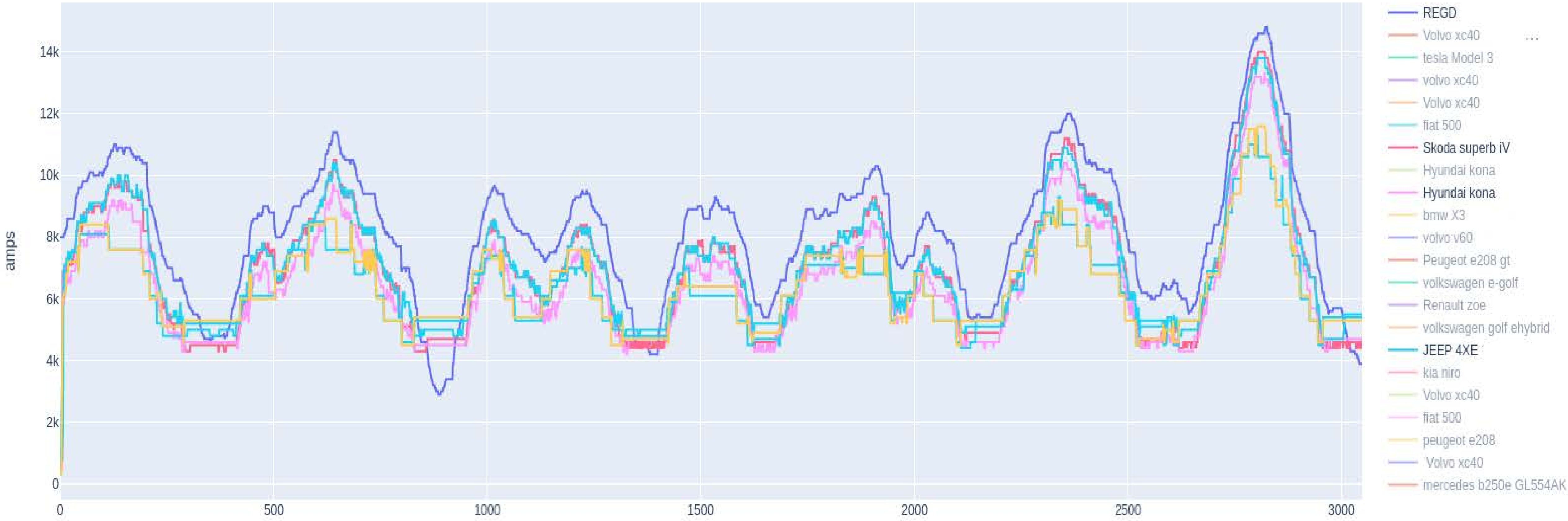
At the charge park, there is only monophase (7.2kW max) available currently. **We apply a test profile of 120 sec at the beginning of every new charging process.**

due to the RFID login, ***we*** could retrieve, which type of registered car is actually charging.

But we want to find an ***anonymised*** method, applicable at any mall, hospital or other public access place.

Our final goal is clustering & curbing EVs AC-charging to typical utility balancing and freq-stabilization load-profiles, like the REG D curve

(for *really* doing so, our charge park would need to be bigger)

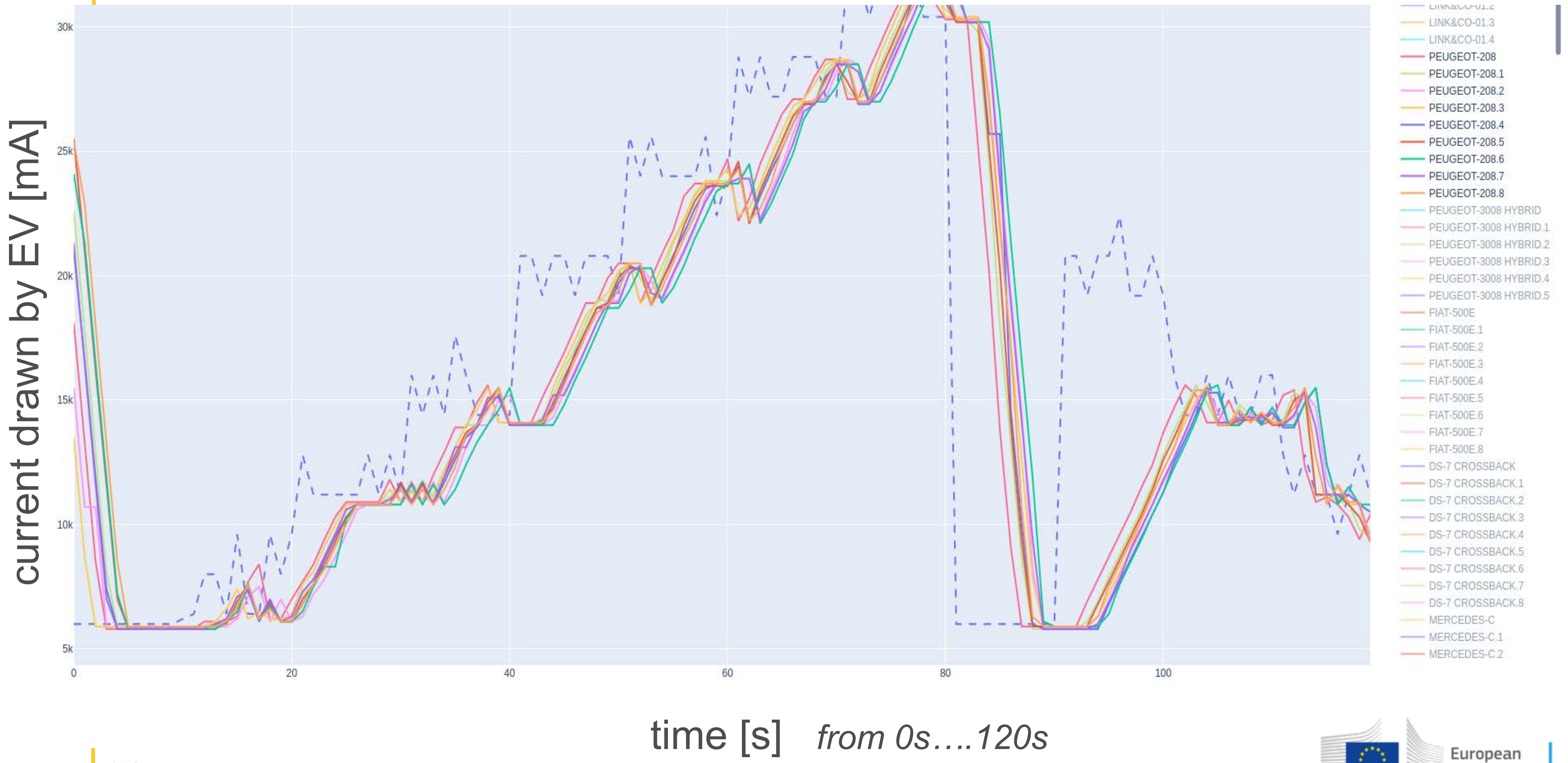


We let **AI** automatically recognise each EV-types “slew and amperage limitation profile”

Modelling specifics:

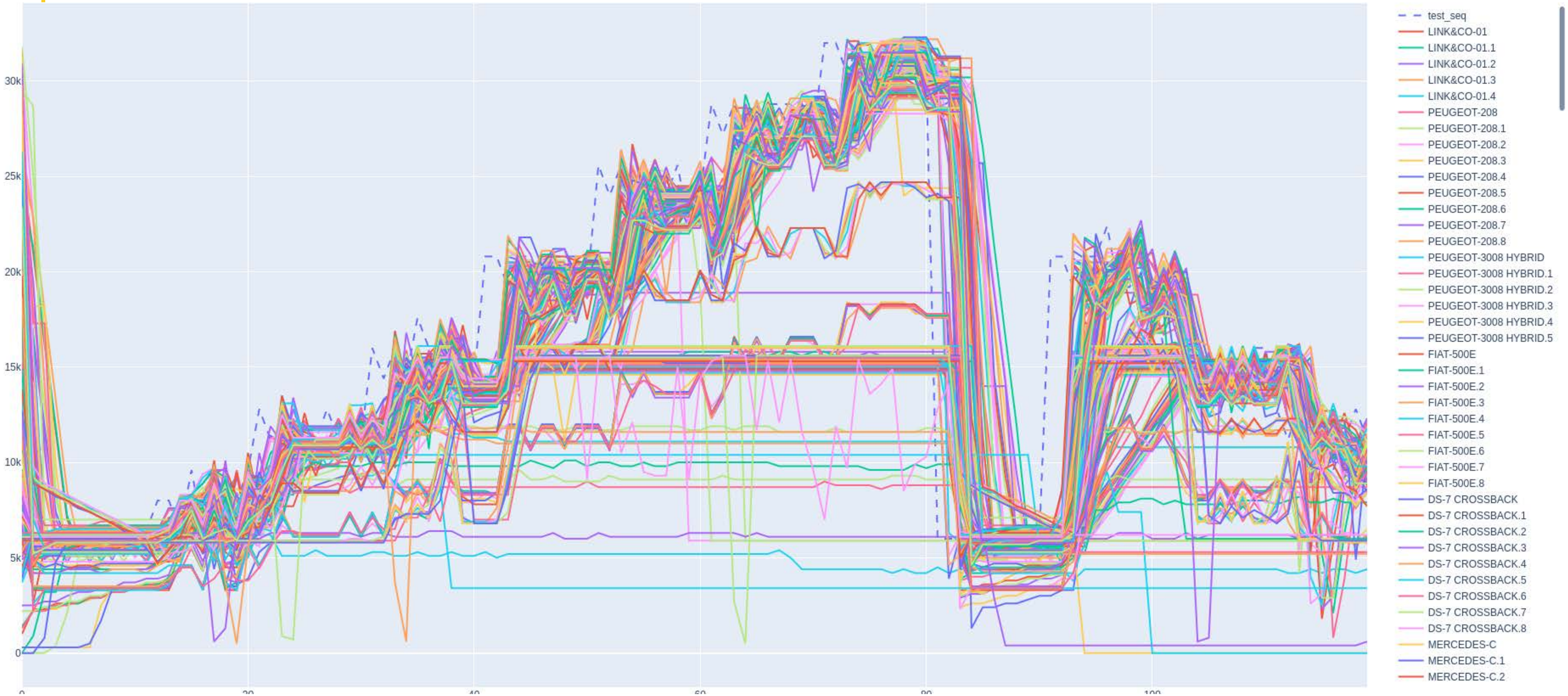
- We sampled 70 EVs (52 different types) 10 times each, leading to a training set of 700. This is devided into 80% **training** and 20% **testing**.
- The machine learning algorithm used is based on a *Random Forest* with 200 estimators, and fed with 200 best features (using Python library *tsfresh* and *Kbest*).
- For informatical details, pls contact Federico.Ferretti@ec.europa.eu

Harvested fingerprints (1): *6 EVs of the same type*



Harvested fingerprints (2): the messy lot… **is** readable

current drawn by EV [mA]



time [s] *from 0s….120s*

Results

- We trained an AI system to predict the EV –marks and –models **only** from the EV-drawn current patterns over time. First, we got only 63% recognition rate.

+ Options

actual	predicted	date_insert	n_samples	
VOLVO XC40	['VOLVO XC40']	2023-06-08 16:28:50	33	
BMWX1	['BMW X1']	2023-06-08 17:18:57	34	
MINICOUNTRYMAN	['MINI COUNTRYMAN']	2023-06-09 07:18:27	54	
MINICOOPER SE	['MINI COOPER SE']	2023-06-09 07:42:21	71	
JEEPRENEGADE	['JEEP RENEGADE']	2023-06-09 07:42:21	53	
RENAULTZOE R135	['RENAULT ZOE']	2023-06-09 07:57:48	97	
PEUGEOT208	['PEUGEOT 208']	2023-06-09 08:14:35	73	
CITROENE-BERLINGO	['CUPRA FORMENTOR']	2023-06-09 08:14:36	74	error
SKODASUPERB IV	['VOLVO XC40']	2023-06-09 08:19:23	51	error
CITROENZOE	['FIAT 500E']	2023-06-09 08:19:23	72	user error
BMWX1	['JEEP RENEGADE']	2023-06-09 08:26:38	63	error

- **By re-iterative learning, we increased it to 78%, with 52 different EV types using the facility at JRC Ispra**

- **One needs to train with more than one car per type**

Conclusions from 2 min “finger-printing”:

- *An AC Plaza can distill from its “momentary client cohort” not yet SoC, but EV-types and thus individual power-envelope metrics*

- *At minimum added hardware cost, 1..3 phase AC-charging could be roughly DS-managed, in a fair and anonymous way*

- *This could support to follow flexibility curves especially in big multi-hour work- and home-charging cohorts*

Thank you
and keep in touch:
Harald.Scholz@ec.europa.eu

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joint-research-centre.ec.europa.eu

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European Commission

Electric Cooperatives

Smart Charging Management

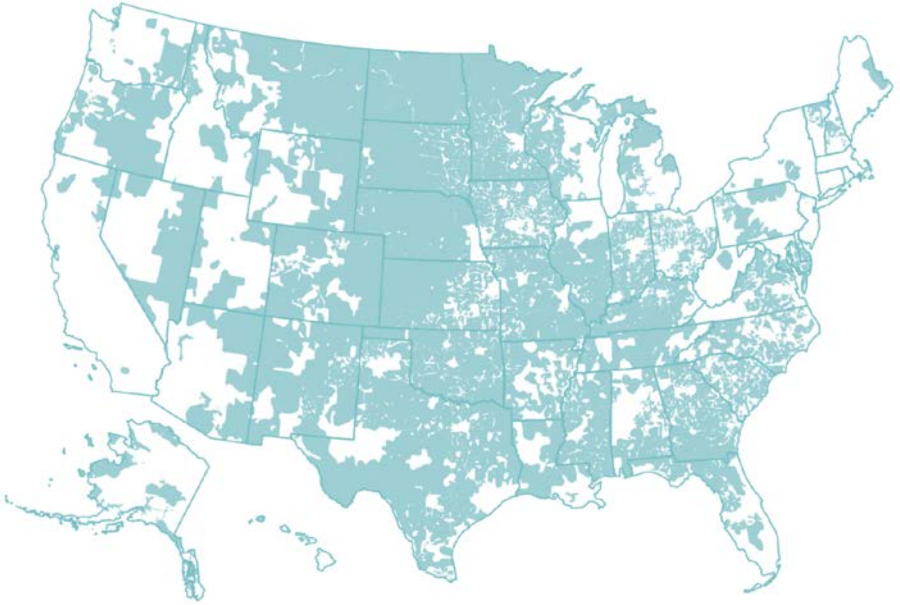
Presented by **Jennah Denney**

Business & Technology Strategies

National Rural Electric Cooperative Association

November 8, 2023

Cooperatives power 56% of the nation's landmass

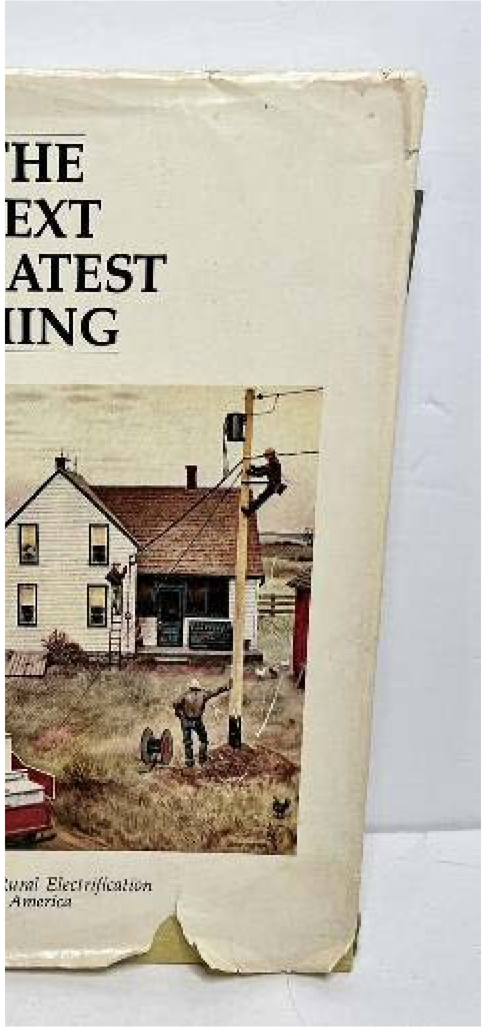


- Co-ops serve **42 million** people, including **92%** of persistent poverty counties.
- Co-ops power over **21.5 million** businesses, homes, schools and farms in 48 states.
- Co-ops returned more than **$1.4 billion** in capital credits to their consumer-members in 2021.
- **832 distribution cooperatives** are the foundation of the electric cooperative network. They were built by and serve co-op members in the community with the delivery of electricity and other services.
- **63 generation & transmission cooperatives** provide wholesale power to distribution co-ops through their own electric generation facilities or by purchasing power on behalf of the distribution members.

Electric Co-ops Are Innovation Hubs

Co-ops are meeting tomorrow's energy needs by investing in the future of their communities.

- **Broadband:** More than 250 co-ops deployed or are planning to deploy broadband service to their members, giving them access to telehealth services, online learning, remote work and new possibilities for local businesses.
- **Smart Meters:** Electric cooperatives lead the industry in smart meter deployment, with a 81% use of AMI meters, compared to 67% for the rest of the industry.
- **Energy Storage:** Cooperatives have developed more than 75 energy storage projects, ranging from residential batteries to large utility-scale projects paired with renewable generation. Storage is an important element of microgrids, including on military installations.
- **Carbon Capture:** Electric cooperatives are partners in innovative carbon capture technology research projects.



Mission: The Cooperative Approach to Vehicle Electrification (CAVE) is a network of electric cooperatives that have implemented or are planning to implement a variety of electric transportation programs.

Goals:

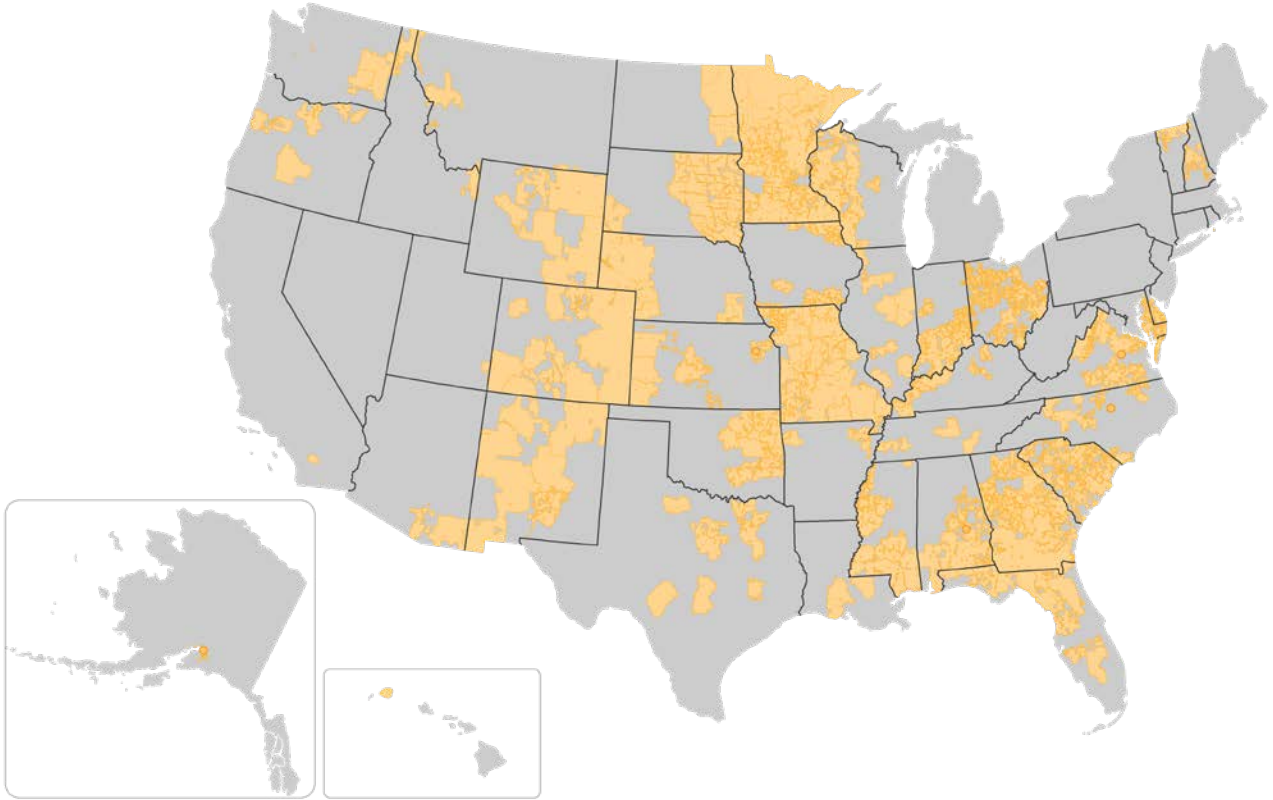
- Focus on charging infrastructure in rural and low-income communities.
- Create education-based programs to inform consumers, dealers and policy makers on the value of electric transportation.
- Explore options for fleets, transit bus, school bus and medium/heavy duty truck adoption and charging solutions.
- Demonstrate unique programs that utilize technologies to improve grid reliability.

NRECA Responsibilities

- Leverage engagement with funding entities to showcase electric cooperative commitment to transportation electrification.
- Advocate co-op projects with funding sources.
- Keep co-op participants up to date on the latest EV-related funding opportunities.

Participating Co-op Responsibilities

- Identify key contact for this effort at their cooperative.
- Share EV plans with NRECA staff as appropriate.
- Receive messages related to funding opportunities.
- Participate in calls with funders as needed.



Service Territories of CAVE participants as of April 2023

- Reliability & Affordability
- Increased electricity sales and decreased emissions
- Grid Upgrades
- How to manage charging behaviors
- How to track adoption
- Clustering
- How to educate car buyers and car dealers
- How can utility use EVs as assets
- Interconnection Processes

BCREMC's Guide to Workplace and Fleet Charging.

Not Sure What Charger to Install?

Visit our Workplace Charging Lab at the BCREMC office located at 1697 W. Deaver Rd. for examples of workplace chargers installed in o employee parking lot.

View BCREMC's Charging Guide

Addressing common misconceptions about EVs

- Range anxiety
- Charging time and infrastructure availability

ELECTRIC VEHICLES

EV Consumer Study: Lack of Public Chargers Is Biggest Obstacle

A shortage of public chargers remains the biggest issue holding Americans back from buying EVs, according to a new study by J.D. Power. Learn more about the research and get the co-op perspective.

COOPERATIVE.COM

Rural challenges in building out capacity for EV charging

- Planning for the load – where/when/how much
- Minimum requirement of 600 kW capacity per NEVI site
- Grid side investments needed

Rural America's role in the electric transportation transition will be critical to national goals.

Increased Electricity Demand:

- The transition to electric vehicles will significantly increase electricity demand, especially during peak charging periods. Utilities will need to anticipate and plan for this increased load to ensure grid reliability and avoid overloading.

Grid Infrastructure Upgrades:

- Utilities may be required to perform grid infrastructure upgrades to support the growing EV market. This includes expanding high-voltage transmission lines, upgrading distribution systems, and implementing smart grid technologies to manage charging demand effectively.

Grid Management and Resilience:

- With the influx of EVs, utilities must develop grid management strategies to balance electricity supply and demand, implement demand response programs, and enhance grid resilience to withstand potential strain or disruptions caused by increased EV charging needs.

Contact – Questions?

Jennah Denney

EV Strategy & Solutions Manager

Business & Technology Strategies

o: 501.400.5548   m: 309.519.7731

email: jennah.denney@nreca.coop

NRECA
America's Electric Cooperatives

EVs@Scale
U.S. Department of Energy

SCM/VGI Panel Discussion

Jesse Bennett, NREL

September 27, 2023

SCM/VGI Panelists

Kacy Marrs

Energy Specialist, Lion Electric

Nate Baguio

Senior VP Commercial Development, Lion Electric

Harald Scholz

European Commission, Joint Research Centre

Jennah Denney

EV Strategy and Solutions Manager, NRECA

SCM/VGI Discussion Topics

- **Grid Benefits/Program Development**
  - What are the primary grid challenges that require SCM/VGI solutions?
    - Distribution equipment limitations, substation/subtransmission capacity, generation/emissions considerations…
  - What are the key barriers to developing SCM/VGI programs?
    - Customer participation, systems development, quantifying benefits, operations/maintenance…
- **Integrating with Fleet/Vehicle Operations**
  - What are some of the biggest challenges to integrate SCM/VGI into fleet operations?
    - fleet/SCM systems integration, detailing dwell period/energy needs, driver inputs, operations variability, system reliability…
  - What are the most common “drivers” for adoption of SCM/VGI?
    - What are desired benefits to delay/modify EV charging sessions
- **Deployment/Enabling Technologies**
  - What elements essential to SCM/VGI need further development/demonstration?
    - EV/EVSE communication, communicating grid needs/signals, driver/operations inputs, others…
  - How do we quantify the value of SCM/VGI with new or existing metrics?
    - Mitigated upgrades, emissions reductions, system reliability, EV/driver reliability…

Time for Tours!

Reminder that we start at 8:15am tomorrow.

EVs @ Scale
U.S. Department of Energy

Jason D. Harper, Akram Syed Ali
ANL EV-Smart Grid Interoperability Center
Advanced Mobility and Grid Integration Technology
September 2023

EVs@Scale
U.S. Department of Energy

High-Power Charging Pillar: eCHIP

High-Power **E**lectric Vehicle **C**harging **H**ub **I**ntegration **P**latform

Lion Electric Bus V2G Demonstration

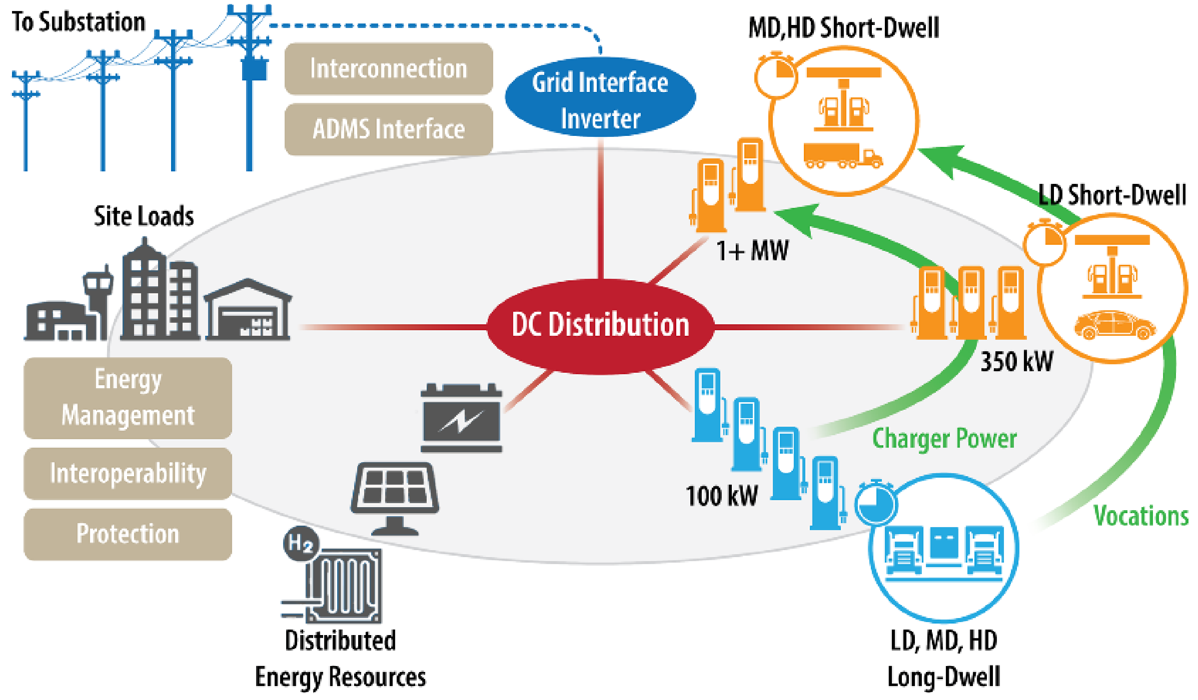
Building 362 Hi-Bay

Objective:

Develop a plug-and-play solution allows a charging site to organically grow with additional chargers and distributed energy resources (DERs) through predefined compatibility with standards that will ensure interoperability and reduce upfront engineering expense

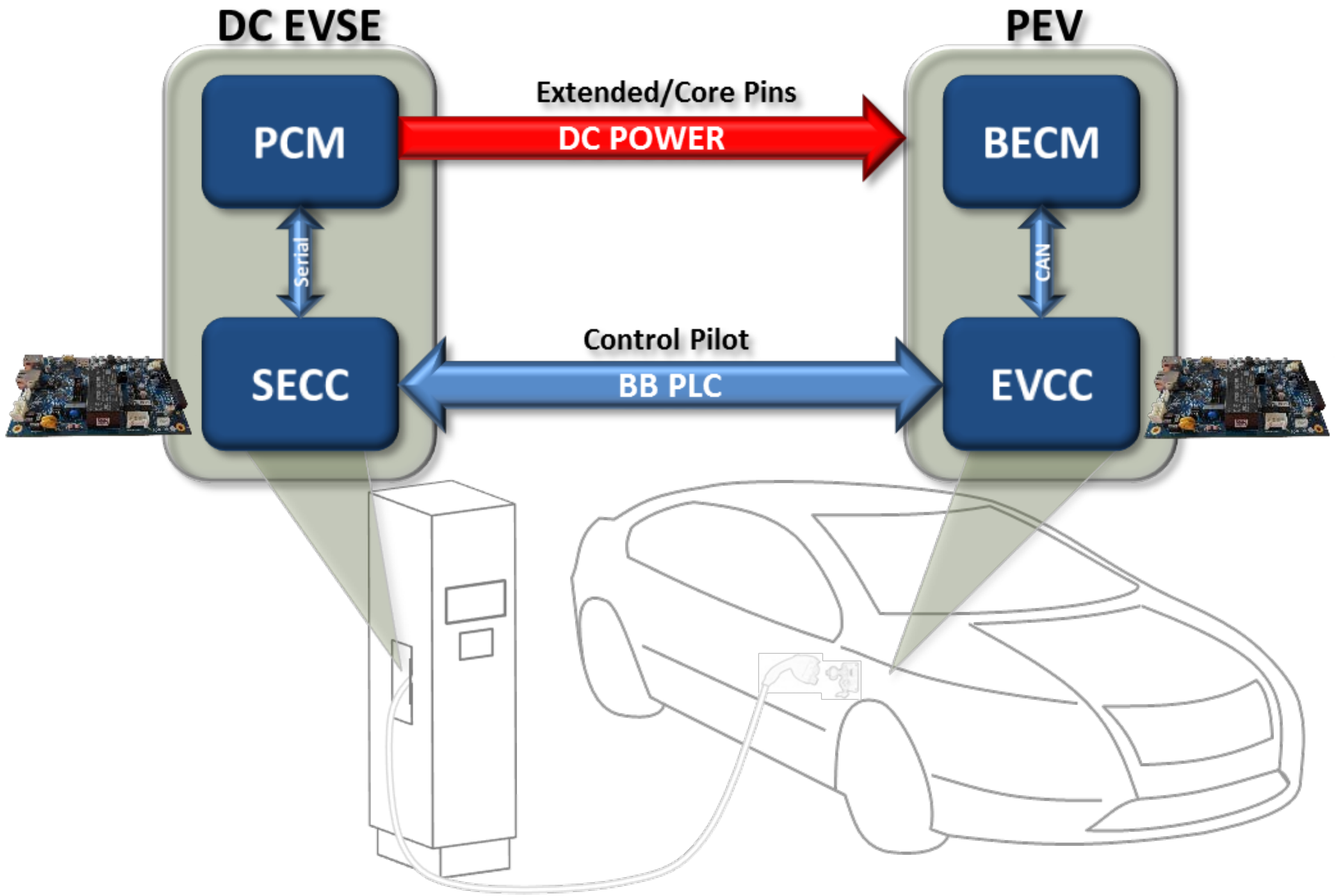
Outcomes:

- **Broadly identify limitations and gaps** in DC distribution and protection systems that would allow for modular high-power charging systems
- Develop and demonstrate solutions for efficient, low-cost, and **high-power-density DC/DC** for kW- and MW-scale charging
- Determine interoperable hardware, communication, and control architectures for high-power charging facilities that support **seamless grid integration and resilient operation**



DC Charging

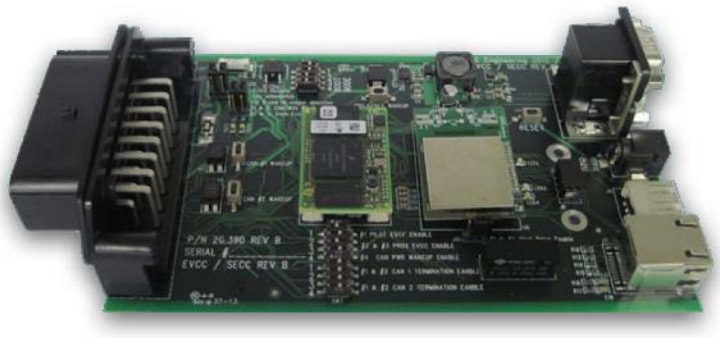
Overview



SpEC Module

ANL

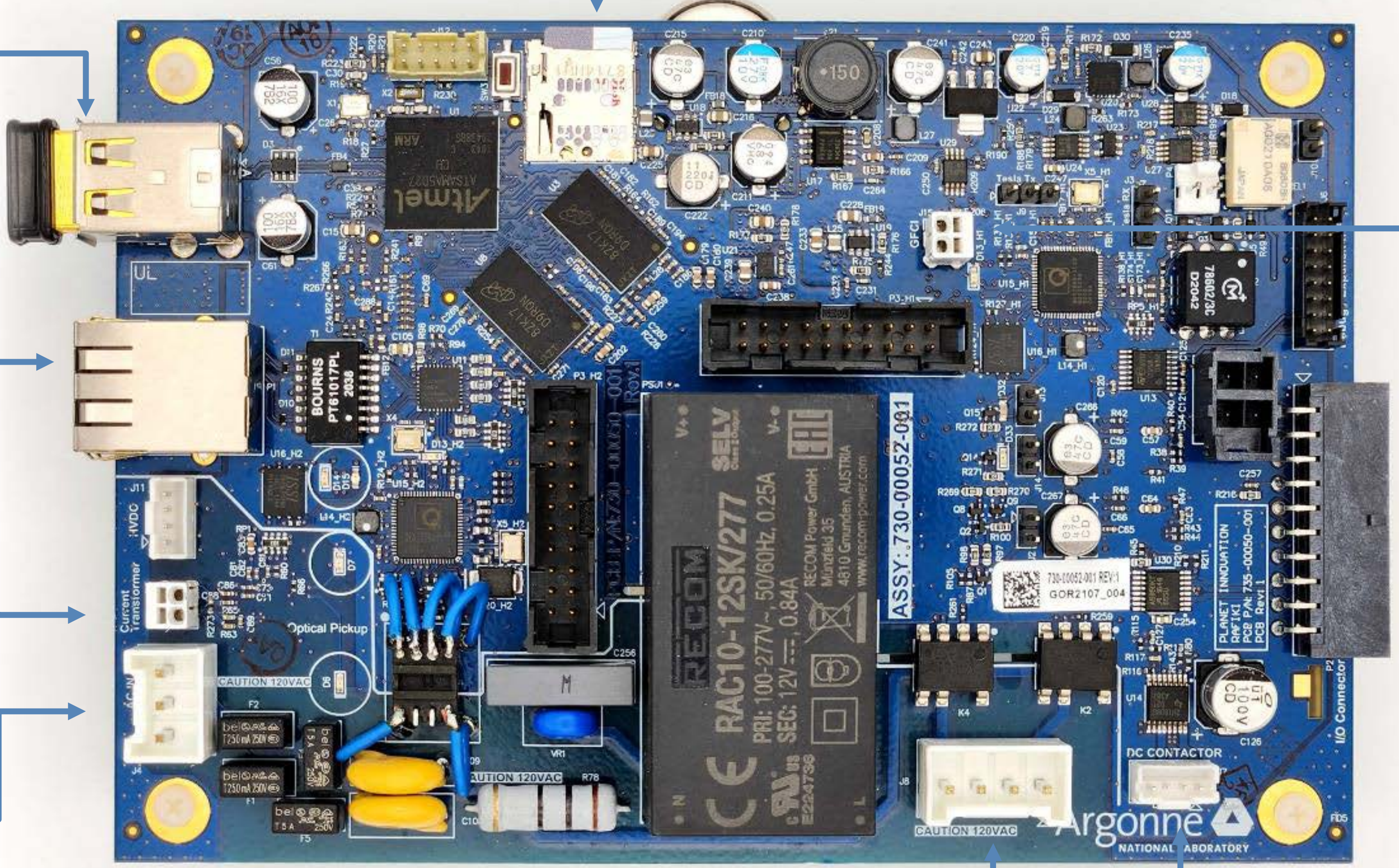
- The SpEC module developed by ANL is a smart plugin EV communication **controller**
- Enables DC fast charging communication between an EV and the charger
- Implements **high-level communication** required for *fast DC charging* based on DIN SPEC 70121 and ISO 15118 standard
- The SpEC module will translate the XML/EXI **messages** to and from the EV, as well as accept **commands** from the SEM system
- Custom C/C++ firmware
- Currently licensed to industry as an SECC



SpEC module (Gen I)

SpEC Module – Gen II

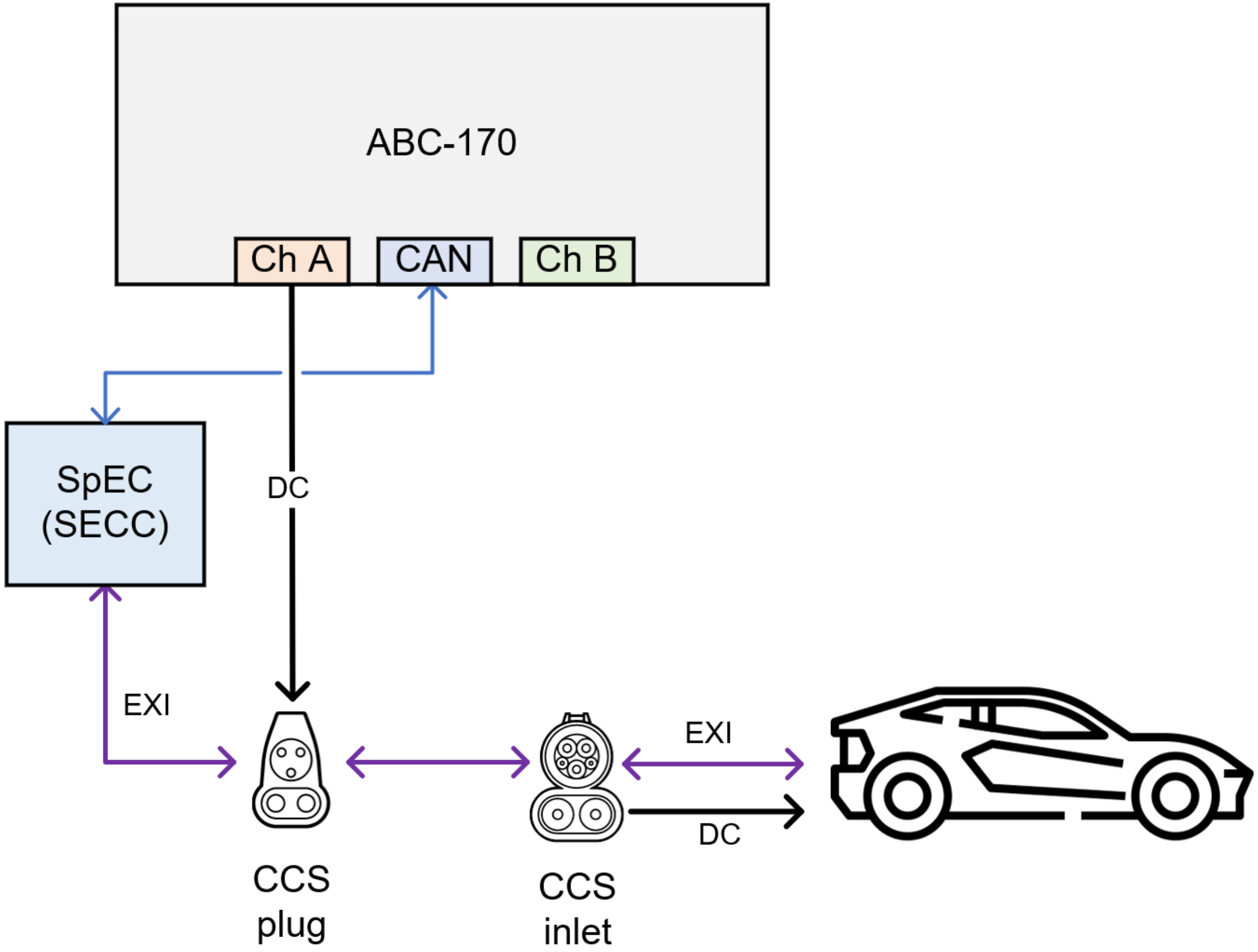
ANL



Test Setup

Actual EV

	Channel A
Max Voltage	450V
Min Voltage	0V
Max Charge Current	150 A
Max Discharge Current	-150A
Max Charge Power	48 kW
Max Discharge Power	-48 kW



Lion Electric Bus

All-Electric Type C School Bus

Technical Specifications*

WEIGHT & DIMENSIONS

Vehicle length	473 in.
Vehicle widths	96 – 102 in.
Vehicle height	122 in.
Wheelbases	278 in.
Gross vehicle weight rating (GVWR)	Up to 31,000 lb
Capacity	Up to 77 passengers

ELECTRIC POWERTRAIN

Top speed	60 mph
Maximum power	250 kW • 335 Hp
Maximum torque	2,500 Nm • 1,800 ft-lb
Ranges	Up to 155 miles**
Battery capacities	126 – 168 kWh
Motor and inverter	SUMO MD • Dana TM4
Transmission	Direct drive No transmission
Charging types	CCS Combo
Level II – Charging Time	
19.2 kW	6.5 – 11 hours
Level III – Charging Time	
24 kW	5 - 9 hours
50 kW	2.5 - 4.25 hours

CHASSIS

Front Axle	Up to 10,000 lb
Rear Axle	Up to 21,000 lb
Suspension	
Standard	Spring suspension
Optional	Rear air ride
Braking	
Standard	Hydraulic disc brakes
Optional	Air brakes

* SPECIFICATIONS ARE SUBJECT TO CHANGE.

** Based on 65% GVWR, on a Rowan University Composite School Bus Cycle.

LION ELECTRIC thelionelectric.com

ISO 15118-2 BPT Demonstration

Thank You

EVs @ Scale

U.S. Department of Energy

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TRANSPORTATION AND POWER SYSTEMS

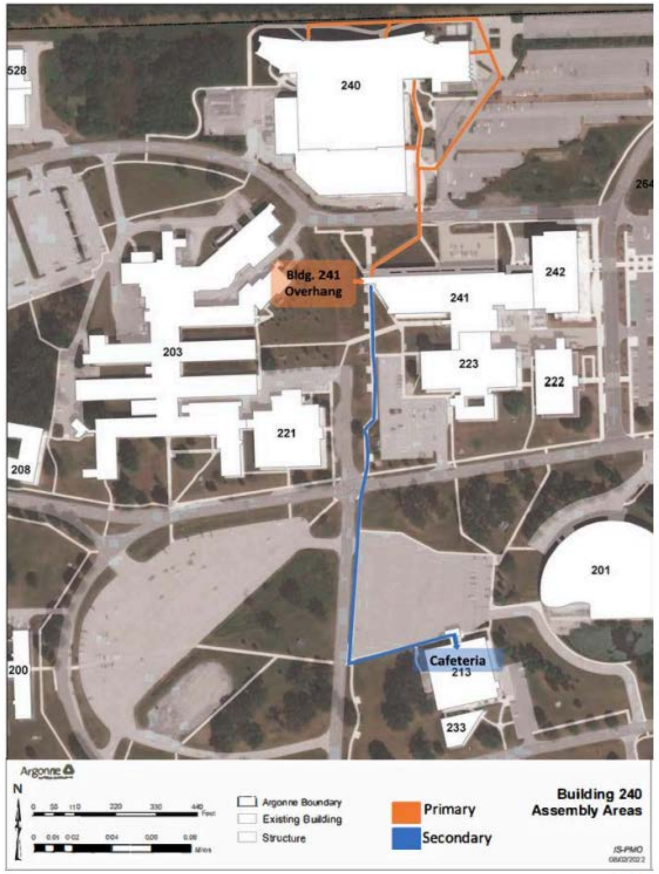
EVs@Scale Lab Consortium Semi-Annual Stakeholder Meeting

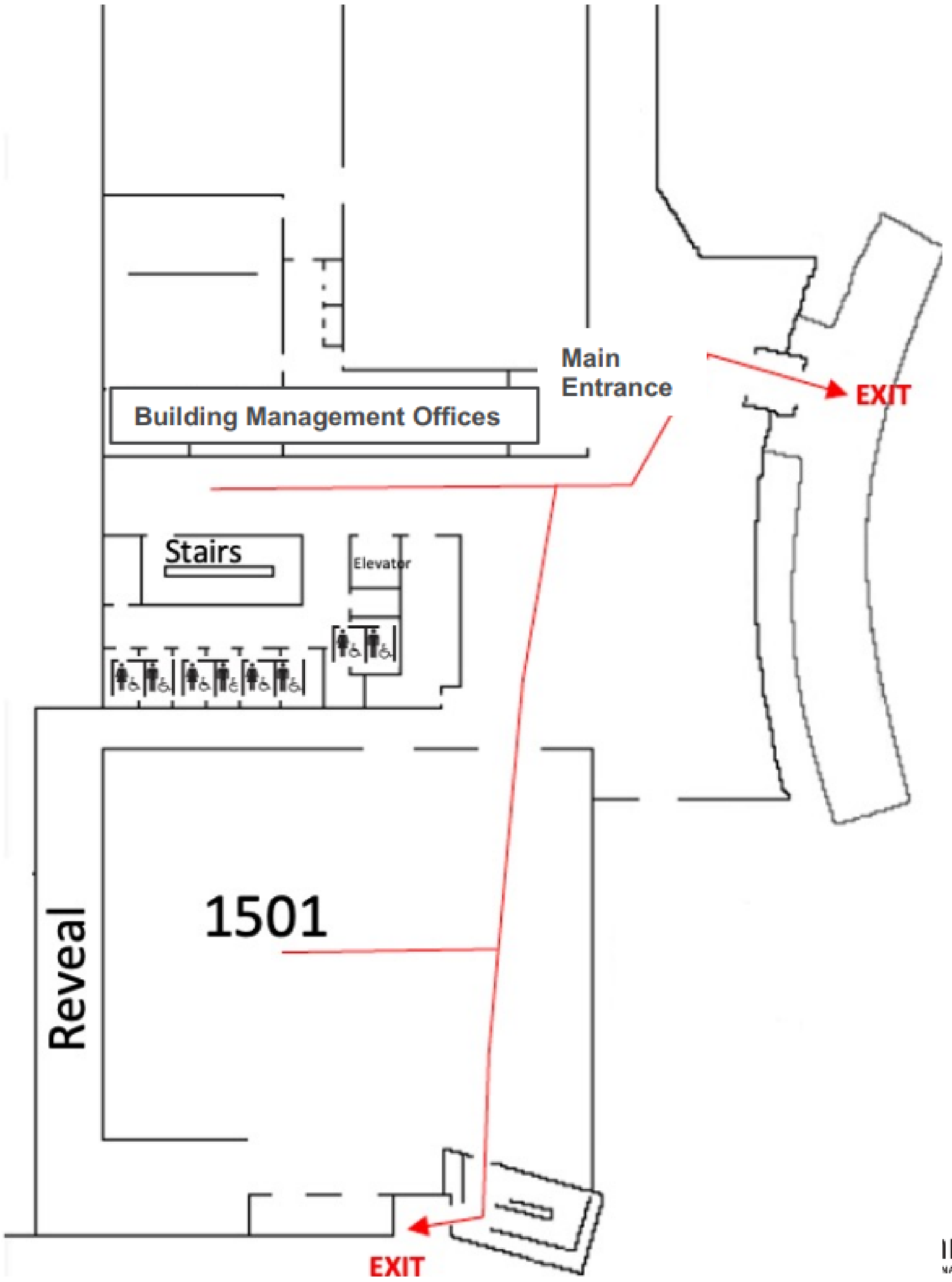
EMERGENCY INFORMATION FOR BLDG. 240 ROOM 1501

DIAL 9-1-1 ON AN ARGONNE PHONE OR 630-252-1911 ON YOUR CELL PHONE AND FOLLOW OPERATOR INSTRUCTIONS

ROOM 1501 EMERGENCY EVACUATION ROUTE

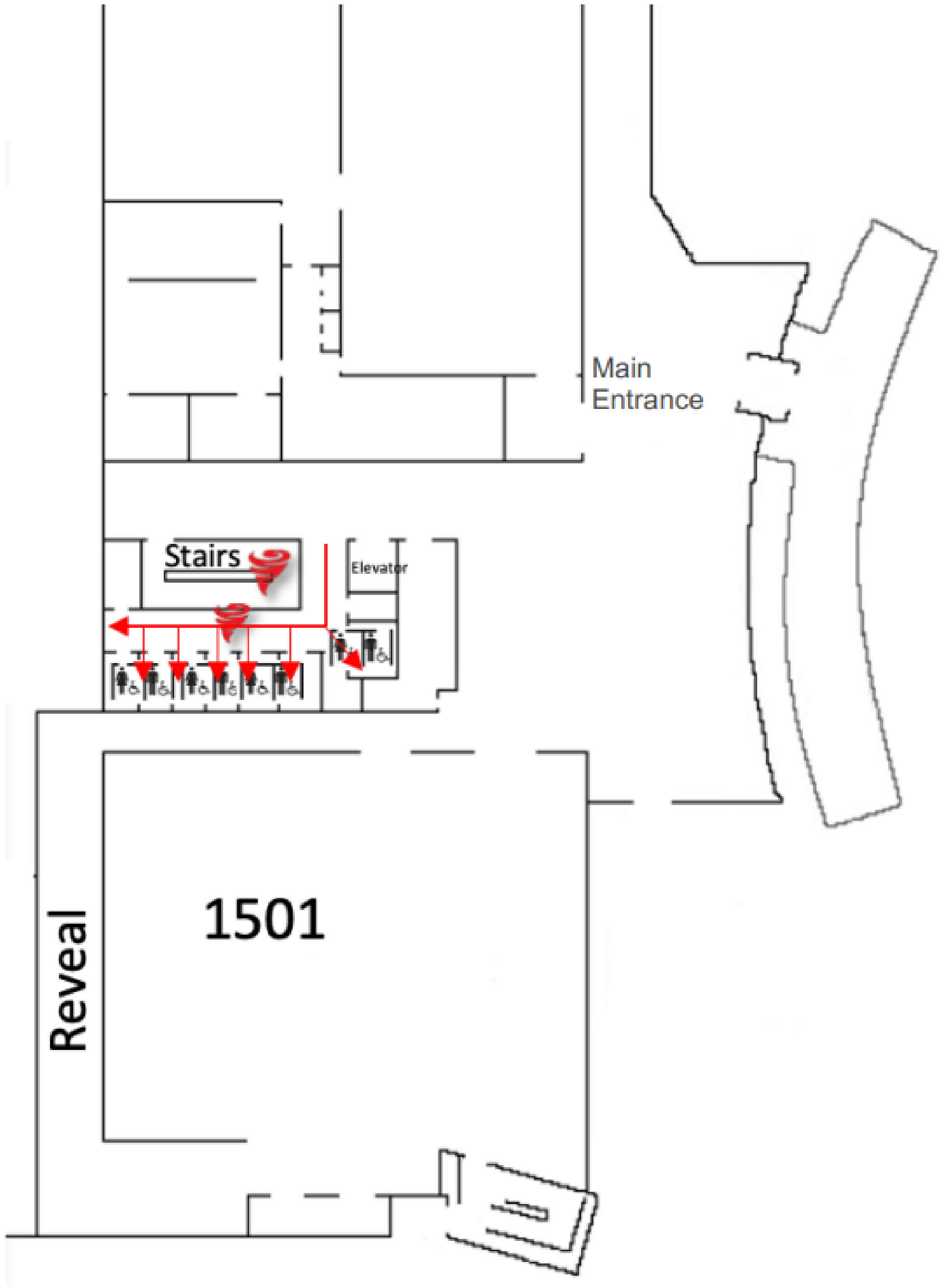
In case of evacuation emergencies follow the exit signs





EMERGENCY SHELTER LOCATIONS

In case of severe weather relocate to shelter areas; central stair well, the first floor restrooms and adjacent hallway



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U.S. Department of Energy

Advanced Charging and Grid Interface Technologies Pillar

September 2023 Stakeholders Meeting

Madhu Chinthavali

Prasad Kandula, Veda Galigekere, Michael Starke
Don Stanton

Oak Ridge National Laboratory
9/28/2023

Advanced Charging and Grid Interface Technologies

Address System Integration Challenges

EVs@Scale
U.S. Department of Energy

Vision : Advancing EV station and charger controls, communications, protection, and architectures through developing technology prototypes

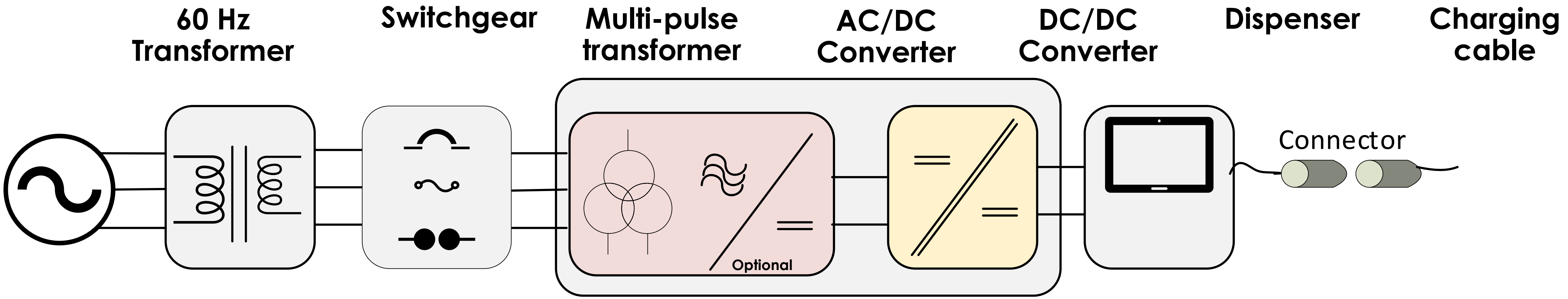
Advance Components → **Charging station Subsystems: development** → **Charger prototyping** → **Advance Controls and software platform development** → **Use case development and pilot demonstration : Virtual and @scale**

Charging Equipment Technologies	Charging Station Infrastructure	Grid Resource Integration	Vehicle and Charging System Interface Technologies
•*Grid interface with advance component technologies and controls for novel charging functionality* •*High power charging equipment prototyping for heavy-duty vehicle and similar applications such as aircraft*	•*Design and develop station architectures* •*Novel communication and control station level strategies.*	•*Energy storage, photovoltaic, and other technology integration* •*EV substation design and development for future large scale muti-vehicle stations*	•*Interface protection, safety and interoperability* •*Flexible, modular, multiport Interface configurations for LD, MD, HD, off-road, and e-VTOL applications*

Synergistic cross cutting technology opportunities with other programs - OE,GMLC

Gaps in EV charger Implementation

EVs@Scale U.S. Department of Energy



- Lack of standardized high-power building blocks to achieve high charging powers
- Limited to 950 V-Improved density reduces foot-print and simplifies installation
- Lack of direct MV grid connected converters to improve power density and handle high powers

- Lack of isolated DC/DC converters in the market is a major constraint for charging system implementation
- Lack of fast DC protection hardware and coordination algorithms
- Coordination of multiple DC/DC converters

- A test system to evaluate multiple charger performance – emulator
- Protection schemes for grounding, fast acting devices
- Hybrid interface options for new non-commercial vehicles (ex. eVTOLs)

- Mix of air cooled and liquid cooled thermal management systems

Gaps in EV charger Power Conversion stage :

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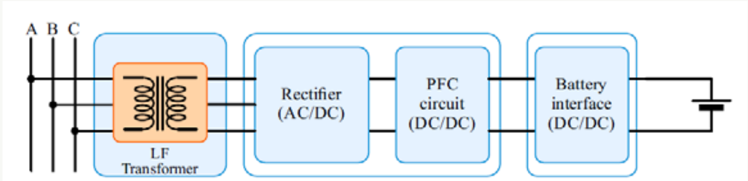
U.S. Department of Energy

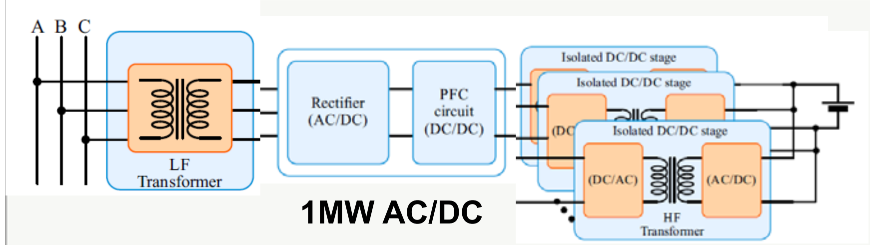
Vendor	Voltage class	Bi-directionality	HF Isolation	Power rating Block/full unit	Efficiency	Power density	Thermal Management
A	500 V DC	Claim- Not implemented	Yes	125/375 kW DC-DC 70 kW AC-DC			liquid
B	950 V DC	None	Yes	60/360 kW DC-DC	98% (AC-DC) 98.5 % (DC-DC)	92"x24"x40" (AC-DC) 79"x 22.5"x15.5" (DC-DC)	Air Cooled
C	920 V DC	None	No	175 kW/350 kW	94% (Grid - Car)	46"x 30"x 30"	Air Cooled
D	920 V DC	None	Yes	100 kW/1 MW	94% (Grid - Car)		Air cooled

	AC-DC	DC-DC (unidirectional)	DC-DC (Bidirectional)
480 V class	2-level, 3-level NPC, 3-level ANPC, Current source	LLC, Phase shifted full bridge	CLLC, DAB
13 kV class	MMC, CHB-DAB, CHB-Resonant		DAB

Topologies/ power block ratings are not standard

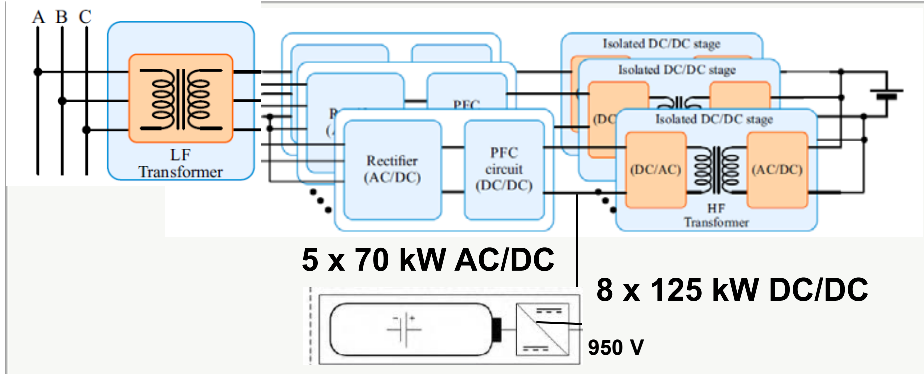


1 x 175 kW AC/DC



1MW AC/DC

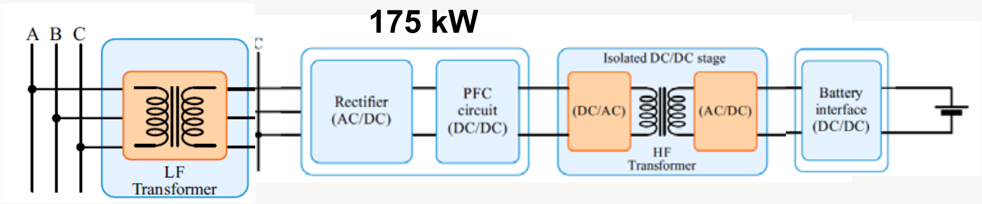
10 x 100 kW DC/DC



5 x 70 kW AC/DC

8 x 125 kW DC/DC

175 kW

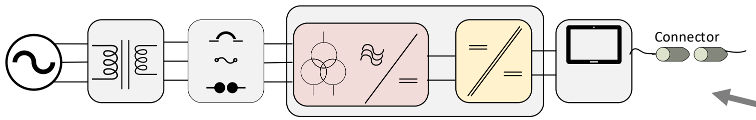


1 x 360 kW AC/DC **6 x 25/60 kW DC/DC**

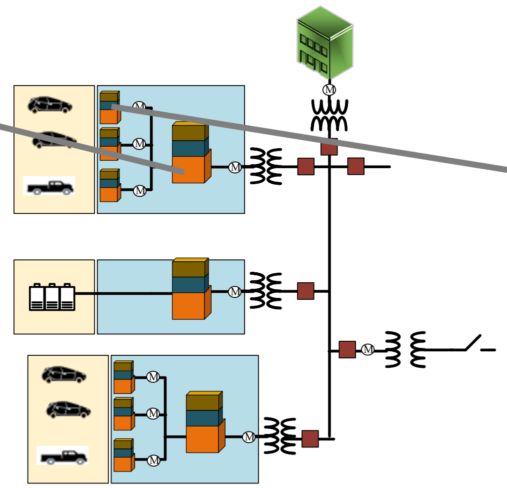
Potential Target: Metrics of isolated DC/DC chargers

- Voltage : up to 1500 V
- Power: > 100 kVA
- Isolation: > 4 kV
- Efficiency: > 99%
- > 2 W/cm^3 water cooled
- > 0.7 W/cm^3 air cooled

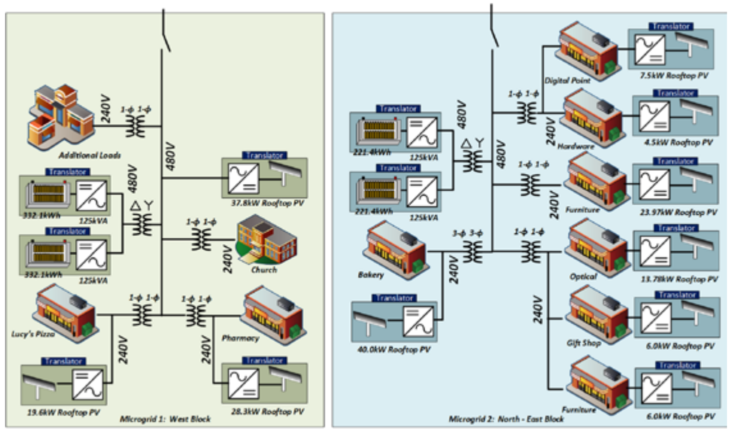
Gaps in Charging Infrastructure and Resource Integration- Commercial Charging Infrastructure



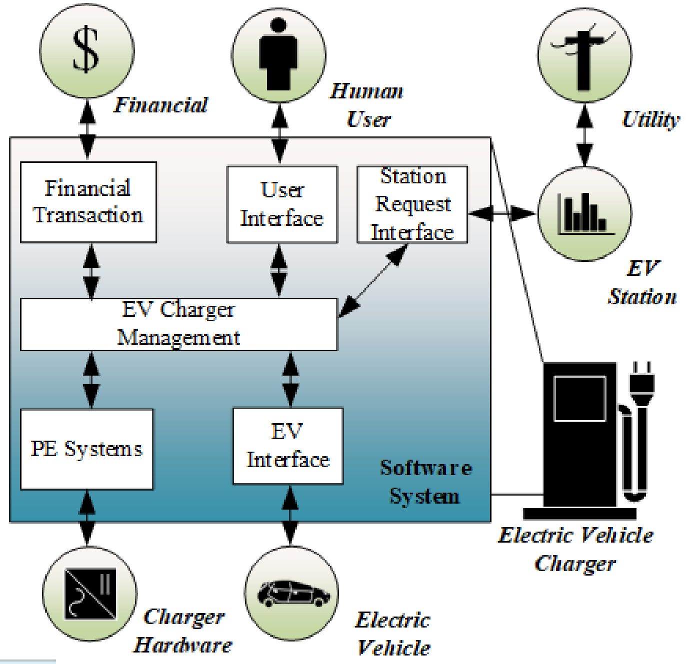
BTM solutions



Single Owner Commercial Entity



Multiple Owner Commercial Entities



- Unidirectional converter systems: designed to serve EV as a load
- Application of V2G : Requires advance controls beyond setpoint control methods, EVs treated as DER for V2G
- Autonomous controls for charger, Power quality issues
- Resource Integration and management: building loads not integrated yet. All treated as separate loads
- O&M costs:
- Multi vendor product integration needs standardization
- Diagnostics and Prognostics: reduce BOS systems costs

Ownership model: Utility+ Business Owner/Owners

- EVSE ownership
- Infrastructure planning and installation
- Operation and maintenance: software and hardware

Gaps in Charging Infrastructure and Resource Integration: Large Scale Charging Infrastructure

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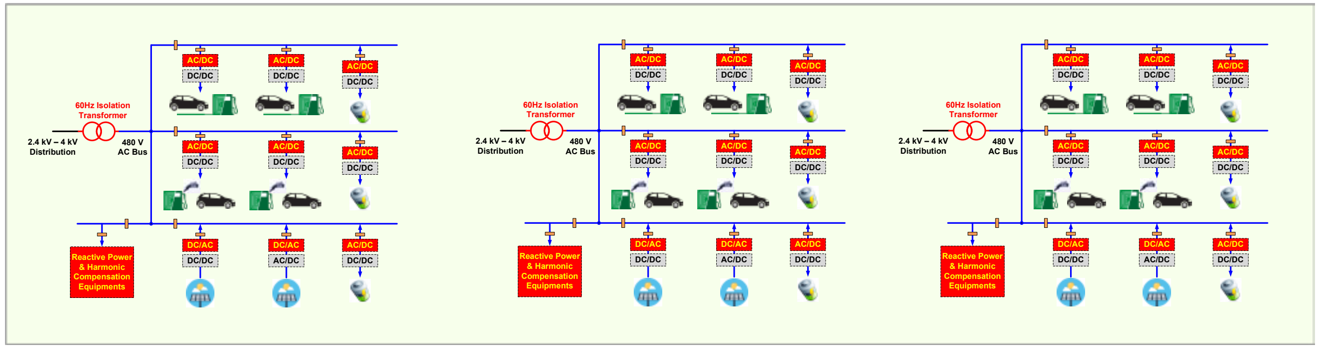
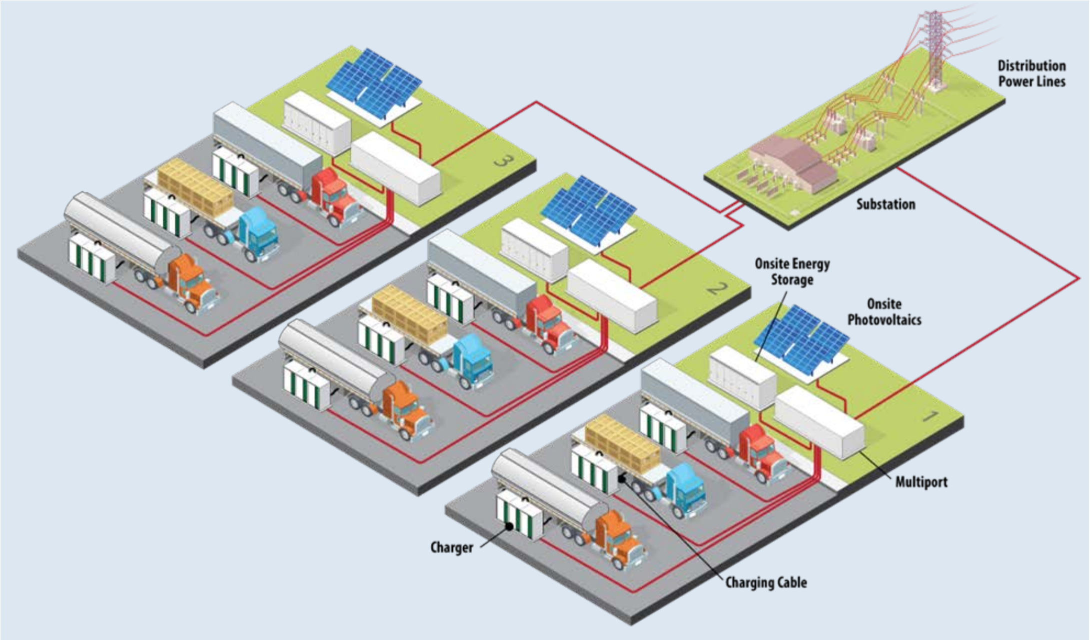
- Distribution, sub-transmission and transmission scale charging stations
    - need the substations to be designed for bi-directional functionality
    - Need to address power quality issues
    - Leverage DER based substation design guidelines?
- Large scale charger stations lack
    - standardized architectures to support Resource Integration into EV Charging Stations and understanding Implications
    - Utilization of the EV stations for grid services- under different load scenarios
    - Interoperable, plug and play system integration control platforms: Multiple vendors platforms focus on chargers
    - Protection Coordination





Gaps in Charging Infrastructure and Resource Integration: Large Scale Charging Infrastructure

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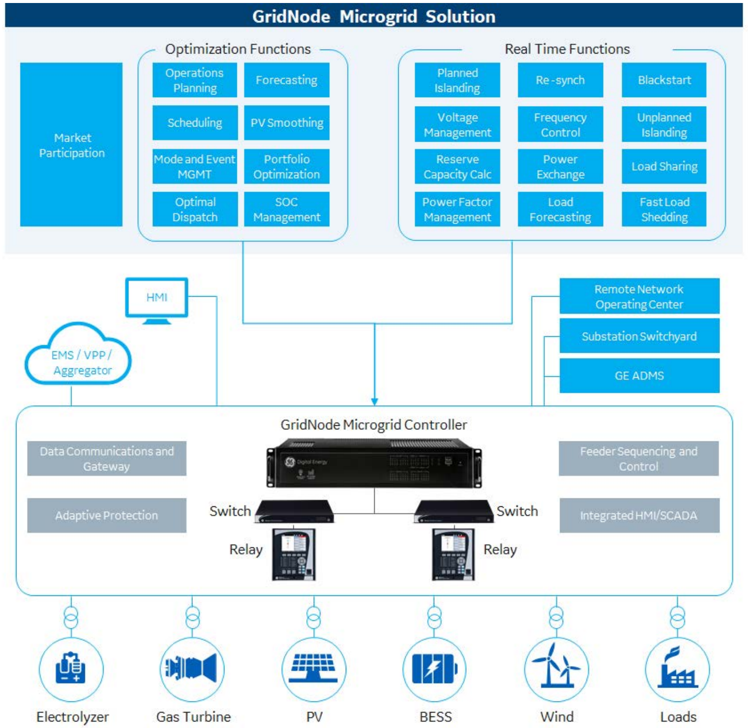
- Charging stations operated as a microgrid leverage the microgrid controllers and their functions for grid services:
  - Networked/coordinated station segments for BTM and distribution scale not explored yet.
  - Optimization limited to energy management : lack of operation-based controls for station
- **Ownership models? UTILITIES? LARGE COMMERCIAL entities, Public charging infrastructure?**

  a. Control boundaries and data boundaries needed to meet requirements for different functions of the charging station
     a. Different Ownership Models (Data Sharing)
     b. Different Owner Objectives (Optimizations and Use Cases)
     c. Different Service Offerings (Control Functionality)



Microgrid Functions	Necessary Data
Energy Management (Forecasting and Demand Management)	electrical model, resource information* value functions and signals weather data
Voltage and Frequency Control	electrical model, resource information*
Islanding/Resynchronization/Black Start	electrical model, PCC information* resource information*
Ancillary Service Provider (frequency regulation, reserve, volt/var)	electrical model, PCC information* resource information*
Power Quality Management	electrical model, resource information*
Protection Coordination	PCC information* Protection device information*

Information includes*:

- mode options/settings
- system ratings
- measurements/state
- cost factors

Technical Approach

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Advance Components → **Charging station Subsystems: development** → **Charger prototyping** → **Advance Controls and software platform development** → **Use case development and pilot demonstration : Virtual and @scale**

Advance Components

- Identification of gaps in components : semiconductors, breakers, aux power systems
- Establish testing practices and protocols
- **Evaluating early-stage reliability of the subsystem components**
- Advanced magnetics with high insulation and low PD (partial discharge) while maintaining compact size/weight that will ensure reliable component life

Charging station Subsystems: development

- **Library of power stages:** Standardization techniques to achieve Plug-n-play
- **Communication and data interfaces for in-situ monitoring**
- **Diagnostics and Prognostics**

Charger prototyping

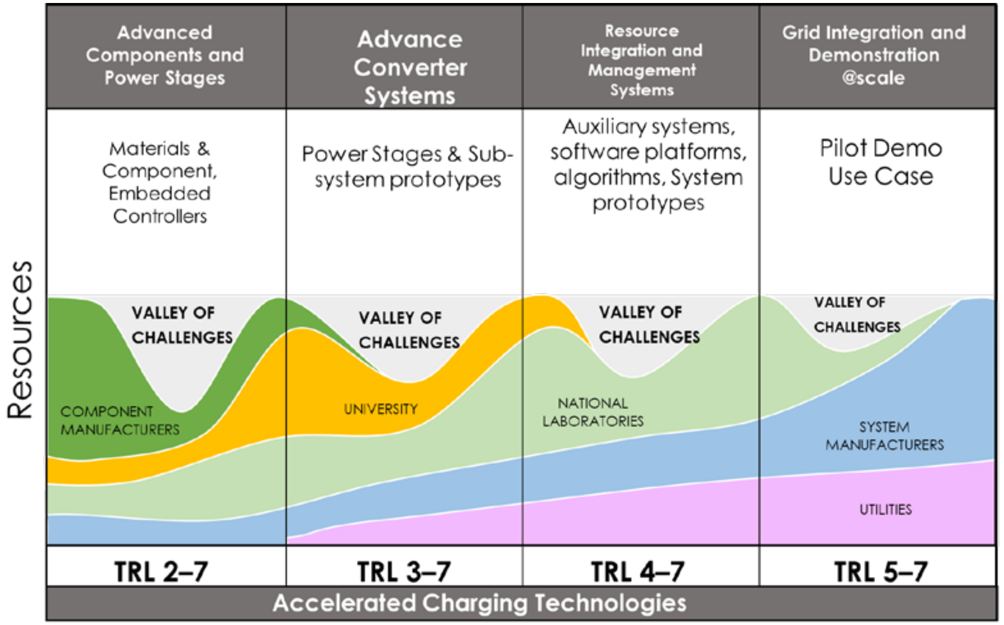
- **Novel topologies** that can achieve efficiency improvements, cost reduction or/and control simplifications
- Converter control architecture to handle multiple modules

Advance Controls and software platform development

- **Software architecture** and platforms for resource integration
- Real time management of resources beyond the chargers
- Multiple control schemes for multiple grid services for autonomous or coordinate secondary control

Use case development and pilot demonstration : Virtual and @scale

- **Use cases** for charging stations- large scale applications
- Real time, CHIL test beds for use case validation for future charging station architectures
- Evaluation of novel station architectures using @scale test beds



Madhu Chinthavali, chinthavalim@ornl.gov

EV Charger Development: Accomplishments

1700 V, 280 A/560 A, SiC

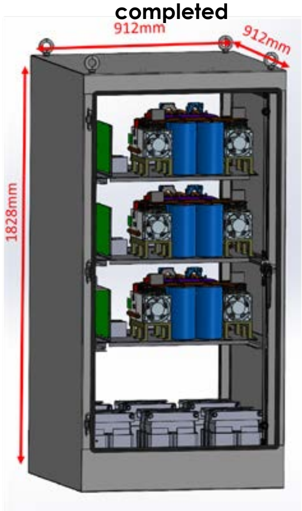
1000 V class 175 kW/350 kW charger	
Vin	800-1200 V (TBD)
Vout	200-950 V
Imax	225 A/ 450 A
Eff	>98.5%
Temp	-30°C to 50°C
Comms	CAN
Power flow	Bidirectional

1000 V, 175 kW, 20 kHz DC/DC Converter Prototype
Evaluated up to 150kW

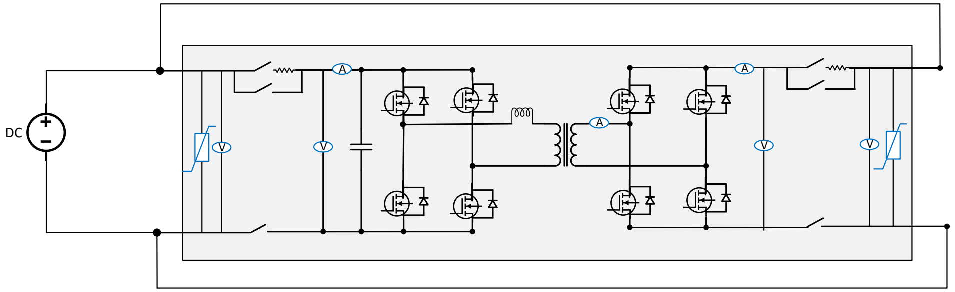
3300 V, 500 A SiC

2000 V class 350 kW charger	
Vin	1500-2000 V (TBD)
Vout	500-1500 V
Imax	250 A
Eff	>99%
Temp	-30°C to 50°C
Comms	CAN
Power flow	Bidirectional

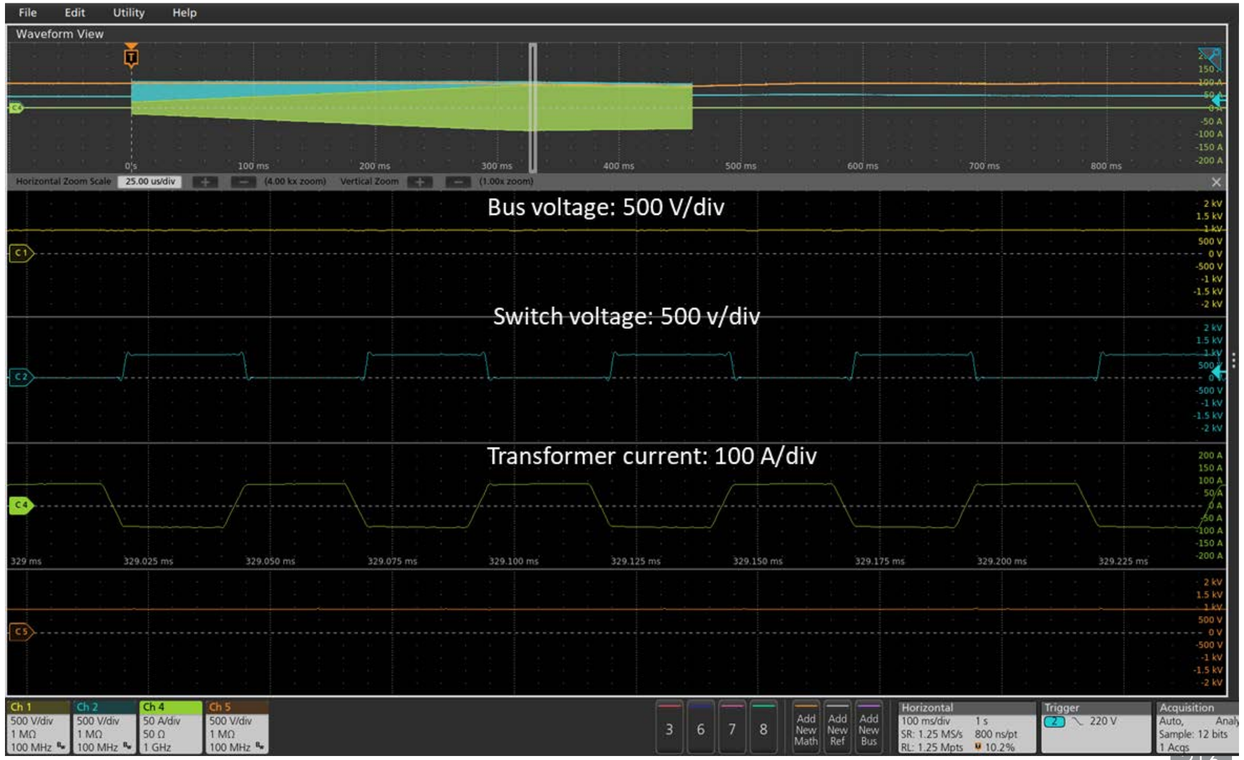
MV DC/DC Converter design completed
Component design, built and evaluation completed



Schematic of Converter test setup



Results at 950 V and 100 A: ~100 kW



Pillar Portfolio : Multi port Advanced Charging and grid interface demonstration at ORNL

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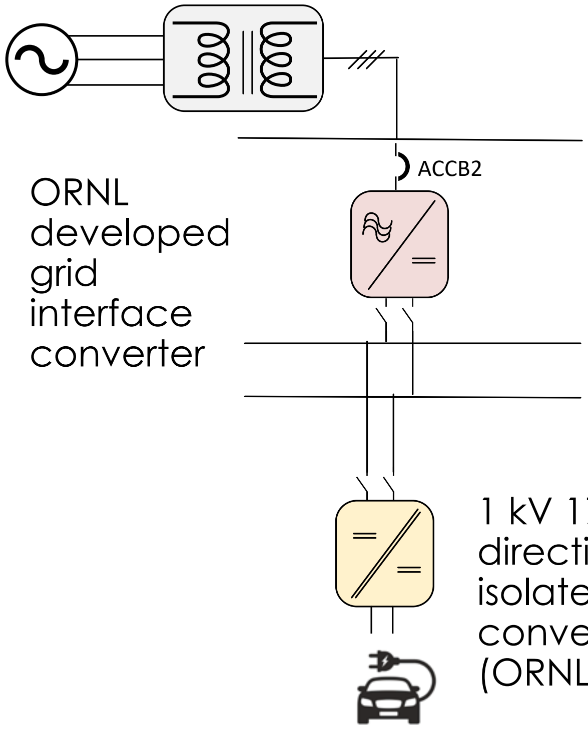
Phase 1: Demonstrate complete integrated charger (Grid to vehicle) with Advance Grid Controls : **Grid Forming Charger**

→

Phase 2: Demonstrate energy storage and charger integration and energy management: **Modular systems and Resource Integration with open source software**

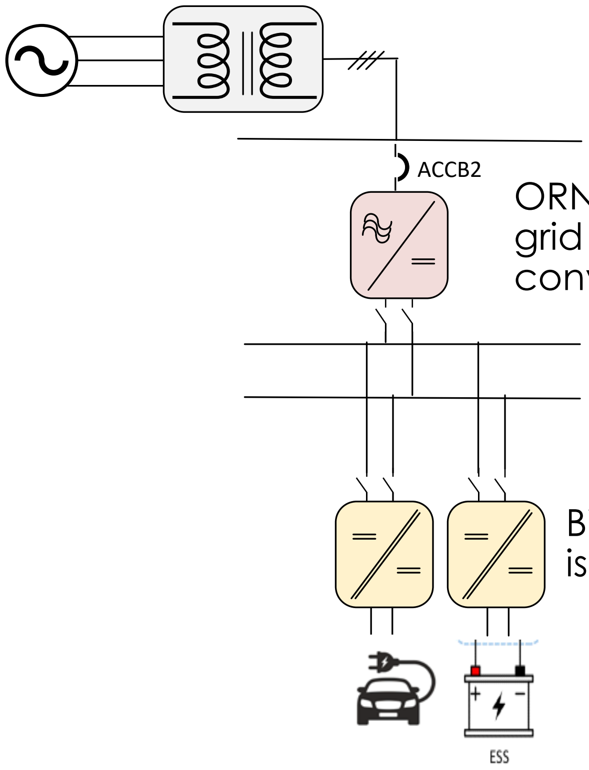
→

Phase 3: Demonstrate Multiple chargers and advanced grid converter capabilities: **Station control platforms with resource optimization**



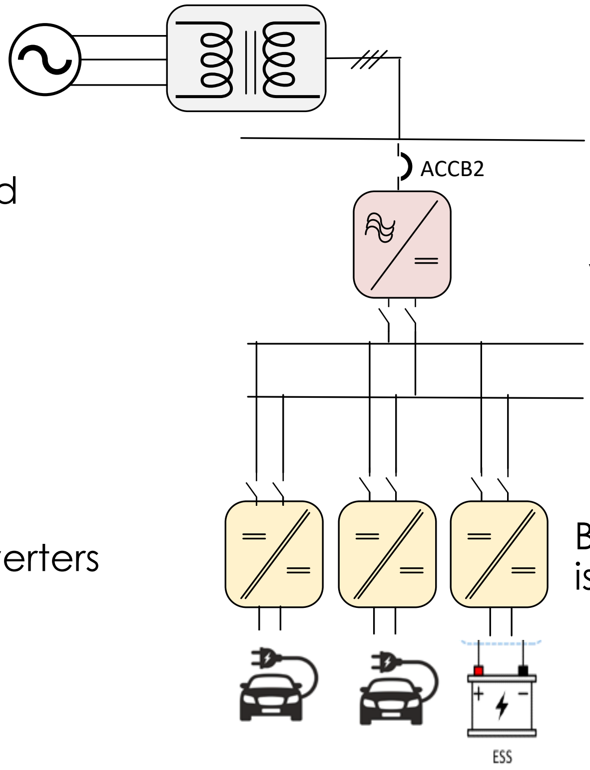
ORNL developed grid interface converter

1 kV 175 kW Bi-directional isolated converter (ORNL)



ORNL developed grid interface converter

Bi-directional isolated converters



ORNL developed advanced grid interface converter with advance grid controls

Bi-directional isolated converter

Pillar Portfolio: Hardware Prototypes- 480 V , 1 kV Final Demonstration

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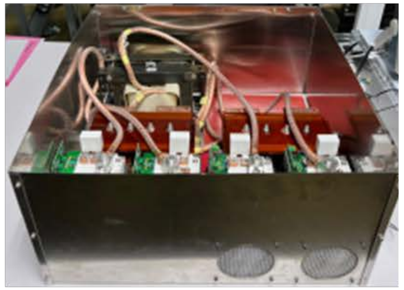
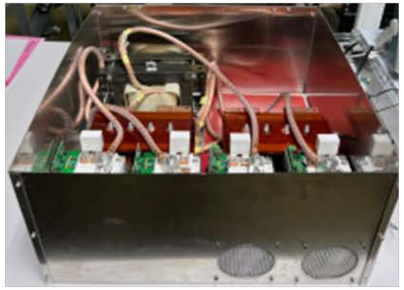
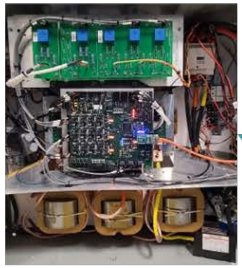


ORNL Developed 175 kW DC-DC fast charger 1 KV

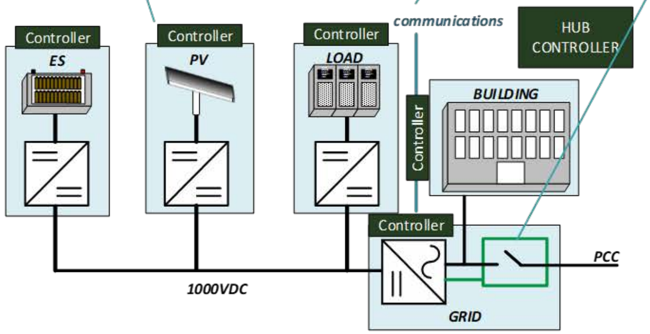


ORNL Developed 175 kW DC-DC fast charger 1kV

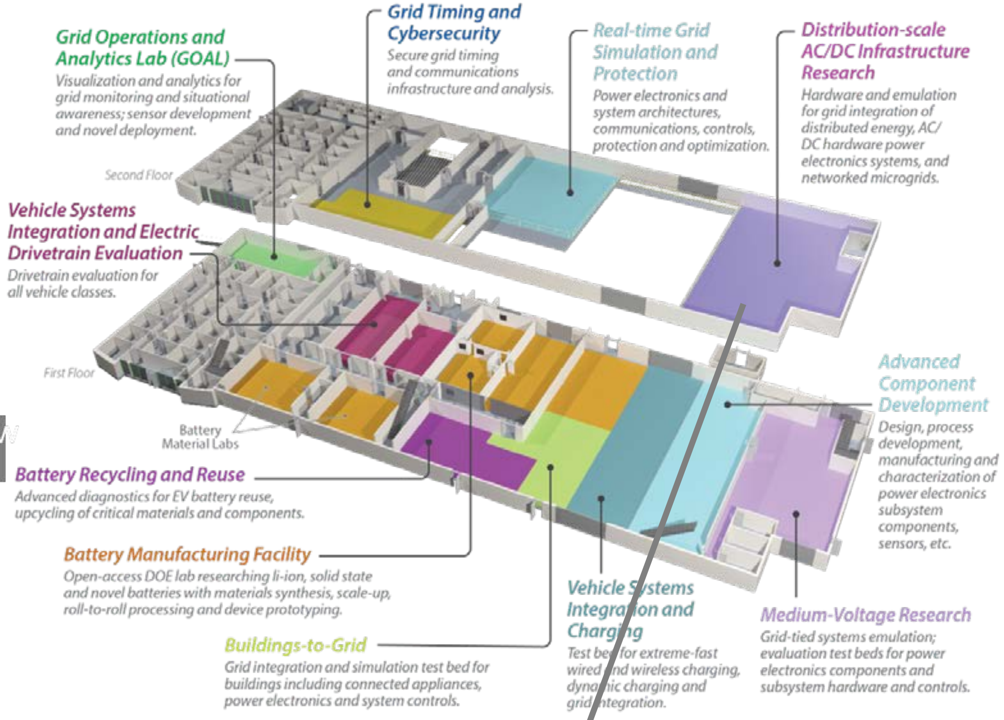
Semikron Developed 250 kW DC-AC



ORNL Developed 100 kW Inverter



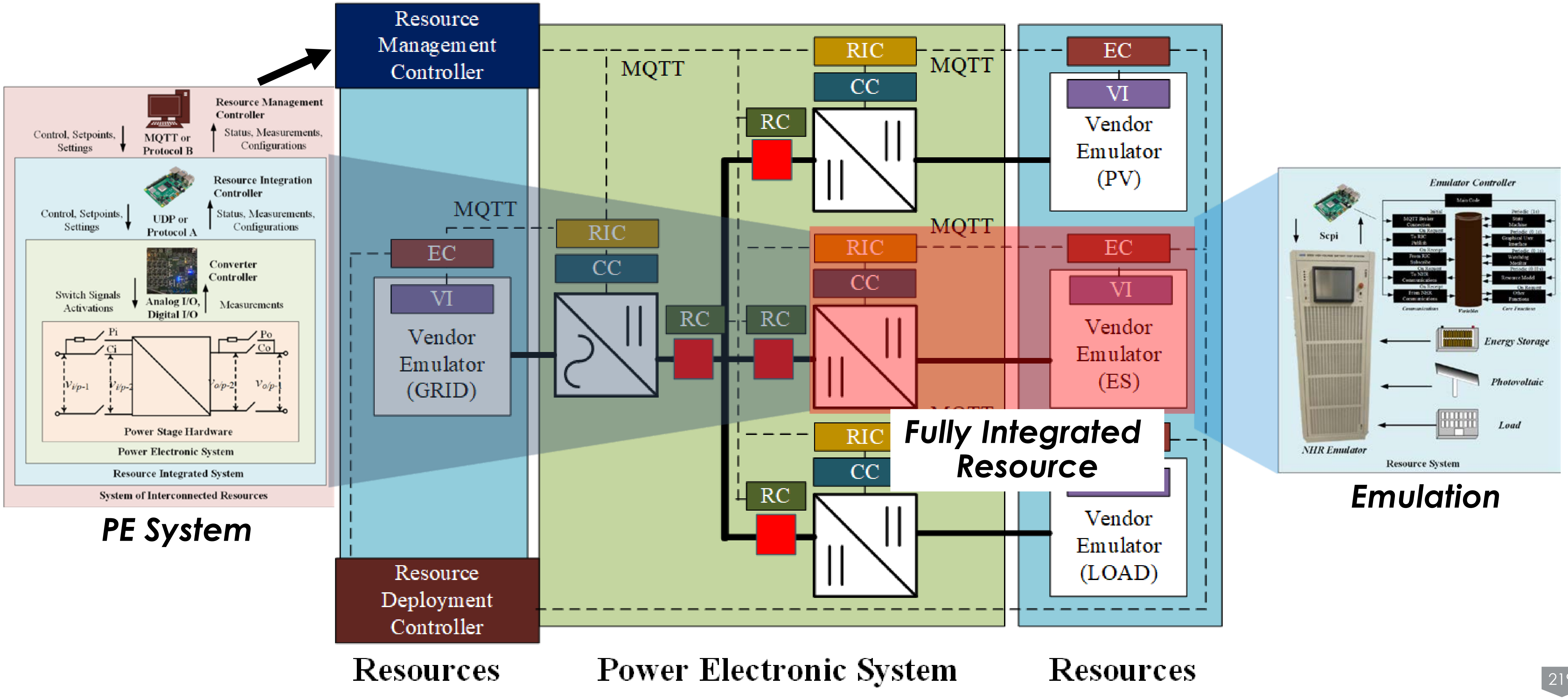
Grid Research Integration & Deployment Center (GRID-C) @ORNL



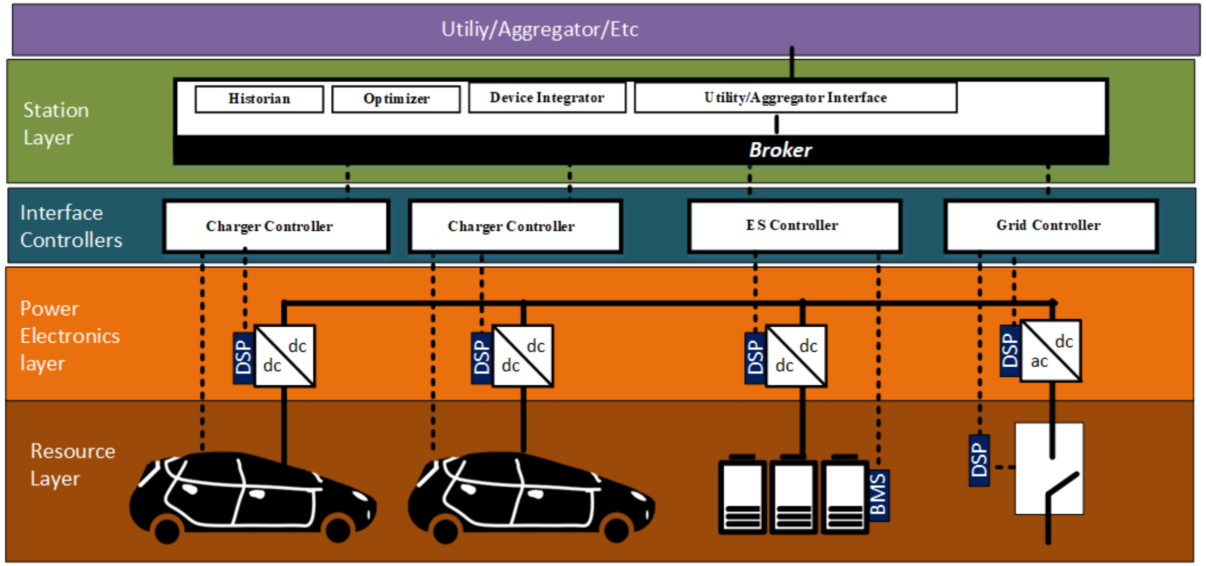
Hybrid AC-DC 9 Nodes test Bed DER, Energy storage, EV Charging, Commercial Buildings R&D

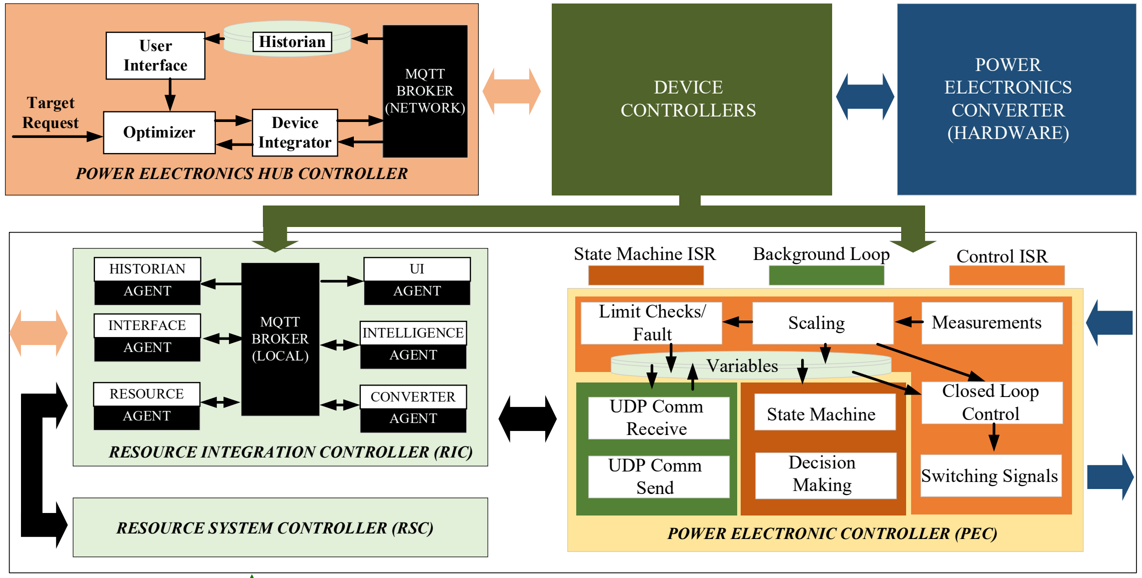
Pillar Portfolio: Charging Infrastructure Test Bed @ ORNL

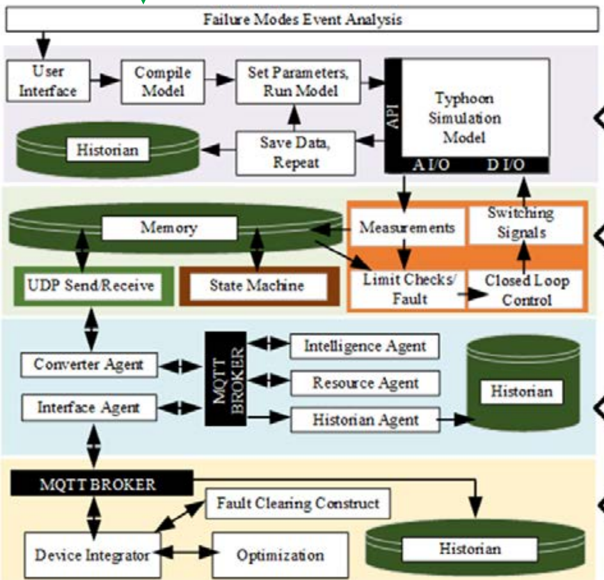
Leverage the multiport system demonstrated at ORNL under the previous GMLC project (Software, hardware, test bed at GRIDC-C)

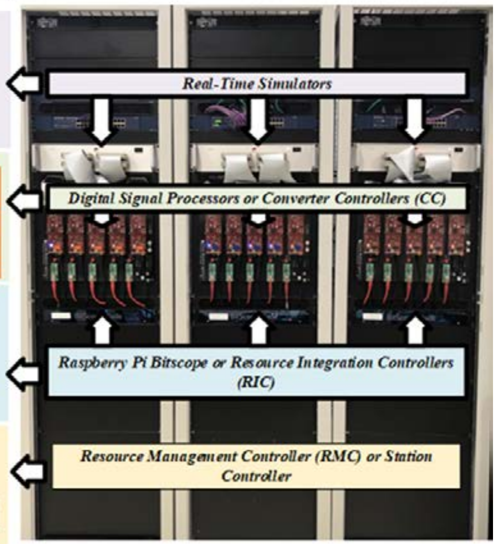


Pillar Portfolio: Plug and Play Architecture Future EV Station with novel hardware and software with comms and controls









Pillar Portfolio: Optimized Flexible Multi-port Vehicle and Grid Interface Architecture – DC/HFAC/DC Universal EV Charger

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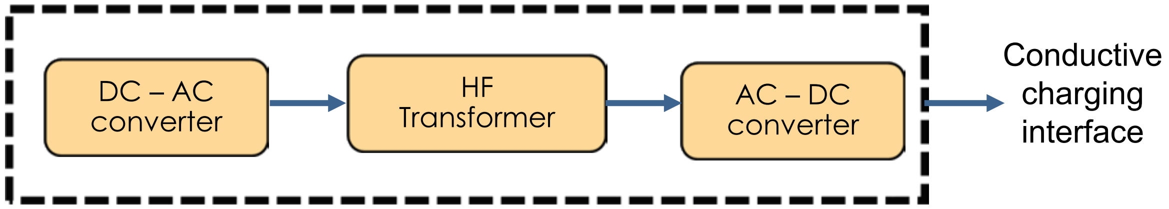
Objective: To develop and validate a universal power electronics architecture with high-frequency AC link to enable interoperability and increased utilization of grind and vehicle interface technology with optimized footprint and cost

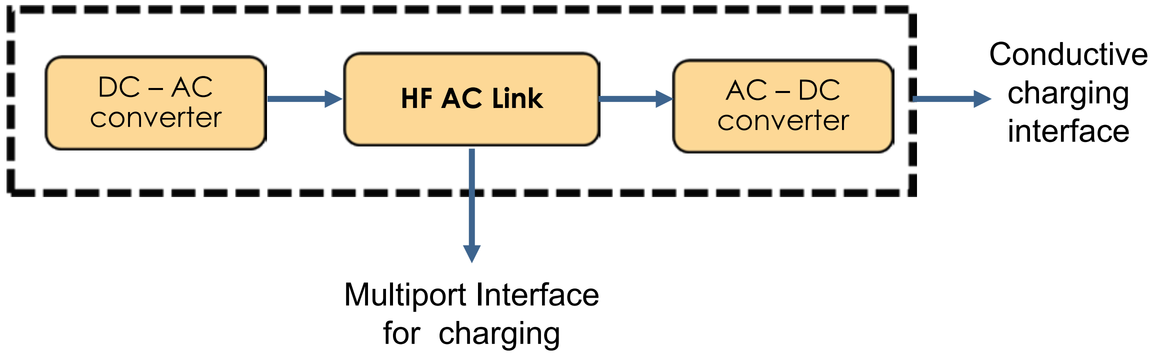
DC/HFAC/DC (flexible multiport dc-ac-dc converter) converter

- **Interoperable:** can supply high power conductive or inductive charge dispensers (at similar or different output voltages)
- **Increased utilization:** increase utilization of charger and throughput of vehicles served
- **Flexible**: can modulate voltage and power at individual charge dispensers
- **Compact:** optimally shared PE architecture with HF AC link
- **Increased efficiency**: with HF AC distribution
- **Reliability**: increased reliability with modular restructuring of architecture

Conventional DC-DC Converter



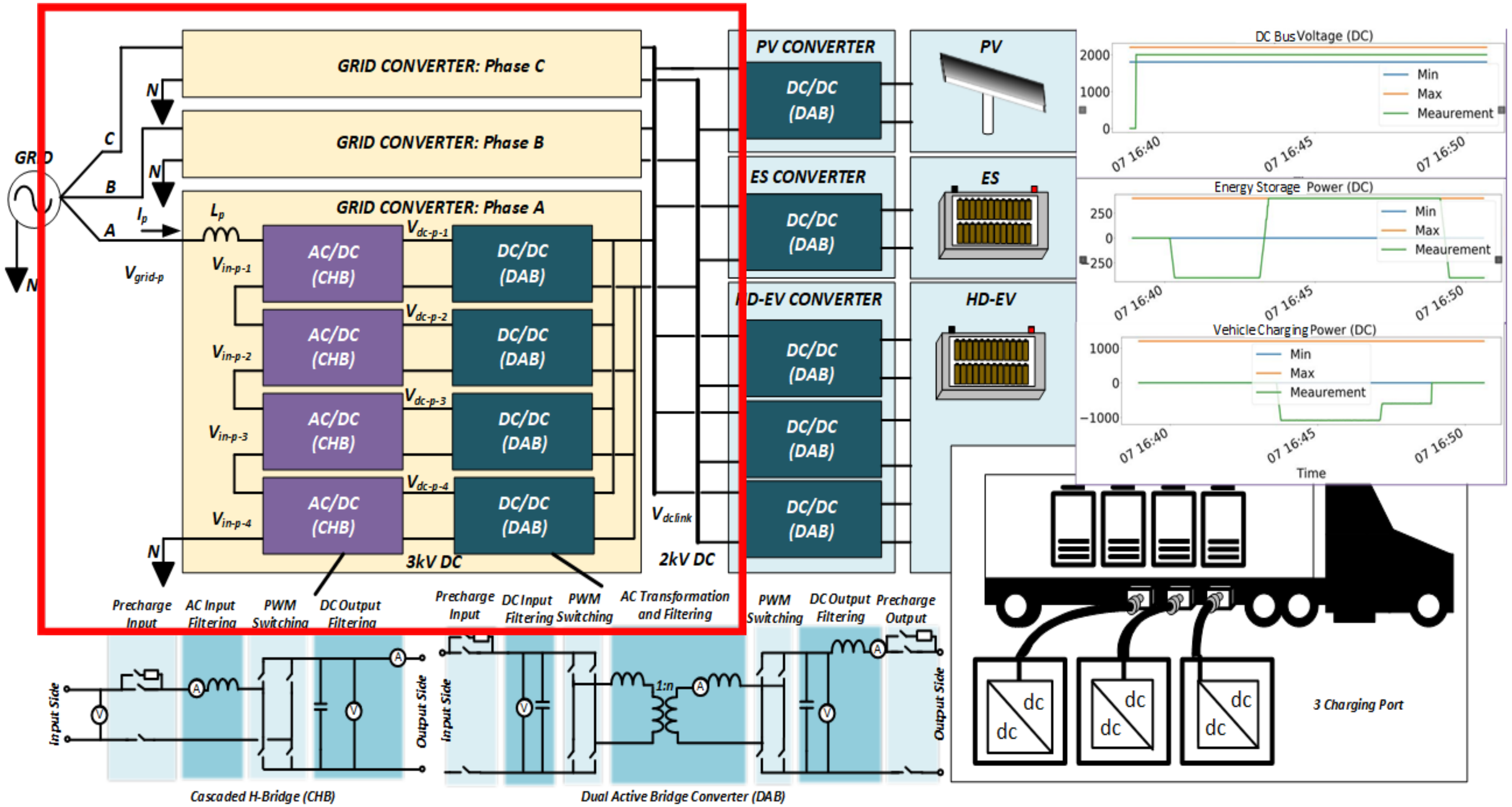
Proposed DC-AC-DC Converter



Pillar Portfolio : Medium Voltage Charging Technologies

- Leverage GMLC Multi Lab(13.75 M- 3 yr – FY24-FY26) and VTO funded 1+MW charger project
- Integration with direct MV DC/AC converter to increase power density
- Controls to integrate multiple resources

Up to13.8 kV (MVAC)



Thank You

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Codes and Standards Support

Theodore Bohn
Argonne National Laboratory

September 28th, 2023

Outline

- Initiative Overview
- Identification of codes and standards activity priorities enabling EVs at Scale
- ‘Divide and Conquer’ approach by lab teams to cover mulitiple standards areas
- Standards areas covered by each participating laboratory
- Focus areas and progress in standards development in FY2023
- Summary of FY23 deliverables/milestones
- Conclusion and Next Steps

Codes and Standards Support Initiative Overview

Objective: Codes & standards support priorities focus on development of the most critical standards for EVs at Scale, i.e., high power DC charging, storage (microgrid, DERMS) integrated with DC charging, vehicle-grid integration, high power scalable/interoperable wireless charging, vehicle-oriented system standards and energy services to support transparent optimized costs/delivery.

Outcomes:

- Establish and complete draft of SAE J3271 Megawatt Charging System (MCS), AIR7357 TIRs
- Create work group to develop EV Standards Roadmap based on 2012 ANSI EVSP roadmap
- Develop and demonstrate a reference DC as a Service (IEEE P2030.13) implementation with off-the-shelf hardware and Open API Energy Services Interface (ESI) implementation
- Complete a study w/summary reports in support of identified high importance standards
- Active participation in SDO standards meetings/committees to close gaps in EVs@S standards

Argonne National Laboratory
- Theodore Bohn
- Mike Duoba
- Keith Hardy
- Jason Harper
- Dan Dobrzynski

Idaho National Laboratory
- Richard Carlson
- Anudeep Medam
- Tim Pennington
- Benny Vargheese

NREL National Renewable Energy Laboratory
- Yashodhan Agalgaonkar
- Jesse Bennett
- John Kisacikoglu
- Jonathan Martin
- Andrew Meintz
- Manish Mohanpurkar
- Vivek Singh
- Isaac Tolbert
- Ed Watt

Oak Ridge National Laboratory
- Veda Galigekere
- Omer Onar
- David Smith

Pacific Northwest National Laboratory
- Brian Dindlebeck
- Lori O'Neil
- Richard Pratt

Identifying Codes and Standards Activity Priorities Enabling EVs at Scale

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Filter Criteria: The group of lab team members proposed areas **most** relevant to EVs at Scale

Priority Areas:

- EVs at Scale standards support focus is mostly on scaling charging capabilities. I.e. how to serve more vehicles in more locations without exceeding resource limits, for a spectrum of vehicle sizes/classes (from light to medium to heavy duty; commercial and passenger cars)
  Charging rates from 30A to 3000A for conductive/wireless methods, AC or DC, µgrid, etc

- Electric power delivery oriented standards areas; V2G, local DER, integrated storage, system controls including the Energy Services Interface method of bi-directional information exchange leading to contract based optimization of resources, DC as a Service, communication protocols

- Vehicle Oriented **System Standards** (including non-road, electric aircraft) that include on-vehicle systems (power take-off, refrigeration units, battery management, battery safety, etc.),

- High Power Scalable/Interoperable Wireless Charging (SAE, J2954-1/2/3) (up to 1MW)

‘Divide and Conquer’ Diverse Coverage of Standards by Lab Teams

5 Lab Teams in FY2023 Covering ‘Top 10’ Standards Areas:

National Lab participants each proposed support/development within the ‘top ten’ areas for EVs@S

General Standards task areas (shorthand summary)

- **NREL** focus on MCS coupler testing, system architectures/impacts study, P2030.13
- **ORNL** focused on wireless (WPT) topics
- **INL** on WPT, P2030.13 (grid side of charging)
- **PNNL** on EVSP roadmap, heavy vehicle charging stds, P2030.13
- **ANL** on ‘umbrella’ (chair of multiple stds groups) coverage of ongoing W&M stds, ANSI meter stds, IEEE P2030 series (.5, .11, .13, etc), MCS ‘everything’, emphasis on communication and reliability, (summary chart of active EV charging/safety standards; testing/date in support of standards)

Snapshot of Standards Engagement/Progress in 2023; Next steps

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Status excerpts on active standards committees support by topic 4E resources, via labs/contractors

- **EVSP EV Standards Roadmap;** Year of effort/work groups, published June 2023; FY24 quarterly update maintenance
- **IEEE P2030.13 DCaaS Functional Specification for charging system feed;** published/for sale; version 2 proposed
- **SAE J3400 NACS;** Committee launched August 2023 with first TIR draft in 28 day comment September 2023
- **MW Level stds (J3271, AIR7357, IEC80005-4, xMCS/mining);** J3271 TIR-v1 released, xMCS(40MW) weekly meetings
- **Energy Services Exchange (ESX) implementation;** subset of P2030.13, demonstration April 2023, possible new std.
- **Weights and Measures;** Meter drift study, GUI for off-the-shelf HB44 test tool; HB105 transfer standard guide
- **'Other' SAE/IEEE standards on interoperability, reliability, safety, recycling, etc:** moving forward/expanding scope
- **Mike Duoba EV Variability study/project(s)** rolled into EVs@S C&S in FY23 {SAE J1634, J1711, J2908, etc}
- **Wireless Power Stds**; J2954/1 light duty published; J2954/2 Heavy Duty TIR released, J2954/3 dynamic charging work group launched

ANSI EVSP EV Charging Roadmap Finalized, Published

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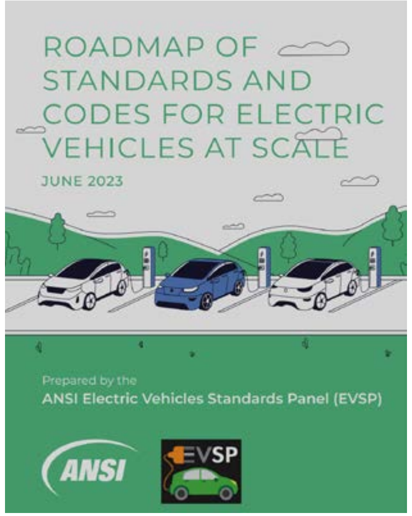
Roadmap Published, Quarterly Updates Planned

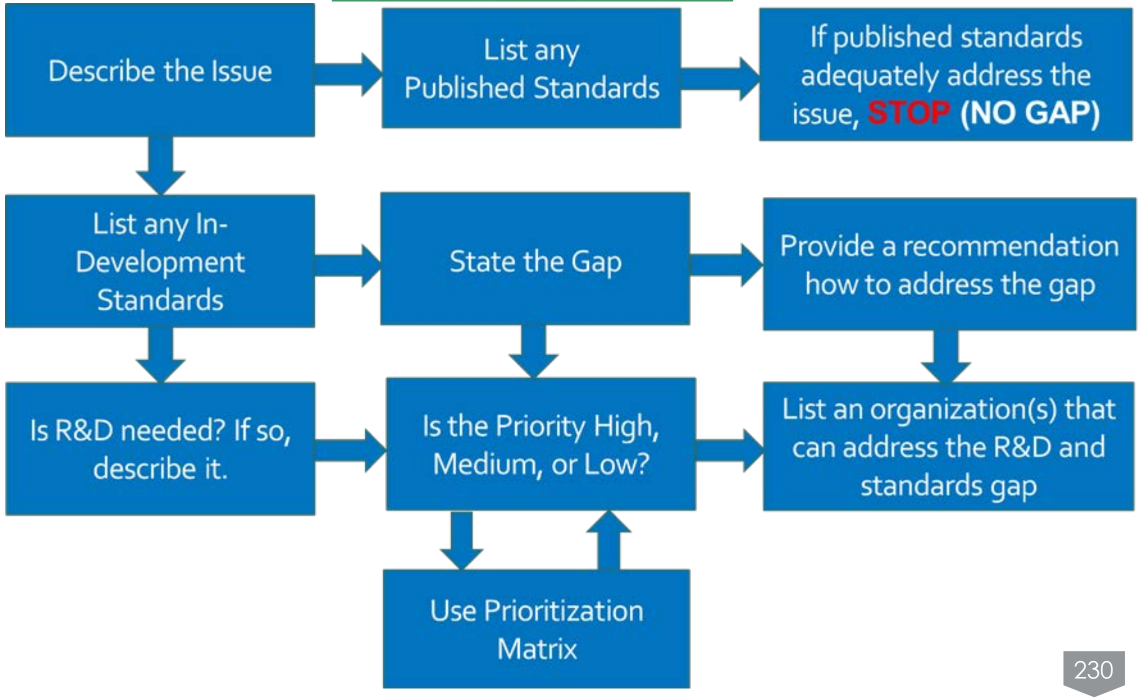
- Identifies issues as well as standards, codes, and regulations that exist or are in development to address those issues

- Identifies "gaps" & recommends development of new or revised standards, conformance and training programs, where needed

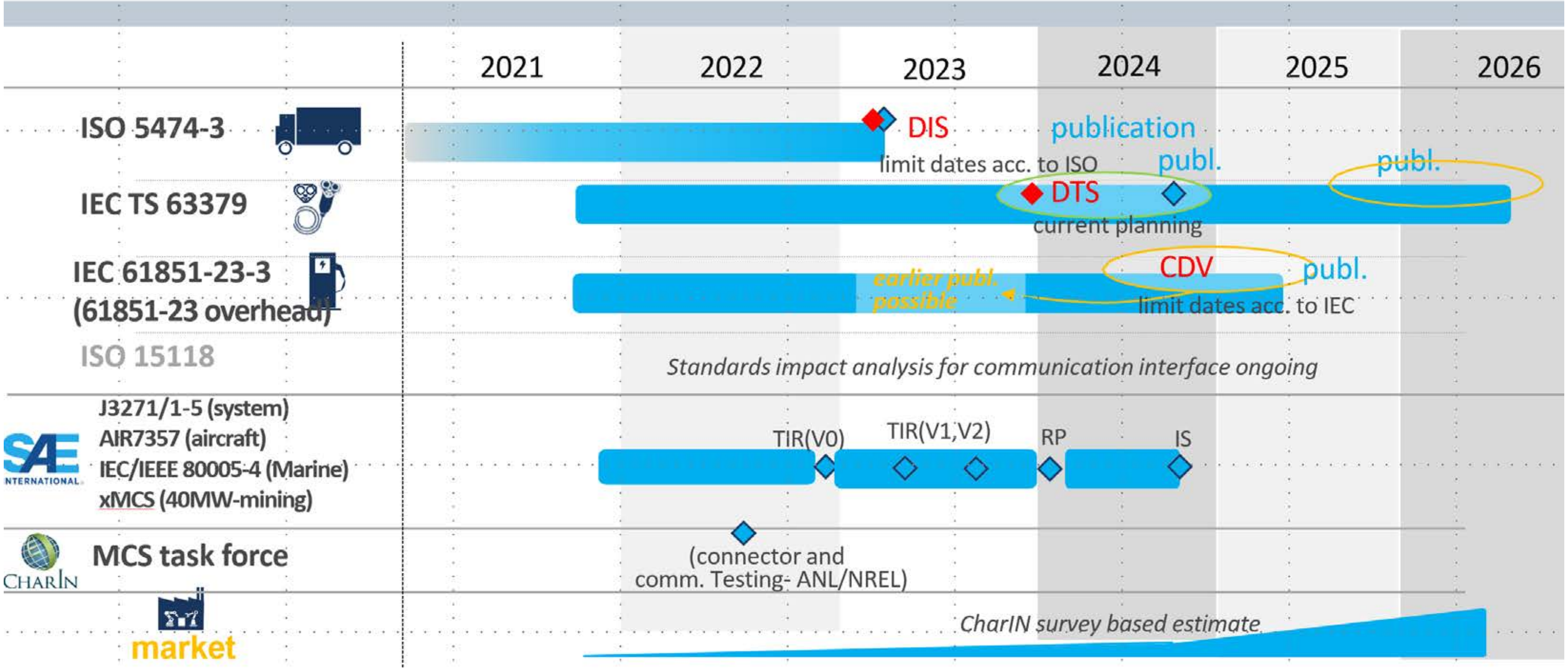
- A "gap" means no published standard, code, regulation, or conformance program exists
- Focus is U.S. market with international harmonization issues emphasized in key areas
- **50 stakeholder input meetings in 2022/2023**

- Final report published June 2023 https://www.ansi.org/standards-coordination/collaboratives-activities/electric-vehicles





Working together as a global team: National Lab participants in these and other standards areas need to have consensus between overlapping standards. There is not one 'global' Standards Defining Organization' so all the SDOs have to 'play nice' and create compatible/harmonized standards as a foundation for global interoperability.



NREL Hosted 2023 MCS Coupler Evaluation Event

Additional evaluations as the design is refined are under consideration:

- Functional evaluation at room temperature for 350 A to 3000 A using the passive- and active-cooled systems
- Quantifying connector insertion force between dissimilar manufacturers and wear-out mechanisms such as insertion cycles, vibration, mechanical shock.
- Electrical resistance trends between dissimilar manufacturers under temperature, mechanical loading (forces in x, y, z directions or torque applied to connector and/or cable, wear-out mechanisms (insertion cycles)
- Reference device development for certification to support IEC TS 63379 standards development

NREL Hosted 2023 MCS Coupler Evaluation Completed, Report Soon

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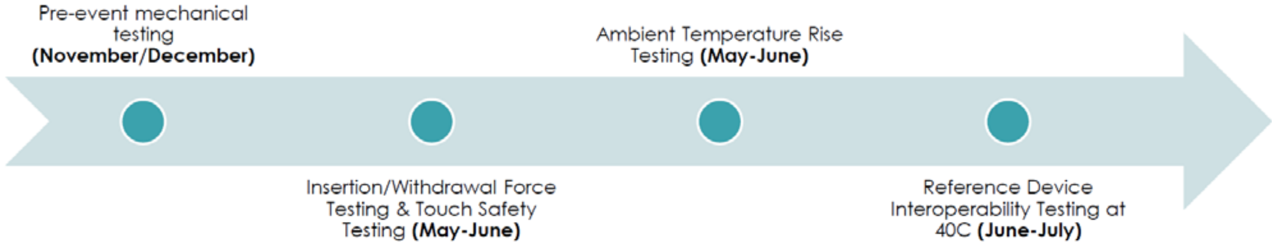
- **November – Early December**
  - Insertion force evaluation for pre-check of component designs prior to tooled-part development
- **Late May – Mid June**
  - Perform ambient-temperature testing
    - Ambient-temperature, round-robin 350A, 1000A, 3000A temperature rise tests
  - Perform mechanical testing
    - Insertion/withdrawal testing, touch-safety finger testing
- **Late June**
  - Modify test bench and move to thermal chamber for reference device testing
- **Late June – Early July**
  - Reference device testing (1500A, 3000A)

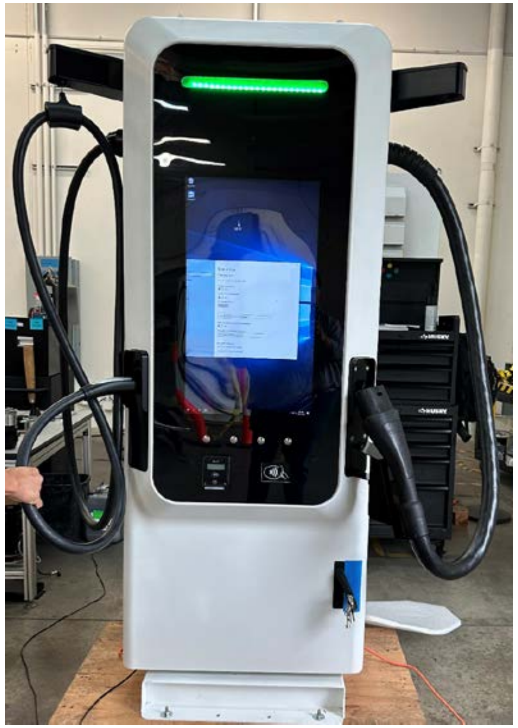


Hardware-Software Development, Validation Testing Supporting Standards

- **SAE J3271 Coupler manufacturers (8), ~UL2251 certification**
  Amphenol, Cavotec, Evalucon, Huber+Suhner, Phoenix Contact, Rema, Staubli, T.E.

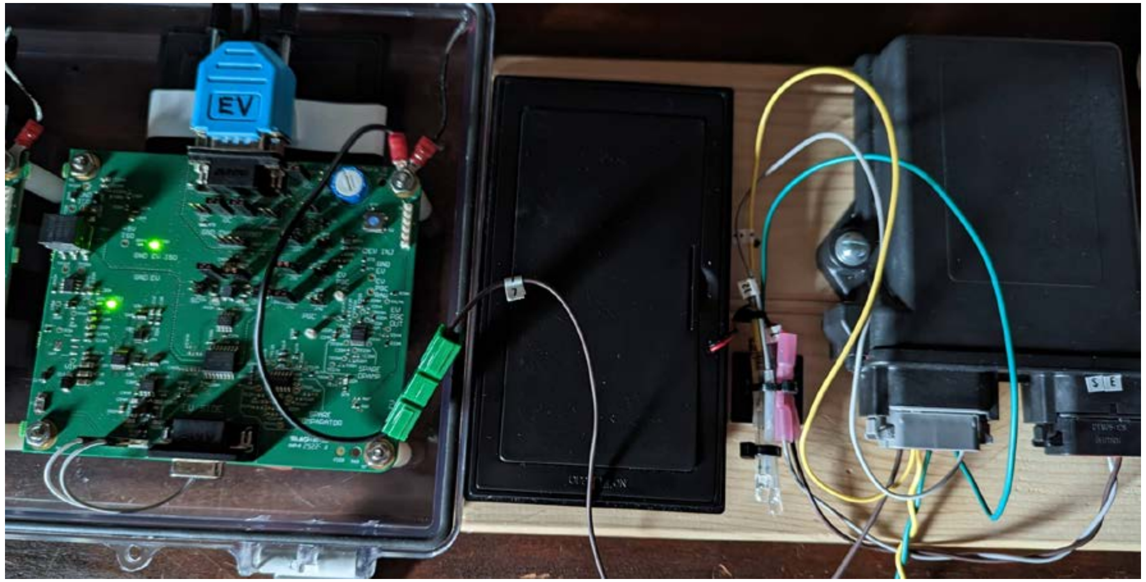
  ~14-18 companies MW MCS EVSEs in development/pilot projects
- ABB, Alpitronic, Atlis, BTCP, Cavotec, (CAT), Charge America, DesignWerk, Heliox, Hitachi Energy, Imagen Energy, Power Electronics SA, Tritium

- Dual output J3400/J3271 NACS-MCS demonstration w/200A-1500A cables
  Platform for open source communication controllers and interoperabillty testing.



Hardware-Software Development, Validation Testing Supporting Standards

- **PLC communication work has ceased** after IEC61851-23-3 ballot eliminated all but 10BaseT1S physical layer
- 3000A Noise immunity testing at BTCP on production grade MCS EVSEs completed
- SAE J3271 communication controller reference design w/ Univ. of Delaware completed
- Balanced Differential CAN module; 10BaseT1s options being developed
- FY24 goal to publish on reference circuit board and software on GITHUB
- Ethernet over CAN mapping/kernel (TCP/IP), J1939 mapping of ISO15118-20 functions; ‘sharing’ message set
- Investigating coexistence of CAN and 10BaseT1S transceivers on same twisted pair communication lines



Hands-On C&S Support Examples; Demonstration activities w/partners

C&S Support Activity Collaborators:

Industry charging stakeholders (manufacturers, operators, planners, researchers, existing projects w/liaison interactions- RHETTA, eTRUC, etc)

Subcontractor subject matter experts (ANSI, University of Delaware, Rema, BTCPower, EVoke)

Standards organizations (SAE, IEC, ISO, IEEE, ANSI), Code panels (NCWM, UL, NFPA)

NIST SP 2022 special publication guide for developing a transfer standard procedure on HB105-10 (Traceability for EVSE field testing tools) Set for 500A/1000vdc today; 3000A/1500v next; 50ppm 'transfer standard'
ANSI C12.32 DC meter standard; **ANSI C12.33** new transducer standard

ARPAe collaboration w/Imagen Energy on 250kW blocks for on DCaaS distribution of MCS ready systems; Shoals example Skid mounted switch gear, storage, power converters (example)

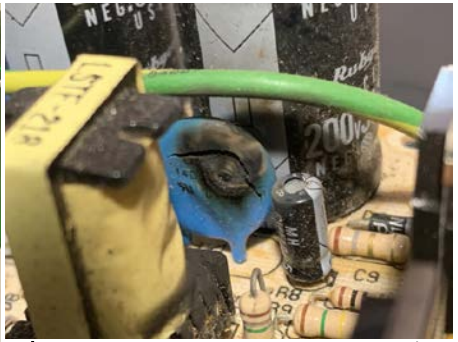
AC-DC Meter Drift Study In Support of NIST HB44-3.40 Reinspection Period

- Experiment plan drafted and peer reviewed with EVSE/W&M stakeholders
- Set up test equipment/software, test article meters, identify field test EVSEs
  Pass-through CCS cable, three parallel reference meters- average reference data
- Powered up seven bench meters for 12 month duration, test monthly (30A/300A)
- AC EVSE test load (30A for all) to nine EVSEs at locations that are used publicly/daily, in seasonal temperature conditions; tested monthly (two tests each)
- Drive Tesla Model 3 (as controlled 60-300A load) to nine DC EVSE locations. Tested monthly (two tests each); compared to transaction receipt data
- **25 total test articles(7+9+9);** two tests on each per month (600 tests total in 12 months), three redundant reference meters yields 1800 measurement points
- **Expect to see ~100ppm variability and drift (if any) below 0.5% over 10 years**
- Report released at 6 month and 12 month test results; extended past 12 months?

AC-DC Meter Test Articles; Monthly Tests, Powered for 1-10 year study

- 7 Sample meters mounted on DIN rail in a NEMA4 chassis, continuously powered, accumulating run time; Ethernet and serial output to a laptop for monthly samples
- Single/common voltage reference connected to all DC meters
- SB350 connector on current source/reference for each meter/sensor (one at a time)
- AC Meters tested using Transdata 2300 AC meter calibrator (208vac/30A)
- Reference meters and resolution vs sample size .1Wh of 1kWhr=0.001%, 100ppm
- Evaluate but not test outlier EUMD4 AC meter with ~61,000 running hours (7+ years)

- AccuEnergy AcuDC 243
- Carlo Gavazzi DCT1
- Isabellenhuette IEM DCC
- LEM DCBM
- Rish Alpha DC
- Evoke/ANL EUMD6m
- Peacefair AC ($15 Amazon example)
- (EUMD4 AC meter)- MTBF example



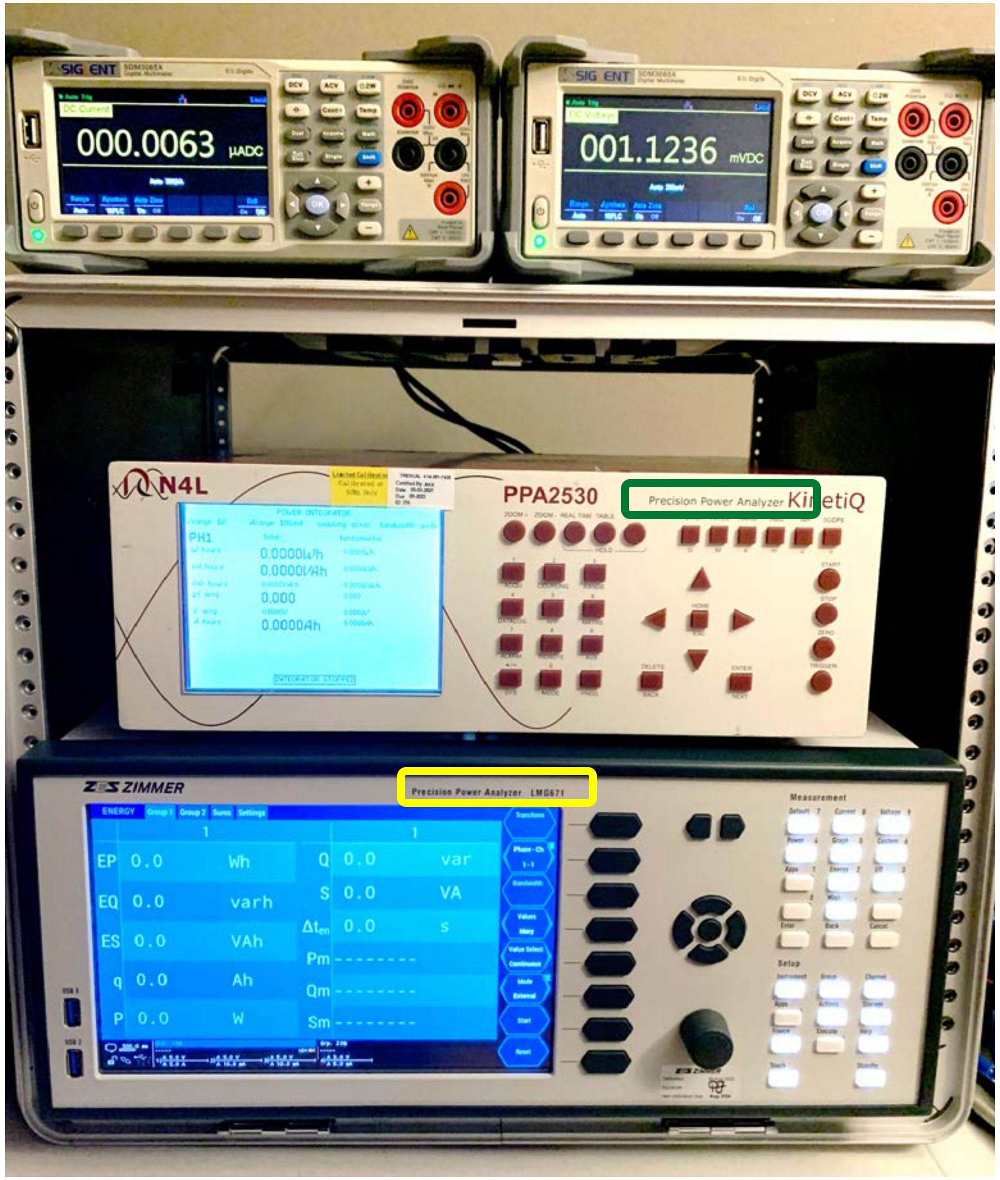
(24v Logic power supply already failed- MTBF?)

9x AC, 9x DC EVSE Test Articles (some replicates), All Madison WI Area

Item	Max amps	Brand	Model#(s)	CPO Network
1	30A AC	Blink/LiteOn	IQ200	Blink
2	30A AC	Blink/Semaconnect	Model 780	Blink
3	30A AC	BTCPower	L2P-30-240-15	AmpControl
4	30A AC	ChargePoint	CT4000	Chargepoint
5	30A AC	ChargePoint(2)	CT4000	Chargepoint
6	48A AC	Emporia	EMEVSE1UL	Emporia Cloud App
7	40A AC	EnelX	JuiceBox Pro40	Enel
8	48A AC	Siemens	Versicharge 8EM1310	Shell Recharge
9	48A AC	Tesla	Gen 3 Wallbox	Tesla 4 Business site host

Item	PWR	Max amps	Brand	Model#(s)	CPO Network
1	25kW	65A	Delta	EVDE25E4DUM	Ampcontrol
2	20kW	60A	ABB	Terra Wallbox	? (non-network)
3	50kW	125A	ABB	Terra54	Chargepoint?
4	60kW	200A	Blink/Tellus	Tellus	Blink
5	350kW	350A	BTCPower	HPCD1-350-02-003	Shell Recharge
6	62.5kW	200A	ChargePoint	Express 250	Chargepoint
7	350kW	350A	Signet	DP350K-DCM	Electrify America
8	250kW	630A	Tesla	SuperCharger V3	Tesla App.
9	120kW	300A	Tesla	SuperCharger V2	Tesla App.

High Precision/High Resolution Parallel Measurement for Consensus



- Using a single reference meter has the risk of drift of the reference that may appear as error on all test article accuracy/difference of measurements

- Stating the obvious, concurrence of measurements requires an odd number of reference meters for a majority.

- The three measurement systems shown here, with associated (20ppm, 0.0002%) precision current sensors, are used in this study. All are NIST traceable/annual calibration certified accuracy.

- 6.5 digit/~20ppm DMM with Labview GUI
- 5 digit/0.025% KinetiQ PPA2530 analyzer
- 5 digit/ 0.015% ZES Zimmer NLG671 analyzer

FY2023 Milestones/Deliverables

EVs@Scale
U.S. Department of Energy

Milestones (shorthand)

- Report on conceptual/functional requirements for P2030.13 w/simulations
- MCS physical layer communication robustness test plan; test results (J3271/2)
- ANSI EVSP standards roadmap, completed and published
- IEEE P2030.13-J3271/4 based 'PowerBroker' Energy Services Exchange (ESX) implementation as an Application Programming Interface (API) (phase 1) complete

Deliverables (shorthand)

- Quarterly/annual progress reports
- MCS coupler thermal-mechanical testing results report
- (critical input to…) first peer review draft of SAE J3271 (part 1-5) MCS TIR
- (critical input to…) first peer review draft of IEEE P2030.13 Functional specs
- Monthly MW+ Charging industry engagement webinar based forum for input

Conclusion and Next Steps

EVs@Scale
U.S. Department of Energy

Review

- Initiative Overview
- Standards Support Priority Selection Methodology
- Significant areas of standards development activities
- Implementation/validation of technology-requirements as part of standards

Next steps

- Continued monthly MW+ Charging Industry Engagement interactions/feedback
- Continued weekly SAE J3271(AIR7357) meetings toward TIR v2 goal in December 2023
- Continued monthly standards work group participation; drafting standards, etc
- Progress toward milestones are studies supporting WPT and P2030.13 standards
- Engagement in Interoperability (Testival) events in 2023 Lincoln Electric hosted- Cleveland OH, Nov 2023

- Codes and Standards Deep Dive web based meeting **tentatively October**
  Contact: Tbohn@anl.gov, Codes and Standards Pillar Lead

Breaktime!

Panel Presentations resume at…

EVs @ Scale
U.S. Department of Energy

Public Charging Challenges for Medium & Heavy-Duty Vehicles

A.J. Palmisano
Director – Zero Emissions Charging and Infrastructure
Andrew.Palmisano@Navistar.com

Public Charging Challenges for MD & HD Vehicles

Interoperability & Reliability

Automotive Shift to NACS

Public Charger Parking

Interoperability: Background

Why is EV charging so painful for the customer?

- *Incomplete standard* → parameters are left open to interpretation by the OEM (Example: restarting a DC charge session is supported by the standard, but the methods to do so are undefined)
- *Lack of commercial vehicle focus* → DIN/ISO standards are primarily for on-the-go, public charging of passenger vehicles. Commercial vehicles are using these standards for DC overnight, unattended charging
- *Unreliable hardware* → liquid cooled cables, exposure to the elements (example – charge plug water ingress), network/payment dependency, and customer misuse all contribute to failed or derated charge sessions
- *Ever-evolving landscape* → constant OTA updates for vehicle and charger invalidate previous confidence in compatibility

PRESS RELEASE

Growing Electric Vehicle Market Threatens to Short-Circuit Public Charging Experience, J.D. Power Finds

Tesla Destination, Tesla Supercharger Stations Rank Highest in Respective Segments

17 August 2022

Public Charging Reliability < 80%

Abstract

In order to achieve a rapid transition to electric vehicle driving, a highly reliable and easy to use charging infrastructure is critical to building confidence as consumers shift from using familiar gas vehicles to unfamiliar electric vehicles (EV). This study evaluated the functionality of the charging system for 657 EVSE (electric vehicle service equipment) CCS connectors (combined charging system) on all 181 open, public DCFC (direct current fast chargers) charging stations in the Greater Bay Area. An EVSE was evaluated as functional if it charged an EV for 2 minutes or was charging an EV at the time the station was evaluated. Overall, 72.5% of the 657 EVSEs were functional. The cable was too short to reach the EV inlet for 4.9% of the EVSEs. Causes of 22.7% of EVSEs that were non-functioning were unresponsive or unavailable screens, payment system failures, charge initiation failures, network failures, or broken connectors. A random evaluation of 10% of the EVSEs, approximately 8 days after the first evaluation, demonstrated no overall change in functionality. This level of functionality appears to conflict with the 95 to 98% uptime reported by the EV service providers (EVSPs) who operate the EV charging stations. The findings suggest a need for shared, precise definitions of and calculations for reliability, uptime, downtime, and excluded time, as applied to open public DCFCs, with verification by third-party evaluation.

https://arxiv.org/ftp/arxiv/papers/2203/2203.16372.pdf

Table 2. Functional states of 657 CCS DCFC EVSEs.

	N	%
Functioning		
Charged for 2 minutes	375	57.1%
Occupied by EV and charging	101	15.4%
Total	476	72.5%
Not Functioning		
Connector broken	6	0.9%
Blank or non-responsive screen	23	3.5%
Error message on screen[1]	24	3.7%
Connection error[2]	7	1.1%
Payment system failure[3]	47	7.2%
Charge initiation failure[4]	42	6.4%
Total	149	22.7%
Station Design Failure		
Cable would not reach[5]	32	4.9%

[1] Charger error, unavailable, under maintenance, etc.
[2] Connection, network, communication error, etc.
[3] 12 of these were evaluated with 2 credit cards but not an app or membership card
[4] Short session failure
[5] At 3 EVSEs the space was too small to safely back into

Interoperability: Combinations and Permutations

- Customer expectation is that everything should just work
- There are dozens of Electric Vehicle Supply Equipment (EVSE) hardware suppliers
- Every supplier has multiple EVSE models
- There are many Vehicle Suppliers (OEMs)
- Interoperability can be affected by:
  - Vehicle hardware or software changes
  - Charger hardware or software changes
  - Cloud software changes for either vehicle or charger
- ‘Suppliers’ X ‘OEMs’ X ‘Models’ X ‘HW iterations’ X ‘SW iterations’ =

1,000s of combinations that may or may not work

OEMs + EVSE Suppliers: Improving Interoperability

CharIN test events help everyone

Public Charging Challenges for MD & HD Vehicles

Interoperability & Reliability

Automotive Shift to NACS

Public Charger Parking

Move to NACS

Confirmed:

- Ford
- GM
- Fisker
- Honda
- Mercedes
- Rivian
- Volvo
- Polestar
- Nissan
- Jaguar

Considering:

- Kia (800 volt)
- Hyundai (800 volt)
- VW

Quickly

FLO Stations to Offer North American Charging Standard (NACS); Supports Broader Use

NEWS PROVIDED BY
FLO →
08 Jun, 2023, 20:37 ET

SHARE THIS ARTICLE

AUBURN HILLS, Mich., June 8, 2023 /PRNewswire/ - FLO Chief Product Officer Nathan Yang issued the following statement in response to the announcement that multiple automakers will adopt the North America Charging Standard (NACS):

Blink, Kempower, Chargepoint to Integrate Tesla NACS Connectors

Sarah Lee-Jones · 3 mins ago · Share

KEMPOWER · blink · chargepoint

The Tesla North American Charging Standard (NACS) continues to see more dominoes fall in its favor. First it was Ford, then GM, and now more third-party charger networks have announced they will integrate the Tesla connector into their chargers.

ABB E-mobility
11,388 followers
2h • Edited •

ABB E-mobility has been driving progress for over a decade as a world leader in the e-mobility industry. We will continue to lead by adding the North American Charging Standard (NACS) as an option for our products. Open standards and interoperability are foundational elements of a robust and scalable e-mobility economy. We will continue our commitment to global and regional standards (CCS, MCS, CHAdeMO, GB/T), and collaboration with our partners and the rest of our industry to deliver charging solutions that accelerate the electrification of transportation for all.

#abbemobility #evcharging

ABB E-MOBILITY UPDATE

ABB E-mobility is adding the North American Charging Standard (NACS) as an option for our products

NACS Now Eligible

Government now including Tesla chargers in federal funding for public chargers.

REUTERS

White House welcomes Tesla to take advantage of federal dollars for chargers

10

Jarrett Renshaw and Abhirup Roy

Fri, June 9, 2023 at 11:14 AM CDT · 4 min read

Time Will Tell

Will fleets with light duty NACS vehicles demand medium and heavy duty NACS vehicles?

Public Charging Challenges for MD & HD Vehicles

Interoperability & Reliability

Automotive Shift to NACS

Public Charger Parking

Parking Challenges: No Room for Commercial Vehicles

Multiple parking spaces need to be occupied or vehicle / trailer combination sticks out into the aisle

Parking Fix: Pull Throughs

Gas stations figured this out 100 years ago

Looks like a gas station

Parking Fix: Pull Throughs

DTNA Charging Island

Parking Fix: Setbacks from Curbs

Tesla Seeing the Need

Final Thoughts

We need to fix interoperability – FAST

Either make a strong case for CCS or switch to NACS

'Push for pull throughs'

A.J. Palmisano
Director – Zero Emissions Charging and Infrastructure
Andrew.Palmisano@Navistar.com

CPOs, Charging, and Standards

Peter Thompson, Director of Standards

September 28, 2023

Talking points

+ Who here likes standards? We do, and we don't.
  - We like them because when companies conform, things just work. And it only requests a single implementation, which saves on resources and maintenance.
  - We don't like them because they are complex, strict, flexible, and difficult to read, so people frequently get things wrong, don't align the business requirements and process, or have no clue how to implement them.
    - » Explain why standards are so complex.
    - » Explain how we embrace worldwide standards (cost and complexity reduction)
+ How do we get things to just work?
  - Testing. Lots of testing – with test equipment and OEMs, on a peer-to-peer basis or at Testivals.
    - » Explain why you can't test just once and be done – no Golden Test Device, for example.
    - » Explain the difference between conformance and interoperability.
+ Interoperability is more important than conformance
  - Without interoperability, not everyone can charge, thus holding back the industry
  - Interoperability is also more than just implementing the standards syntax correctly. Governance and guidance on use-cases/scenarios is just as important to understand what is addressed
    - » Car crash example – OEM knows car has crashed, it must remove certificate from use, etc.
  - Talk about the move to NACS due to systems not working properly (no mention of maintenance)

Who likes standards? Me, sort of.

+ I do because
  - When products fully conform, things just work.
  - This typically only requests a single implementation, which saves on resources and maintenance.
  - No special one-offs for “difficult” companies.
+ I don’t because standards
  - Are complex, strict, flexible, and difficult to read - so people frequently get things wrong,
  - Often don’t align the business requirements and process,
  - Frequently, developers have no clue how to implement them.

So - a Love-hate relationship. How to fix this?

- Testing. Lots of testing.
  - With test equipment (as many different brands as possible)
  - With lots of different product - on a peer-to-peer basis or at Testivals.
  - You have to do this a LOT – not just once.
    - There is no Golden Test Device.
    - Everyone does things differently.
    - Options are rarely part of initial conformance testing.
    - New features come up all the time (Plug-n-Charge is just one example).

Interoperablity vs Conformance

- In my opinion, Interoperability is more important than conformance
  - Without interoperability, not everyone can charge (this is a Bad Thing™).
  - Due to the difficulties in reading the standard, there will always be product that does not conform
    - This happens a lot. Especially with EVs that are already in the market now.
    - Once a EV is in the market, the odds of a software update are slim.
  - Interoperability for EV charging is all about getting power flow between EV and charger.
    - Pragmatism is required to get this flow to happen
    - If someone gets something wrong that is not critical – keep moving forward.
    - If communication times-out – wait a bit longer.
    - If parameters change when they shouldn't – relax and use the new parameter.

Interoperability is more than Conformance

+ Interoperability is also more than just implementing the standards syntax correctly. Governance and guidance on use-cases/scenarios is just as important to understand what is addressed.
  - For example, if certificates are installed in an EV, and that EV gets totalled, that certificate needs to be removed from general use (PKI ecosystem).
  - In case the grid is having frequency problems, there needs to be a way for the charger and EV to cooperate and either reduce load or provide power to the grid.

Conclusion

+ EV charging does not occur in a vacuum – lots of odd things happen.
+ In order for the power to flow, pragmatism and thoroughly tested equipment is required.

Thank You

For further information on this topic,
please contact Peter Thompson:

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+1.831.419.0468

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Managing EV Charging Within A Local Distribution Area With OpenADR 3.0

EVs@Scale Lab Consortium Semi-Annual Stakeholder Meeting

@ Argonne National Laboratory
September 28, 2023

Raymond Kaiser
CIO

The Reality – Fast Load Growth

The clustering of EV charging will significantly increase local loads

- Airports, seaports, other transportation hubs
- Older Commercial & Industrial Areas
- Multifamily
- Upscale Neighborhoods

The Challenge – Local Capacity

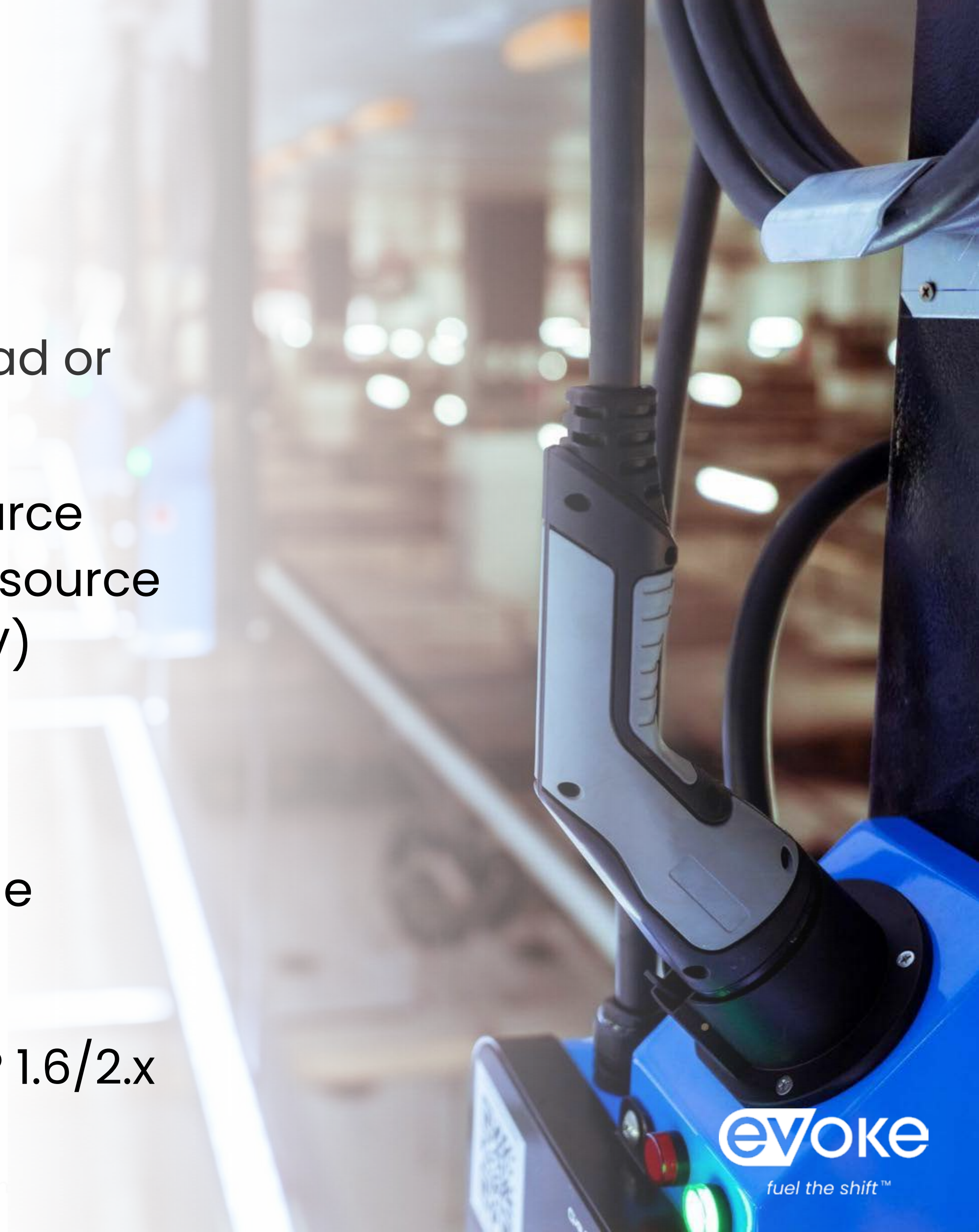
Utilities will be hard-pressed to add capacity in the short term.

Seasonal and daily peak capacity challenges on certain feeders and circuits can delay interconnecting new capacity.

EV charging deployments will be delayed and/or utilities will face capital-intensive upgrades of substations, feeders and transformers.

The Solution –
Local Managed Charging

- Manage EV chargers to grid topology by load or congestion zone
- Standardize information exchanges - resource availability, next day/same day forecast, resource commitment, Proof of service delivery (M&V)
- Know the location and capacity on the distribution grid
- Make resource availability visible in real time
- Coordinate EV charging schedules
- OpenAPIs based on OpenADR 3.0 and OCPP 1.6/2.x



Smart Electric Power Alliance

Standard Energy Services Contract

SERVICES

- Energy Market Price Response
- Peak Capacity Management
- Spinning Reserve/Ramping
- Meet Obligation to supply capacity in a wholesale Energy Market
- Frequency Regulation
- Fast Frequency Response / Artificial Inertia
- Distribution Voltage Management

SERVICE REQUEST

- **ENERGY**
- **POWER**
  - Active
  - Reactive

a common vocabulary
and
well-defined
information exchange messages
for energy services.

INFORMATION EXCHANGE

Item	
Service Requester	who
Service Provider	
Service Location	where
Event Signal Type	how
Requested Service Type	what
Quantity	how much
Cost	
Response Time	
Recurring Type	when
Start Time End Time	

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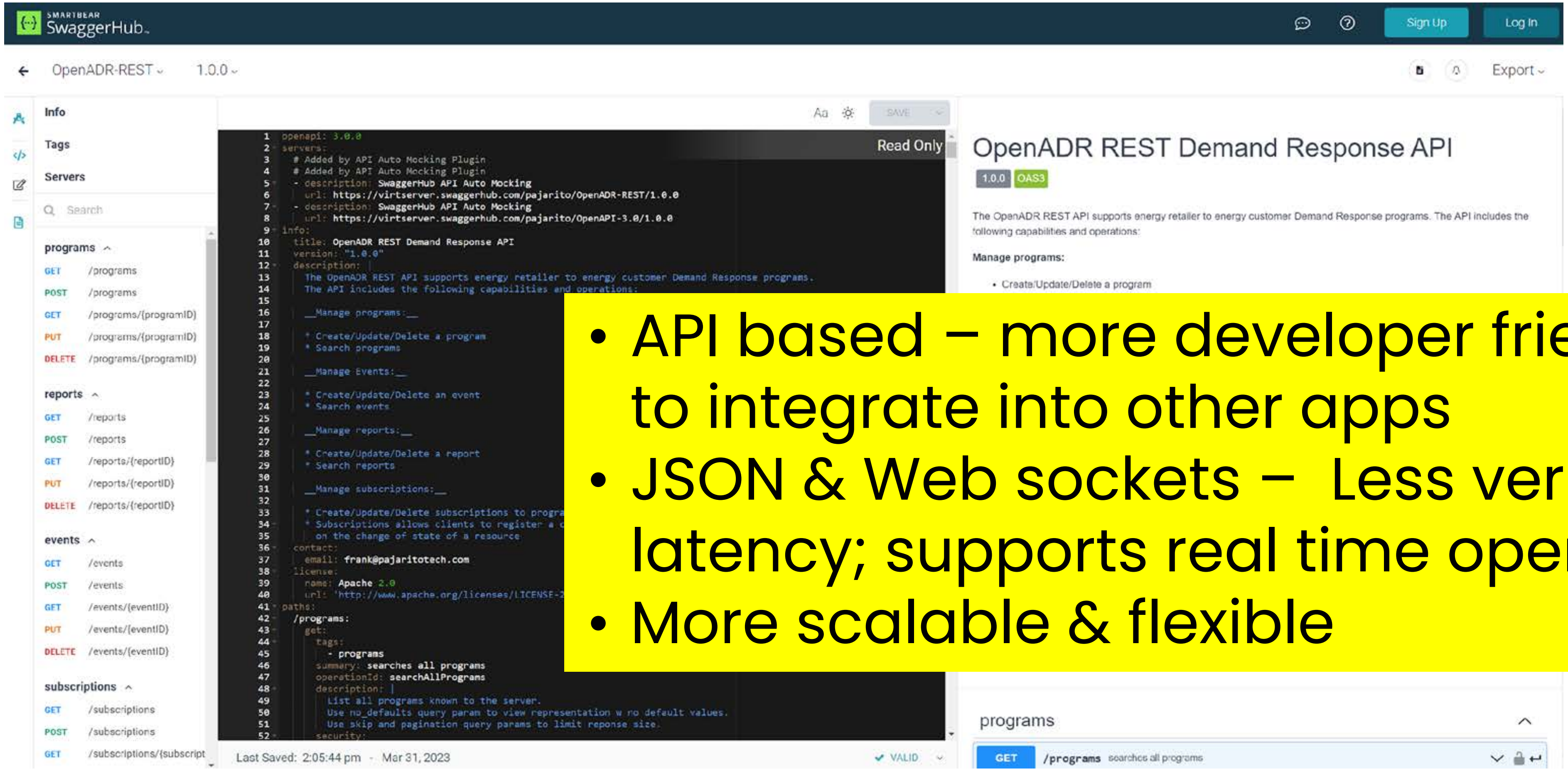
OpenADR 3.0 – a new *syntax* : APIs & JSON



- API based – more developer friendly; easier to integrate into other apps
- JSON & Web sockets – Less verbose; lower latency; supports real time operations
- More scalable & flexible

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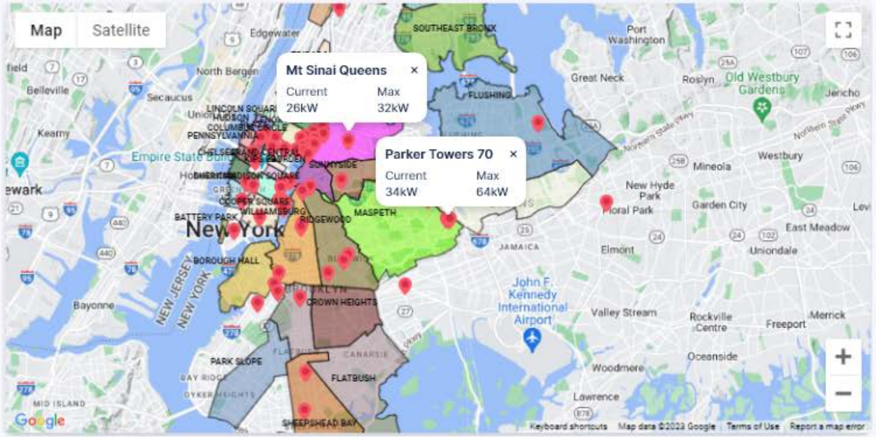
4/14/2023
21:06:12

Con Ed service territory

Current Total Load: 3,184 kW
Max Total Load: 6,386 kW

Coordination Node	Current Load (kW)	Max Load (kW)
☑ BOROUGH HALL	231 kW	246 kW
☑ BRIGHTON BEACH	20 kW	53 kW
☑ CEDAR ST	23 kW	246 kW
☐ COOPER SQUARE	326 kW	719 kW
☐ CROWN HEIGHTS	13 kW	27 kW
☐ ELMSFORD NO 2	31 kW	306 kW
☐ FLATBRUSH	50 kW	80 kW
☐ FLUSHING	29 kW	67 kW



2023 © Evoke.

Powered by Evoke

Demonstration at Scale

New York City

- 1,200+ EVSEs
- 8+ MW Max Power
- Aggregate load in 82 Load Zones every 15 min
- Based on OpenADR 3.0

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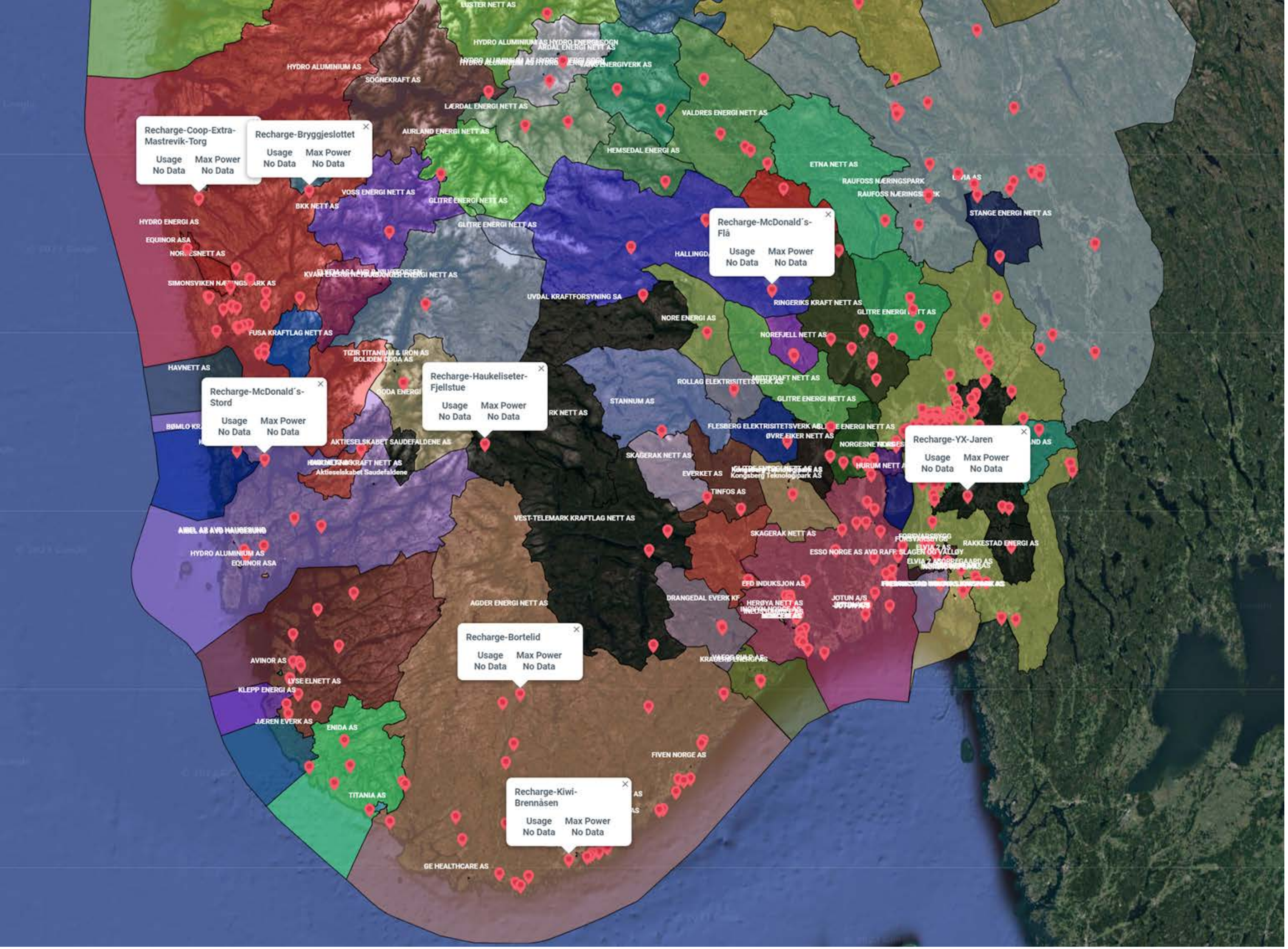

Demonstration at Scale

Norway

RECHARGE
DRIVING CHANGE

- Over 5,700 DCFCs
- 100+ electric service areas

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EVoke Extensions to OpenADR 3.0

1. Match resources to the local grid

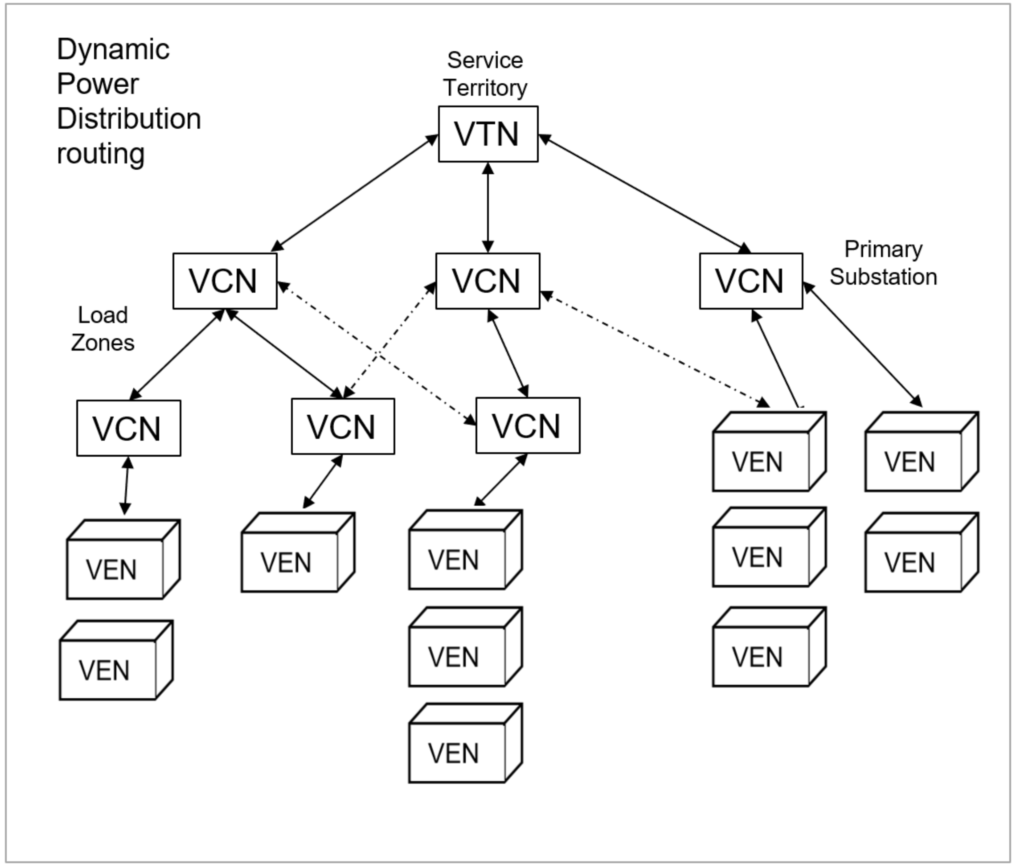
- A Virtual Top Node (VTN) represents a service territory or LMP Node.
- A Virtual Coordination Node (VCN) is a geospatially defined service area.
  - Can support granular resource visibility – at a substation, feeder, or circuit level
- A Virtual End Node (VEN) is a meter (service) point, i.e. a charge station.
- Dynamic routing

2. Standard information exchanges

- What resources are available where and when
- 5 report types: Demand, Forecast, Availability, Commitment, Proof-of-Service (M&V)

3. Clear roles and information flows across the value chain

- EV Drivers.
- Charge Station Operator (CSO).
- Charge Network Operator (CNO).
- DER Service Provider (DSP or aggregator).
- Grid Operators (GO).



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EVoke ANL ESX Road Map

Phase 1 (Complete)	Phase 2 (Just Launched)	Phase 3.1 (Proposed)	Phase 3.2 (Proposed)
• Grid Operator (GO) • Charge Network Operator (CNO) • DER Service Provider (DSP)	• Charge Station Operator (CSO) • Fleet Operator	• EV Driver • Charge Station Operator (CSO)	• Grid Operator (GO) • DER Service Provider (DSP)
• Coordination Architecture • Map DER resources to distribution topology (load zones) • Standardized Reporting (payloads)	Load Management • Sets site limit (max power) • Schedule TOU targets • Set DR response targets	Notifications & Price Offers • Opt in/Opt out	UI/UX to define load shift, shed and shape program requirements and automated requests
OpenADR 3.0	OCPP 2.01	OCPI	OpenADR 3.0

EV Charging & The Grid

01 **EV Growth** New demand can increase faster than the local utility infrastructure.

02 Shift to renewables – greater supply variability.

03 Managed charging can meet the challenge.

04 Generate additional revenue for charge station operators.

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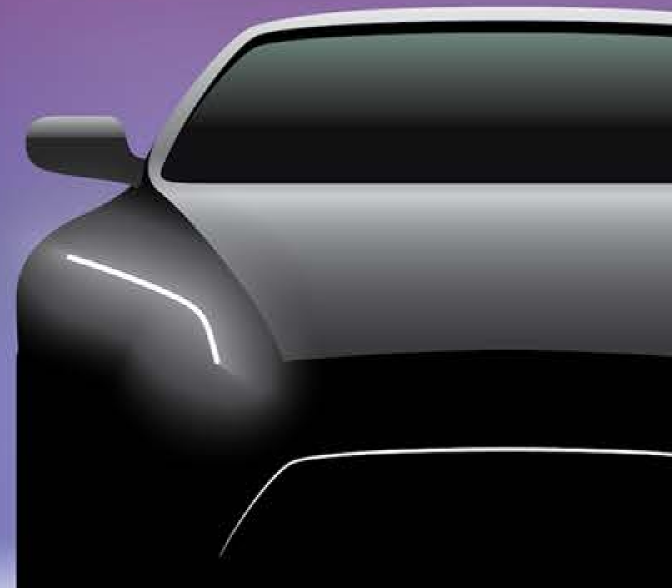
raymond.kaiser@evokesystems.com



Shift to EV Managed Charging

2021 SEPA whitepaper EV Managed Charging Framework

Smart Electric Power Alliance
WORKING GROUPS

An EV Managed Charging Framework: Simplifying Managed Charging with Energy Service Contracts

March 2021

Published by the SEPA Energy Services Interface Task Force

Raymond Kaiser, Evoke Systems, Co-chair
David Holmberg, NIST, Co-chair

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Smart Electric Power Alliance

The Genesis

ENERGY SERVICE INTERFACE TASK FORCE

David Holmberg, co-chair, NIST
Raymond Kaiser, co-chair, EVoke Systems

- **What DER resources are Available?**
- **Where?**
- **When?**

Standard information exchange based on OpenADR *semantics*

Who
- Service requester
- Service provider

Where
- Location

How
- Event or price signal

What
- Requested service

How Much
- Quantity
- Cost

When
- Start time/Duration
- Response time

ESX overview

ESX enables grid operators, DER service providers Charge Network and Charge Station Operators to dial down demand within a distribution zone via an open API.

Deliverables include:

- A hosted energy services exchange
- A public set of open APIs
- Standardized report types, in the form of energy service contracts, to provide:
    - real time EV charging load
    - short-term (next day/same day) forecast
    - resource availability
    - resource commitment
    - proof-of-service delivery

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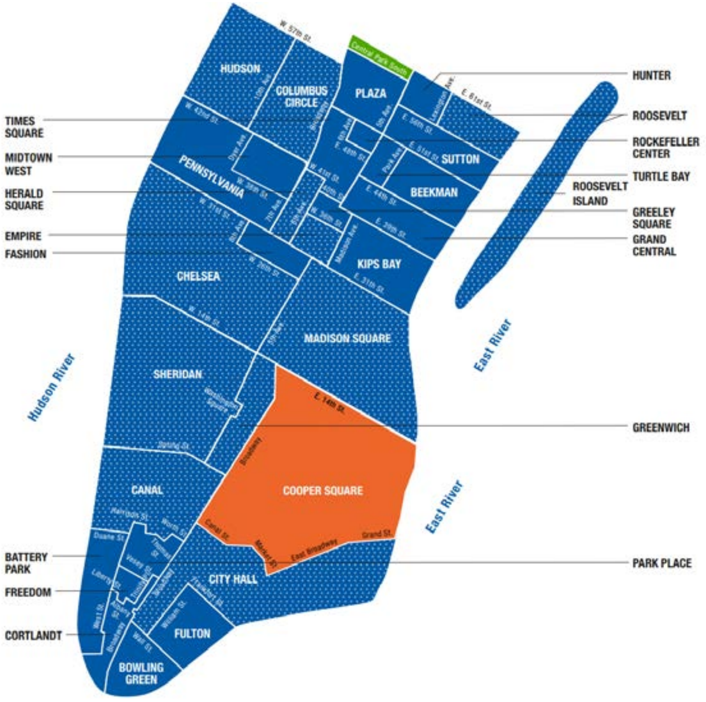
82 Load Zones



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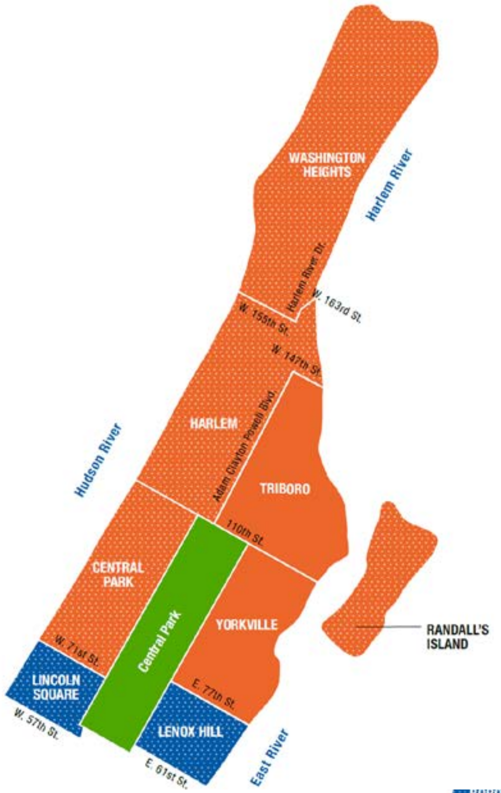
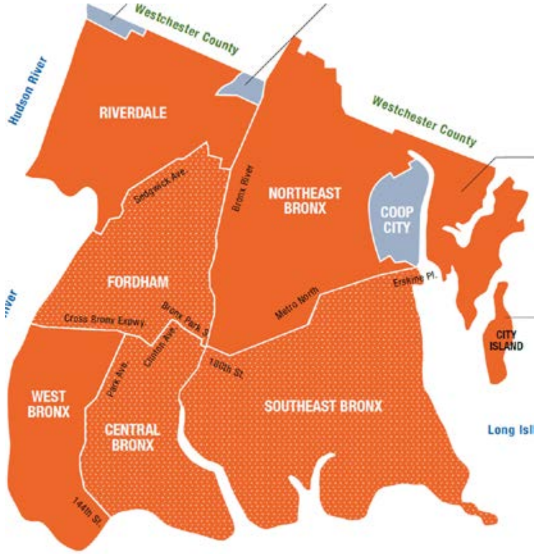
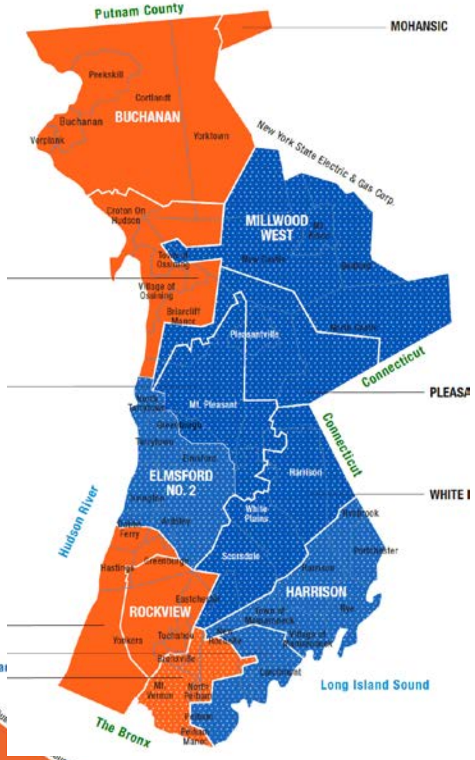
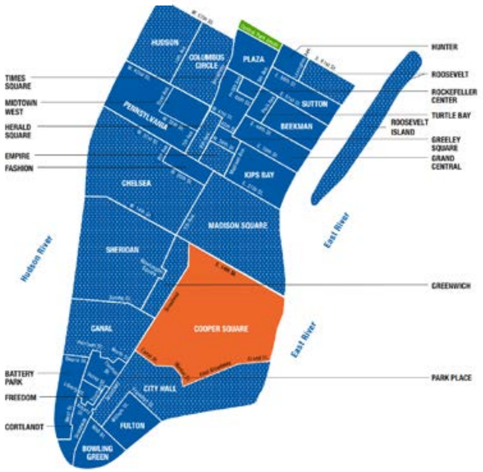
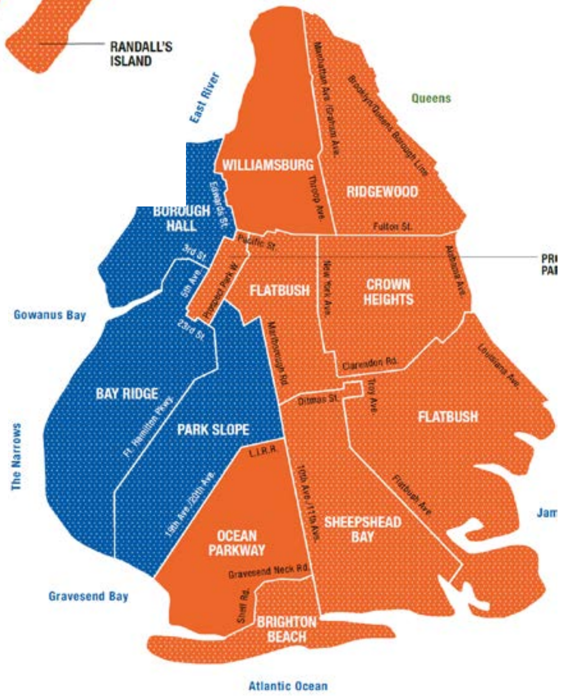
82 Load Zones

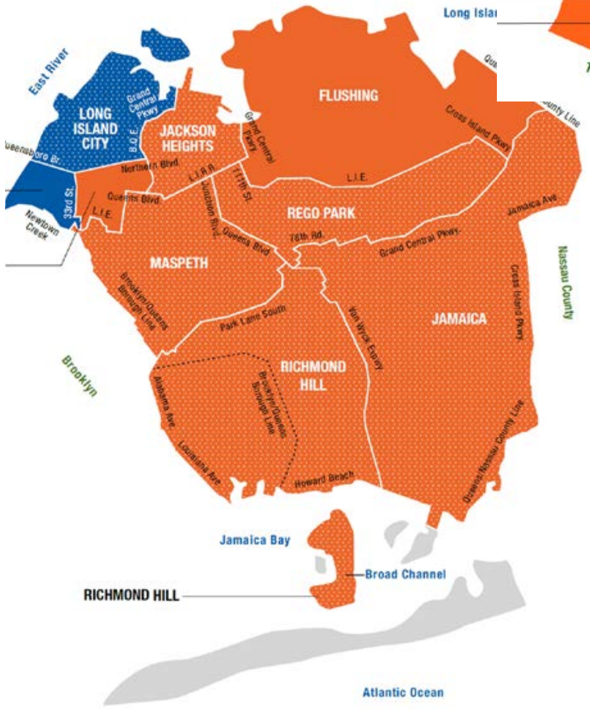












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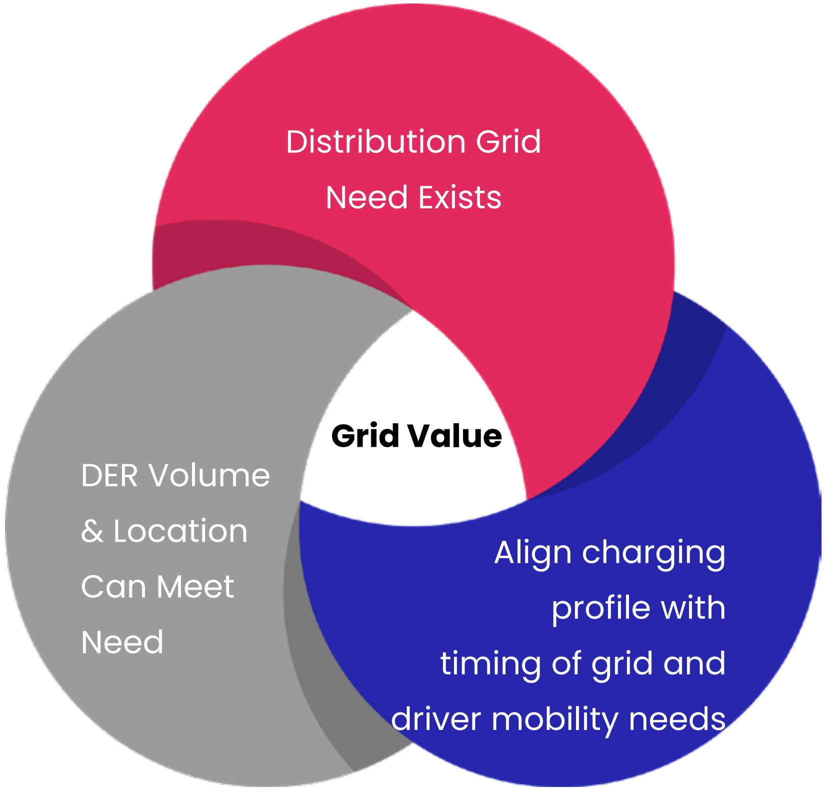
Accelerate the standardization of real time DER interoperability at the distribution level

Increase EV charging hosting capacity, reduce congestion, & enhance demand response

Monetizing Power Flow



Contract Info Elements

contract no <contractUuid>

contract agreement <contractURL>

parties

buyer <energyRequestor> <partyUUID>

seller <energyProvider> <partyUUID>

location

<parentNodeID> <coordination area> <childNodeID>

service

quantitykind ‹qtyType› enum ActiveEnergy, ActivePower, ReactivePower

unit <kwh, kw, kvar)

quantity <value>

time stamp

startTime <dateTime> can be next day, same day, or now

duration <hr:min:sec>

forecast <capacity> <uncertainty> <timeHorizon> <interval>

interval <15 min, < 5min < 1min, <1sec

ramp time <15 min, < 5min < 1min, <1sec

financial terms

USD <currencyType>

$ <currencySymbol>

price <pricePerUnit>

price <priceType> enum – event signal, firm, forecast,

expiration date <priceExpirationDate>

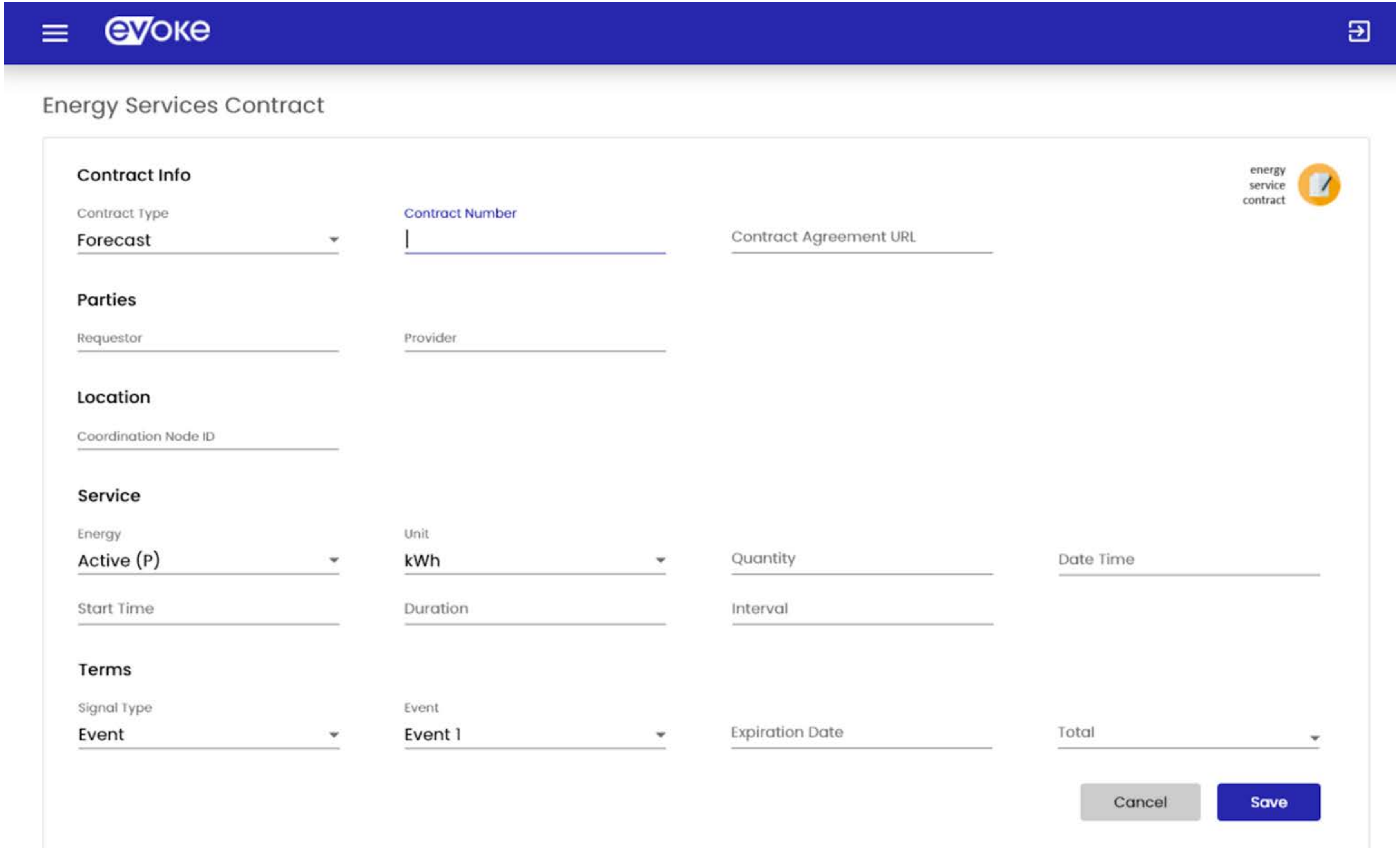
total <totalPrice>

delivery terms

as-needed

price or event signal <enum> 1-4 or pricePerUnit

commitment <eventResponse> enum


evoke
Energy Services Contract
Contract Info
energy service contract
Contract Type
Forecast
Contract Number
Contract Agreement URL
Parties
Requestor
Provider
Location
Coordination Node ID
Service
Energy
Active (P)
Unit
kWh
Quantity
Date Time
Start Time
Duration
Interval
Terms
Signal Type
Event
Event
Event 1
Expiration Date
Total
Cancel
Save

GO/DSP

- Set TOU rates
- Set Smart Charging rates
- DR – request next day/same day load shed/shift

CNO/CSO

- Set site limit (max power)
- Schedule TOU and Smart Charging targets
- Set DR response targets
- Send charge limit, TOU, & DR notifications & offers

Driver

TOU & DR offers

- set & forget
- opt out if needed
- one time offers

BLACK & VEATCH

Decarbonization of Transportation @Scale

Paul Stith

Associate Vice President, Global Transportation Initiatives

What's missing in this picture?

Photo: Paul Stith, Black & Veatch

BLACK & VEATCH

Photo: Paul Stith, Black & Veatch

What's your recipe for program success?

5 Part Answer

Business Models	Stakeholder alignment Multi-stream ecosystems Durable, Scalable, Sustainable
Real Estate (Location x 5)	Portfolio support use cases Private, shared or hybrid facilities? Entitlements, right of ways
Capital, Carbon & Operating Budgets	Strategy Feasibility -> Design certainty TCO Inflection points?
Calendar Realities	Supply Chain Energy Supply Approvals & Permitting Integration with Fleet Operations
Technology & Infrastructure Deployment Alignment	Vehicle Production Efficiency, Physics, Centralized, Distributed & Resilient

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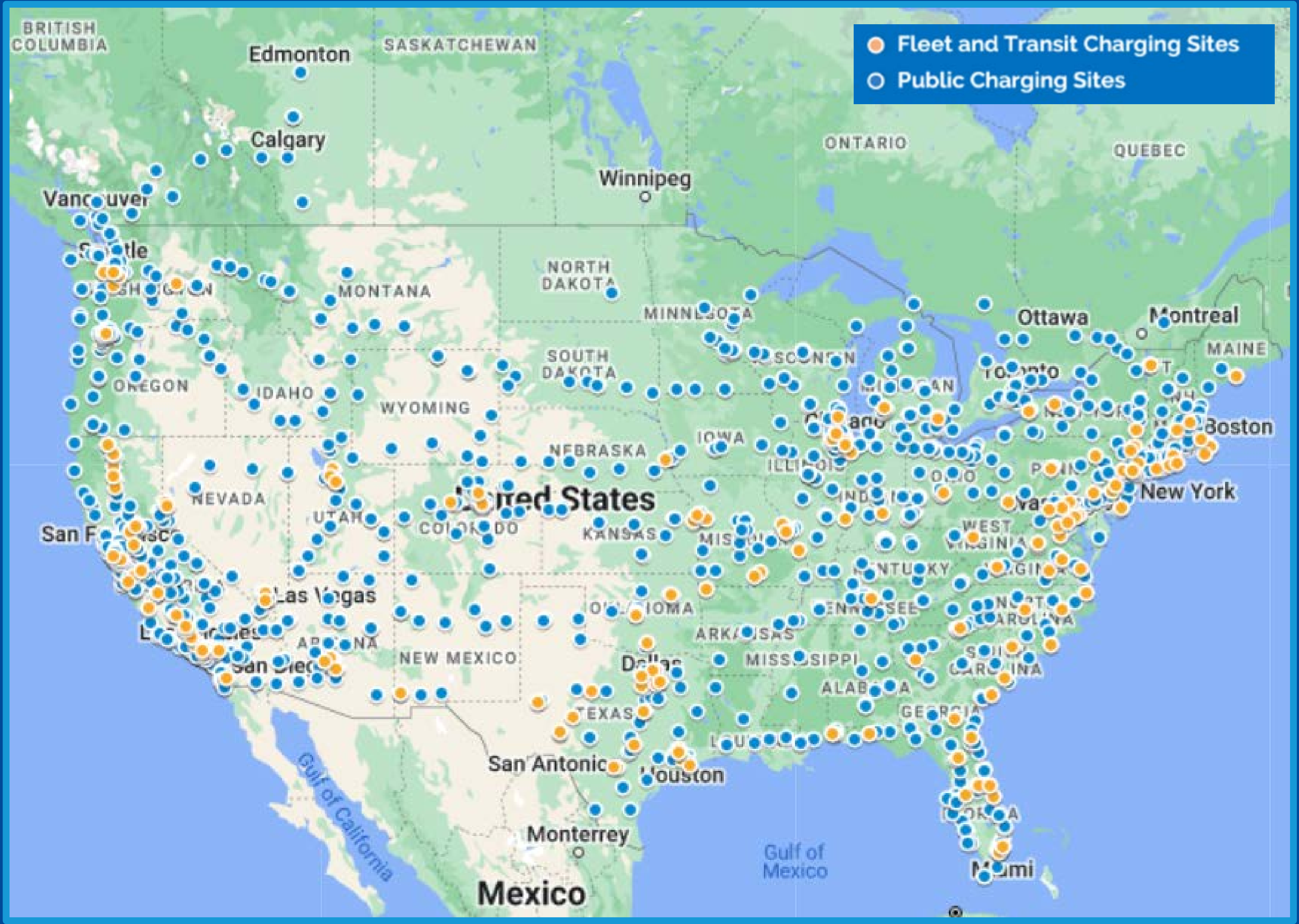
Electric Vehicle Charging Infrastructure Experience



30,134 Dispensers

2,266 Sites

49 States and Canada, Germany, United Kingdom, Spain & the Netherlands

2 GW EV Charging power engaged

326 MW Fleet charging engaged

Grid Connection, Supply Chain, Non-Wires Options, Carbon Intensity: Numerous site and regional variables impact infrastructure investment requirements and scale up roadmap

SAMPLE FLEET	CAPACITY REQ'D	GRID UPGRADE	EXAMPLE TIMELINE REQUIRED
20 overnight charging medium-duty delivery trucks	1MW Charging Site	Service Transformer	~3 - 6 MONTHS
500 overnight charging light-duty delivery vans	5MW Charging Site	Feeder Upgrade	12 - 26 MONTHS
200 daytime fast charging heavy-duty trucks	20MW Charging Site	Substation Upgrade	24 - 48 MONTHS OR MORE

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Infrastructure Development Lifecycle

Portfolio Development & Program Architecture Drive Success

PROGRAM MANAGEMENT

BUSINESS CHOICES

Strategy

- Market view
- Customer markets & buying proposition
- Competitive model
- Provider landscape
- Economic model
- Financial targets
- Competitive strategy

Go-to-Market Deployment

- Customer value proposition
- Target customer segments
- Deal strategy for new customers

Prelim. Feasibility & Design

- Detailed site assessment
- Grid capacity check & load letter submission
- Customer transportation operations survey
- Go/No-Go decision on site

EXECUTION

Detailed Engineering

- Engineering designs
- Zoning, permitting & approval
- Utility interconnection
- Procurement & purchasing
- Inventory Control
- Qualify and manage subcontractors

Construction & Commissioning

- Mobilization
- Site kick-off
- Site prep/civil works
- Skid installation
- Electrical
- Mechanical
- Communications

Operation & Maintenance

- Site turn-over
- Testing and training
- Startup and commissioning
- Energy optimization
- Alarms and monitoring
- Infrastructure management

BLACK & VEATCH

Daimler & Portland General Electric
Electric Island

Black & Veatch designed and built a first-of-a-kind public charging site for medium- and heavy-duty vehicles near Portland, Oregon.

- Up to 4.5 MW utility capacity
- Charging for 9 vehicles
- Flexible pre-cast trenching system for easy equipment swap
- Plans for more chargers, on-site energy storage, solar power generation, and a product and technology showcase building

Sysco Corporation

Electric Fleet Charging with Onsite Power

One of the largest fleet charging sites, the site supports Sysco's pledge to reduce carbon emissions across its global distribution operations.

The charging depot has:

- 40 battery electric truck chargers
- 1.5 MW of solar generation
- Battery Energy Storage System
- Microgrid
- Onsite generation to power charging and reduce grid load

An extension of an Owner's Engineer package, BV provided:

- Engineering Coordination
- Procurement of Photovoltaic and Balance of Plant Equipment
- Construction Subcontracts Support
- Construction Execution
- Project Management

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Schneider National Inc.

Electric Truck Charging Depot

Schneider, a global logistics company, built a truck charging depot to support their electric fleet as part of their initiative to operate more sustainably.

The depot, located in South El Monte, California:

- Powers Schneider's fleet of 92 eCascadia battery electric trucks
- Features 16 350 kW dual-corded dispensers that will charge 32 trucks simultaneously, reaching 80% charge within 90 minutes
- Will help Schneider meet their sustainability goals to slash 7.5% carbon emissions per mile by 2025, and 60% per mile by 2035

Black & Veatch Scope Included:

- Charging feasibility
- Energy planning
- Fleet operation program requirements
- Engineering, Procurement & Construction

Schneider National –Intermodal Facility, El Monte, CA

Joint Electric Truck Scaling Initiative (https://www.jetsiproject.com/)
Power: 4.2 Megawatts, 36 Charging Cords, 92 Class 8 Tractors

BLACK & VEATCH

Thank you!

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Associate Vice President,
Global Transportation Initiatives

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Find me on LinkedIn

Consortium Audience Feedback Session

Adjournment

- Thanks for your attendance and participation.

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