EVs@Scale
U.S. Department of Energy

Emulating EV Charging using Real-Time Simulation

Keith Alan Davidson, P. E.

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Disclaimer

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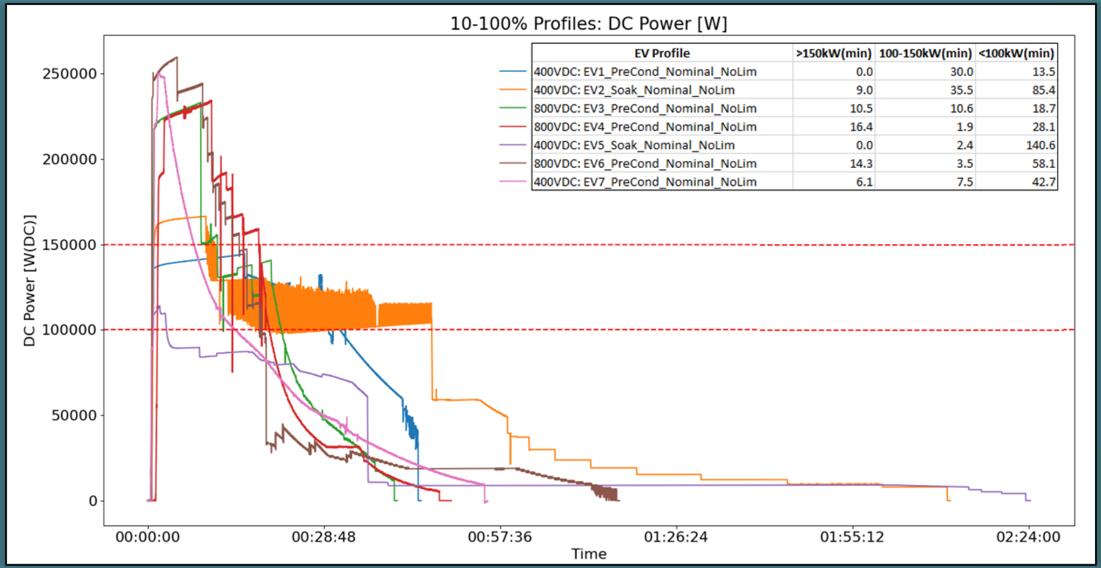
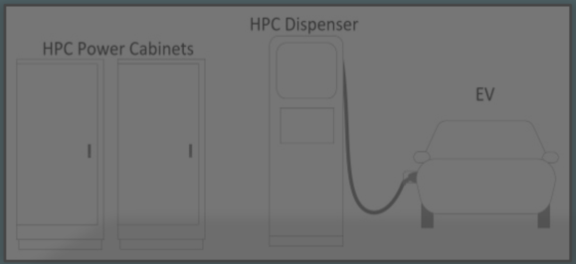
Next-Gen Profiles Overview

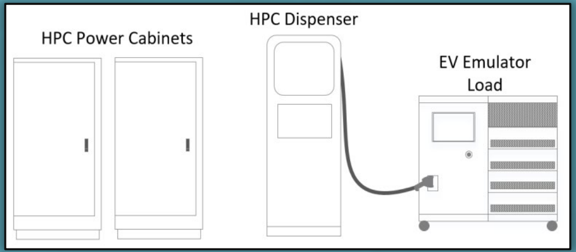
- EVs@Scale > High Power Charging > Next-Gen Profiles
- *“To further understand the most recent technological capabilities of the electric mobility industry related to charging performance.”*
- Many Things to consider when assessing HPC (>200kW):
  - Baseline vs Boundary, Conductive vs Wireless
  - System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



1. EV Profile Capture



2. EVSE Characterization



3. Fleet Utilization

NextGen Profiles NREL Test Team

Keith Davidson

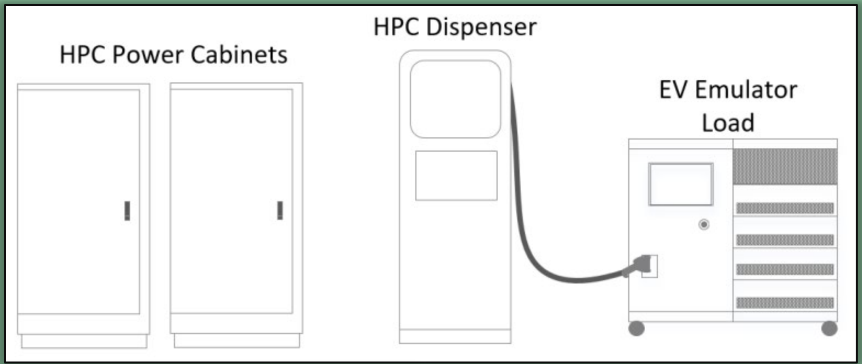
Namrata Kogalur

Isaac Tolbert

Andrew Meintz

EV Characterization Testing

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/DC voltage source 0-1000V_{DC}
    - Future ≥1000V_{DC} charging on roadmap
  - OEM rated between 50-350KW peak DC charge rates
- **EVSE Assets:**
  - Production DCFCs, capable up to 1000V_{DC}/500A Maximum
  - Dual power cabinet/single dispenser topology (currently)
  - Port types are CCS (currently); NACS (future)
- **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]V_{AC}, [58.8, 61.2]Hz, 5% voltage distortion
  - OCPP Curtailed: 65A for 2min via *TxProfile, TxDefaultProfile,* and *ChargePointMaxProfile*

Overview: EVSE Characterization

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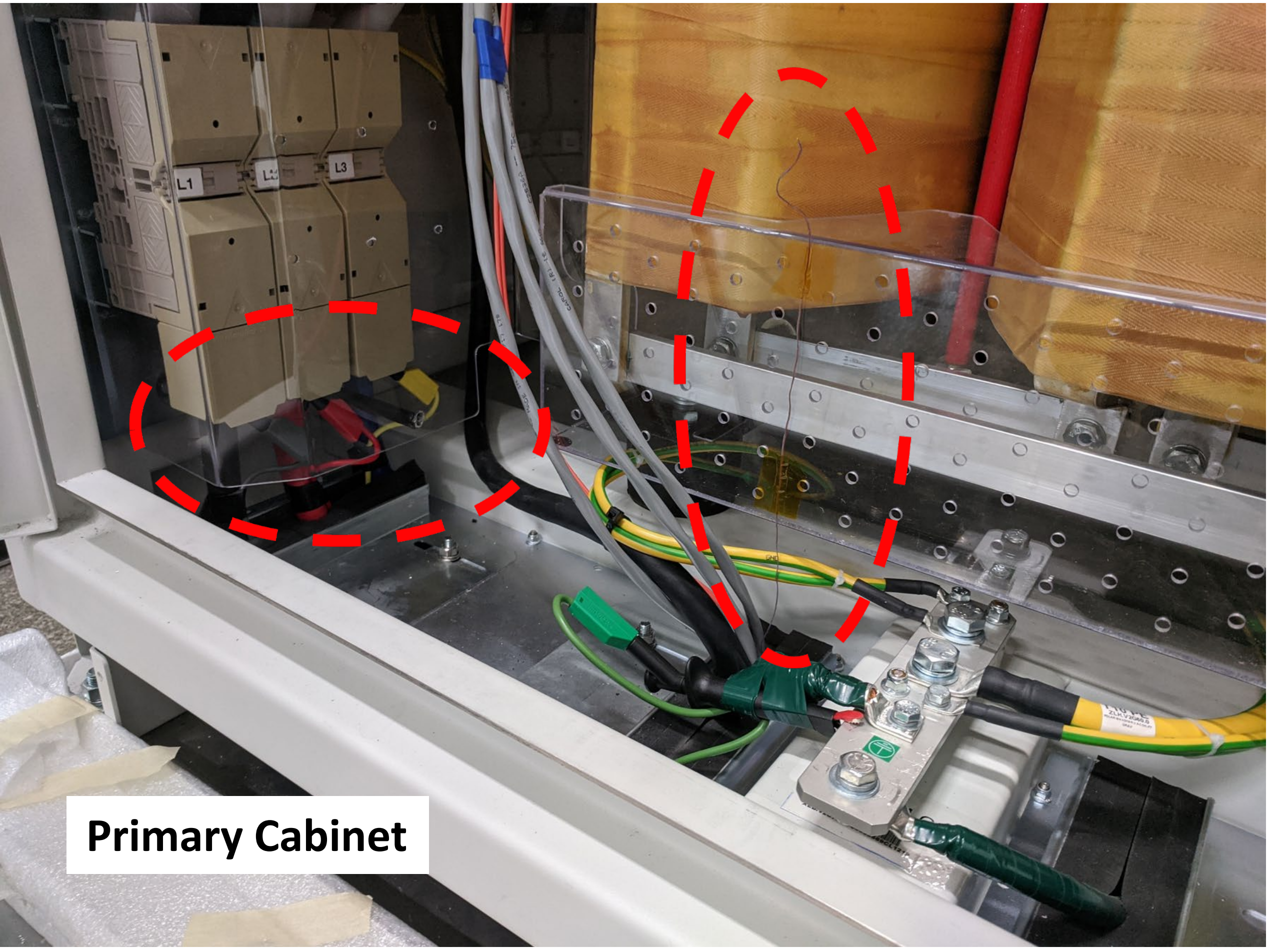

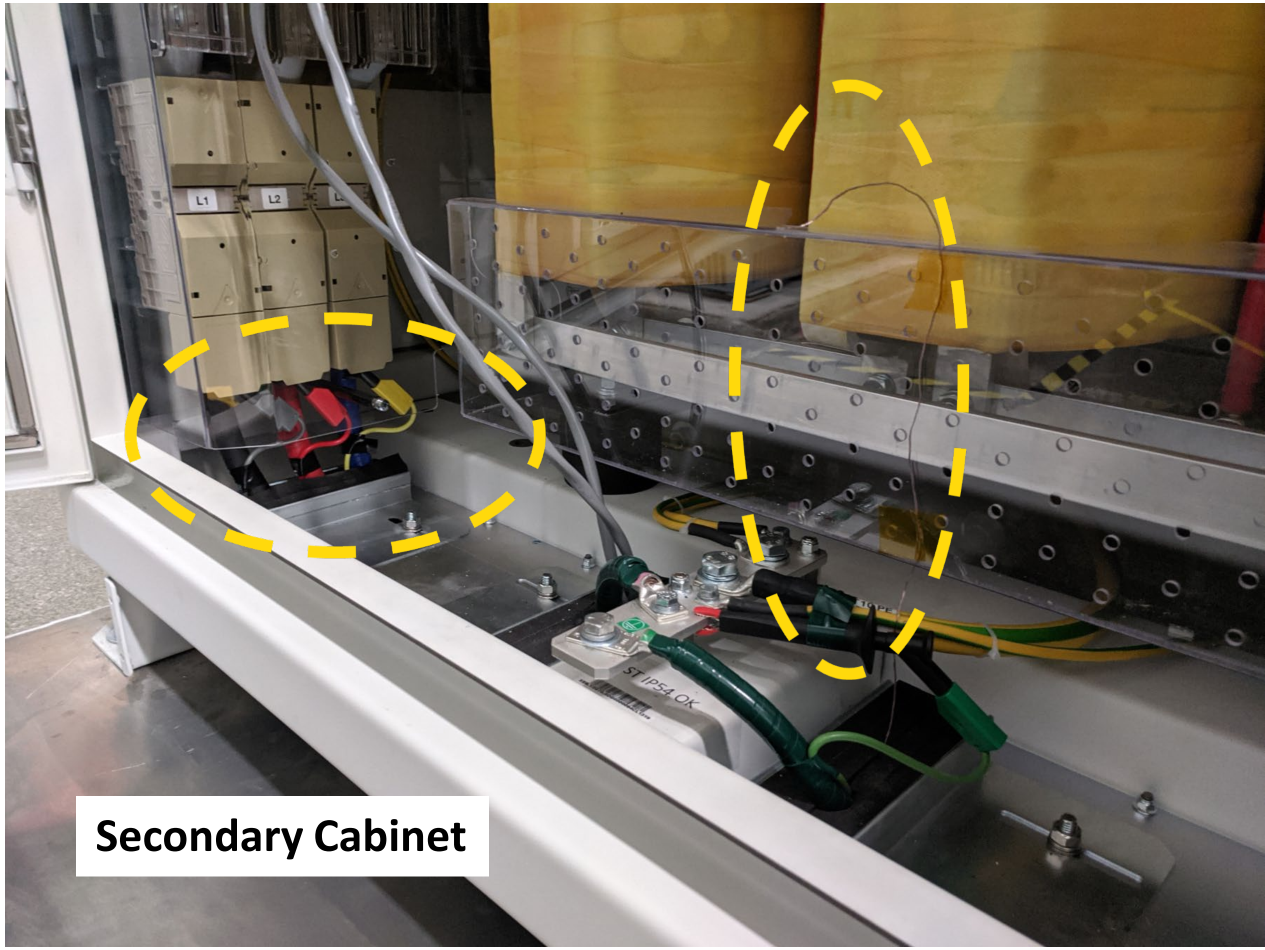

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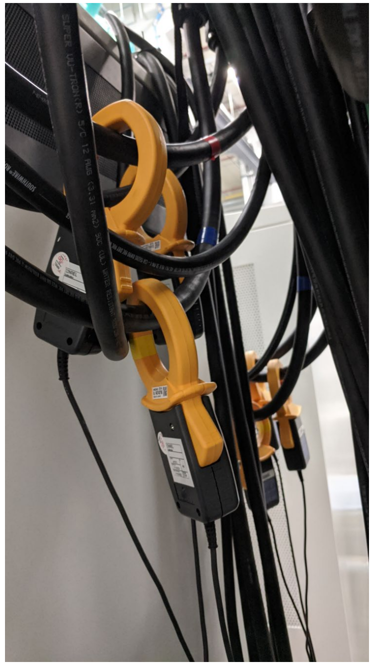

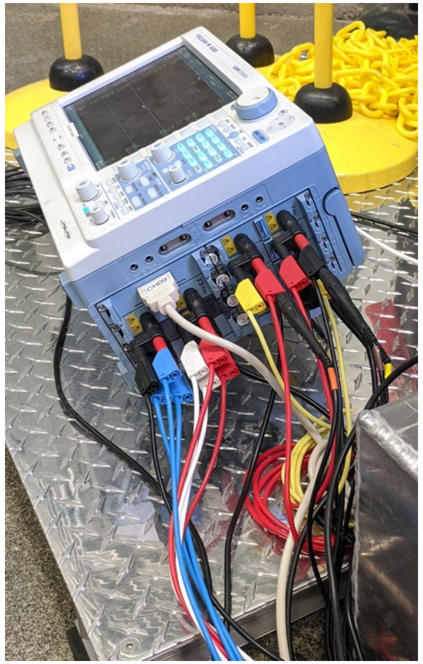

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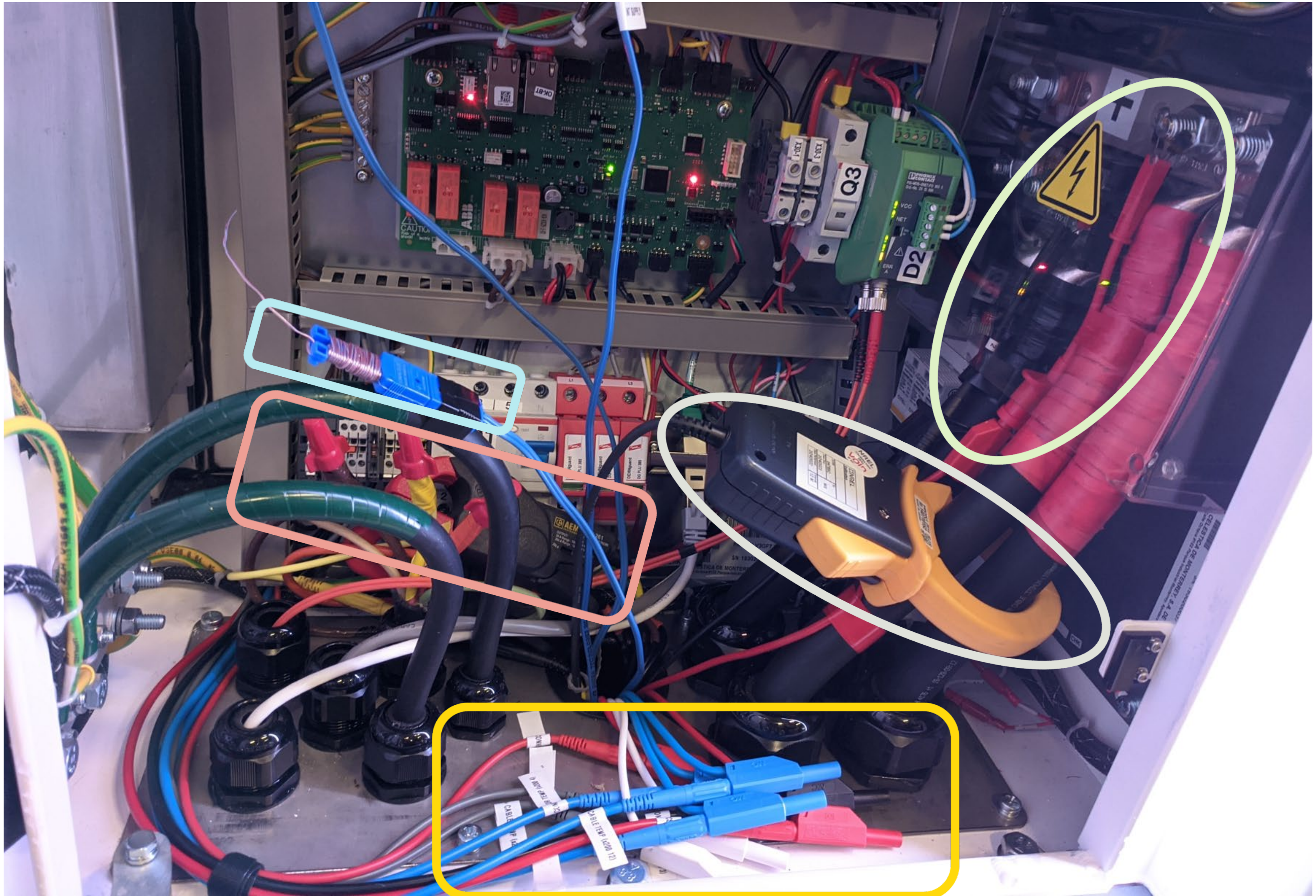

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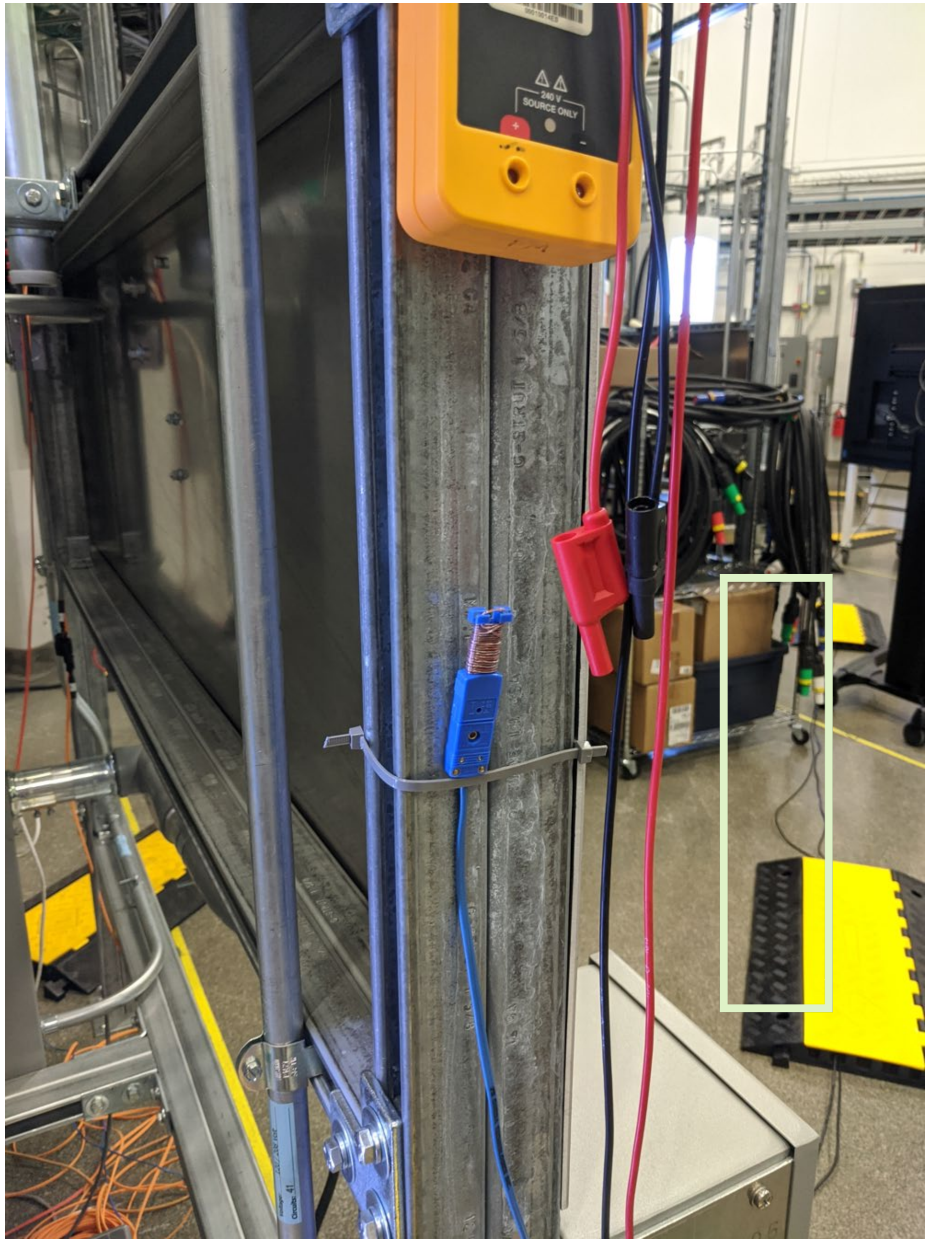

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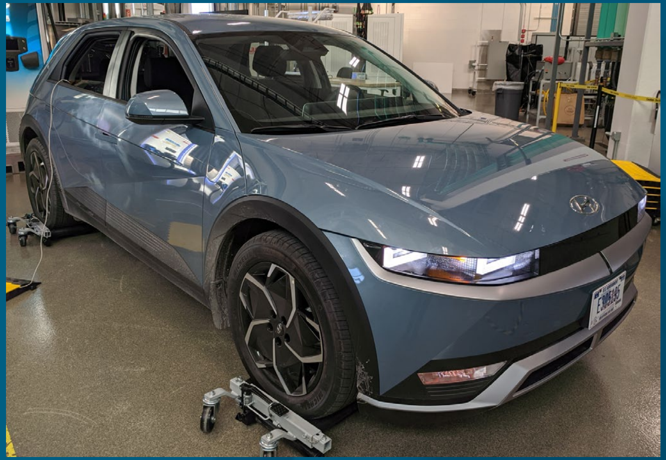

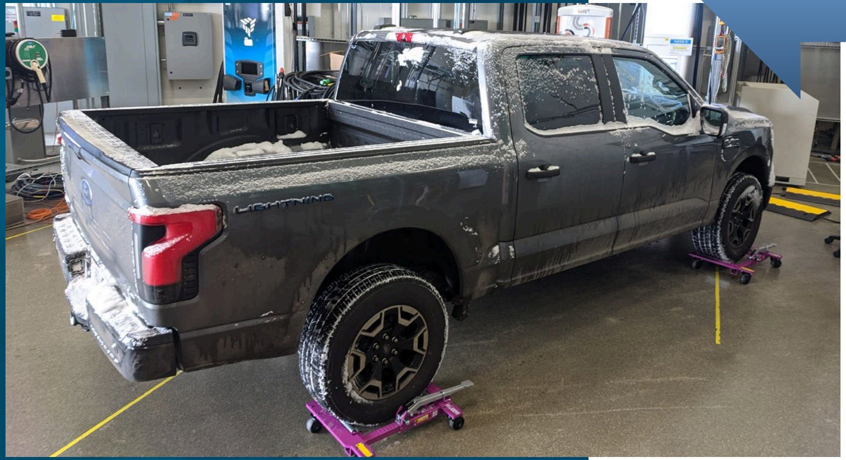

Overview: EVSE Characterization

- CCB tricks the EVSE into thinking it is plugged into an EV and routes DC charging power to a Power Conversion Unit that returns energy to house supply
  - ✓ Decouples EVSE charging performance from EV charging performance
  - ✓ Adaptable
  - ✓ Mobile
  - ✓ Cost-effective
- Designed and built in-house; an audacious undertaking similar in scope to developing a vehicle
  - × Growing pains encountered while developing/debugging/testing this capability
  - × Tools to evaluate and troubleshoot CCB development were not always available

Overview: EVSE Characterization

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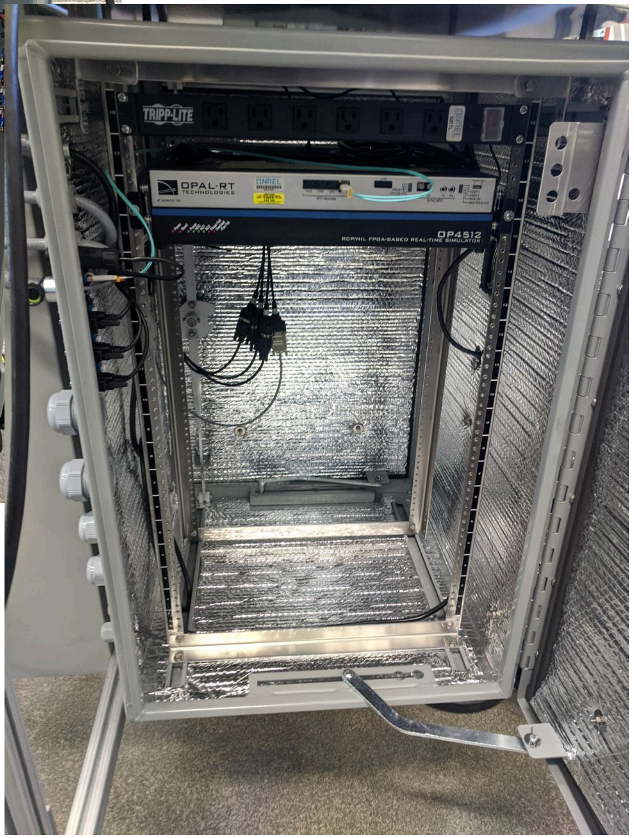
	Charge Control Box	Electric Vehicle
Design Control	✓ Quick and easy to reconfigure in-house ✓ **Adaptable for simultaneous & quick-succession charging of a diverse range of pack designs & initial conditions**	× Third party hardware and support required for testing & data collection × Costly; large time & resource investment required
Battery Discharge	✓ Power is returned to grid minus small conversion loss	× Time consuming, energy mostly wasted
Safety	✓ **Eliminates high-capacity battery pack safety requirements**	× Large stored energy/chemical/thermal/fire hazard
Charge Performance	✓ **Full indication and control of EV charge parameters** ✓ **Decouples EV – EVSE charge performance**	× EV may limit charge performance without end user indication
Charge Profile / Battery Chemistry	✓ Battery chemistry models are precise and tunable ✓ Full observability and control over BMS algorithm operation	× Restricted to a single charge profile/chemistry/voltage × Little to no insight into charge control algorithm × Hard to set required initial conditions (Temperature, SOC)
Physical Footprint	✓ Mobile units – easy to relocate ✓ CCB + XFC Fits in existing thermal chamber	× Heavy, large footprint × Thermal performance testing must be performed outdoors
Future Development	✓ ***Provides a flexible capability suitable to advance a diverse range of research initiatives***. Examples: • EVSE Characterization • ISO15118-2 and -20 • V2X, MCS, WPT & CHIL	× Extensive and committed partnerships required for ground-breaking & transformative research

Overview: EVSE Characterization

- **CCB Design Iteration in progress to improve capabilities and robustness:**
  - 500A charging capability
    - 1000A contactor upgrade
    - Fuse and flexbar upgrades
  - OP4512 upgrade
    - Climate controlled enclosure upgrade
  - Thermal performance upgrades
  - Signal accessibility upgrades
  - “Chassis Ground” path revision and improvements



EVSE Characterization Test Results

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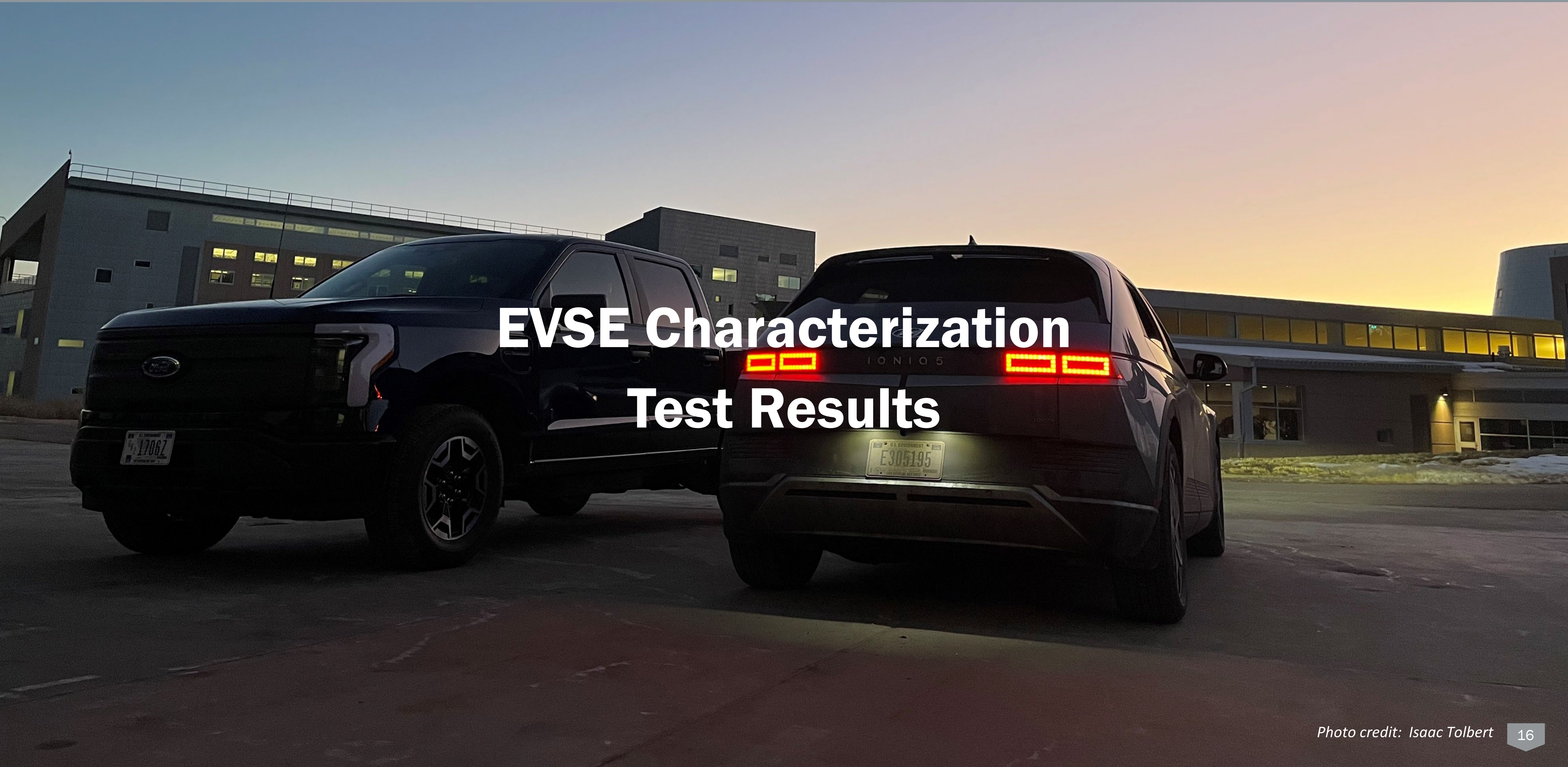
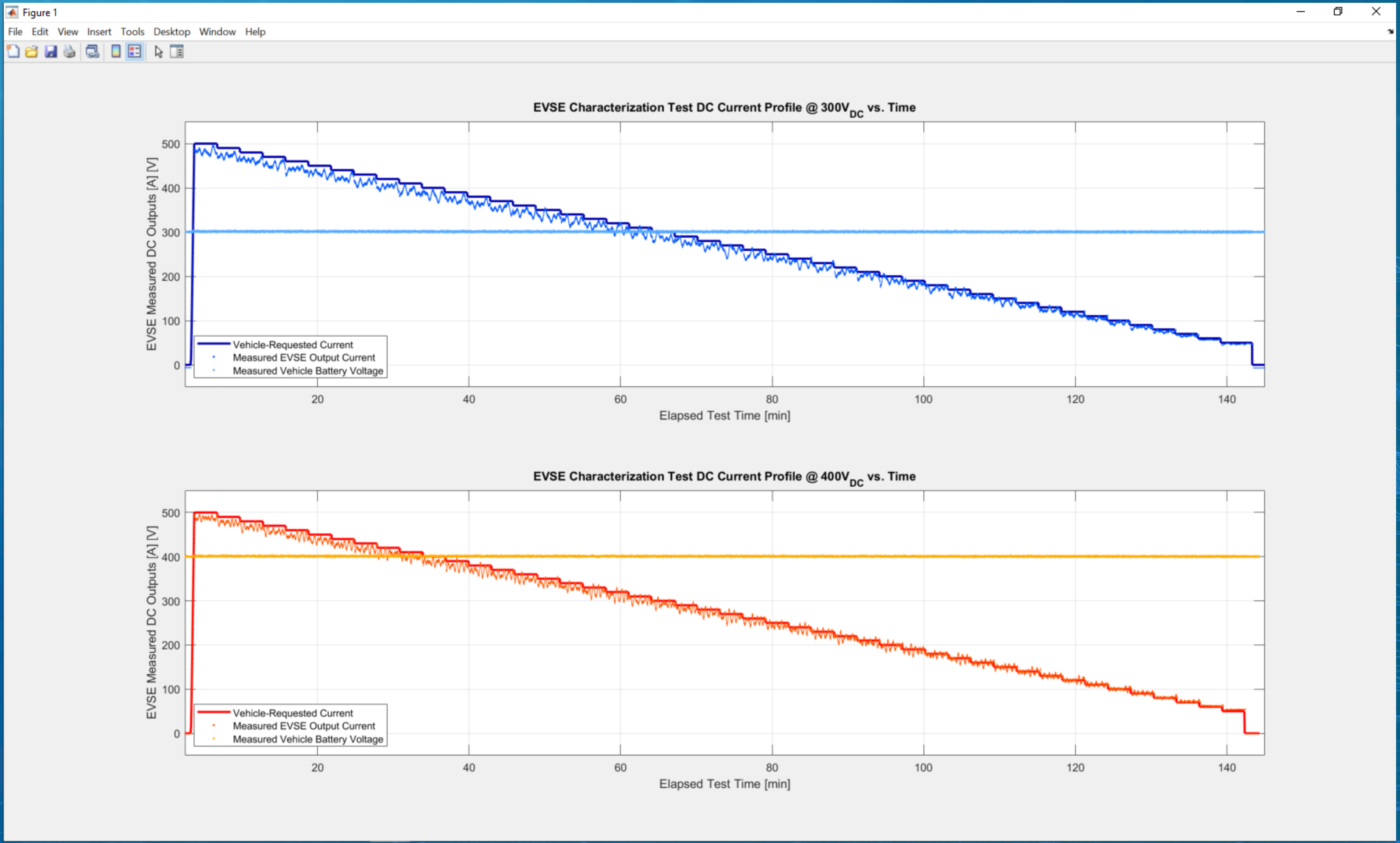


EVSE Characterization Test Results

Photo credit: Isaac Tolbert

EVSE Characterization Test Results



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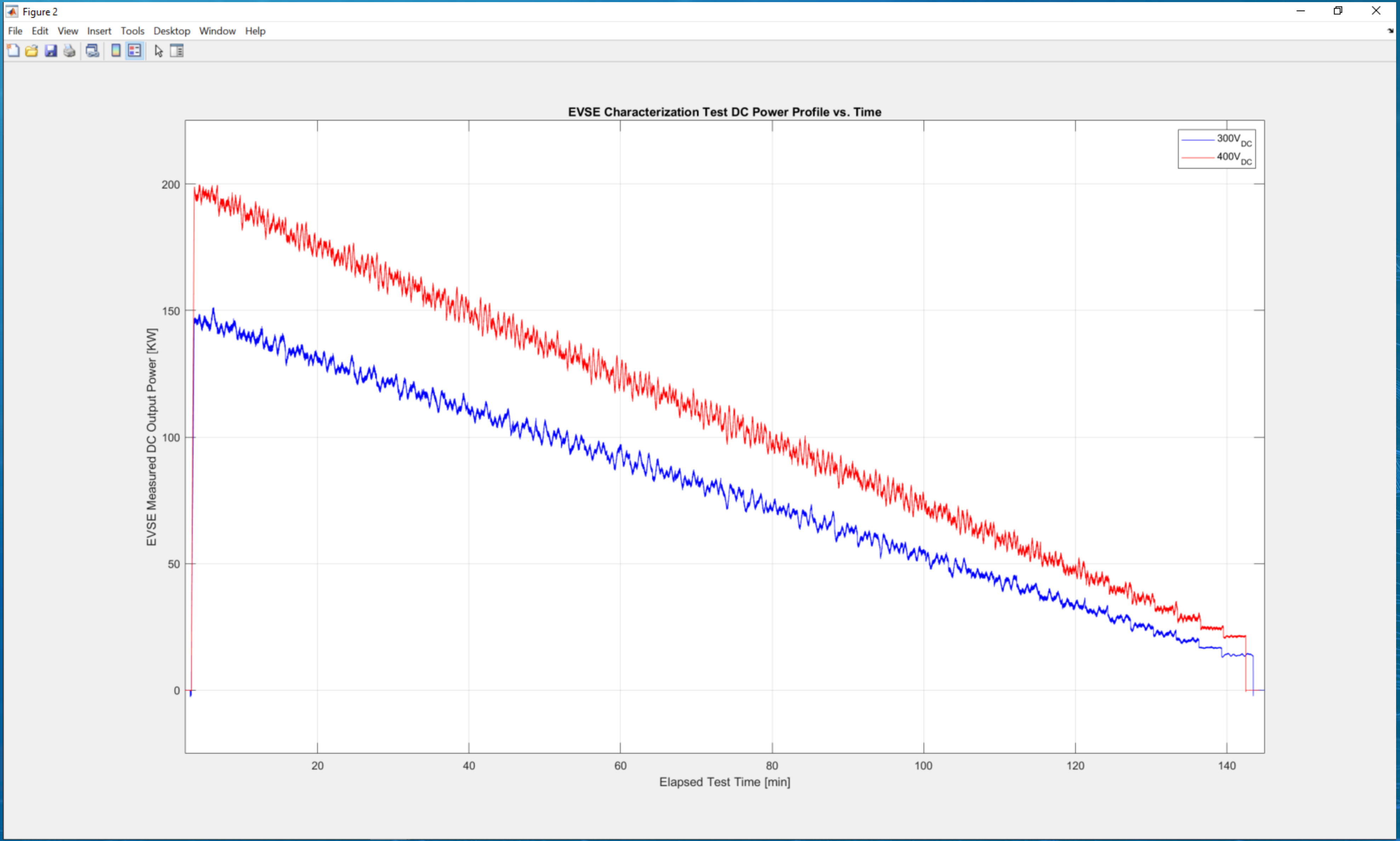

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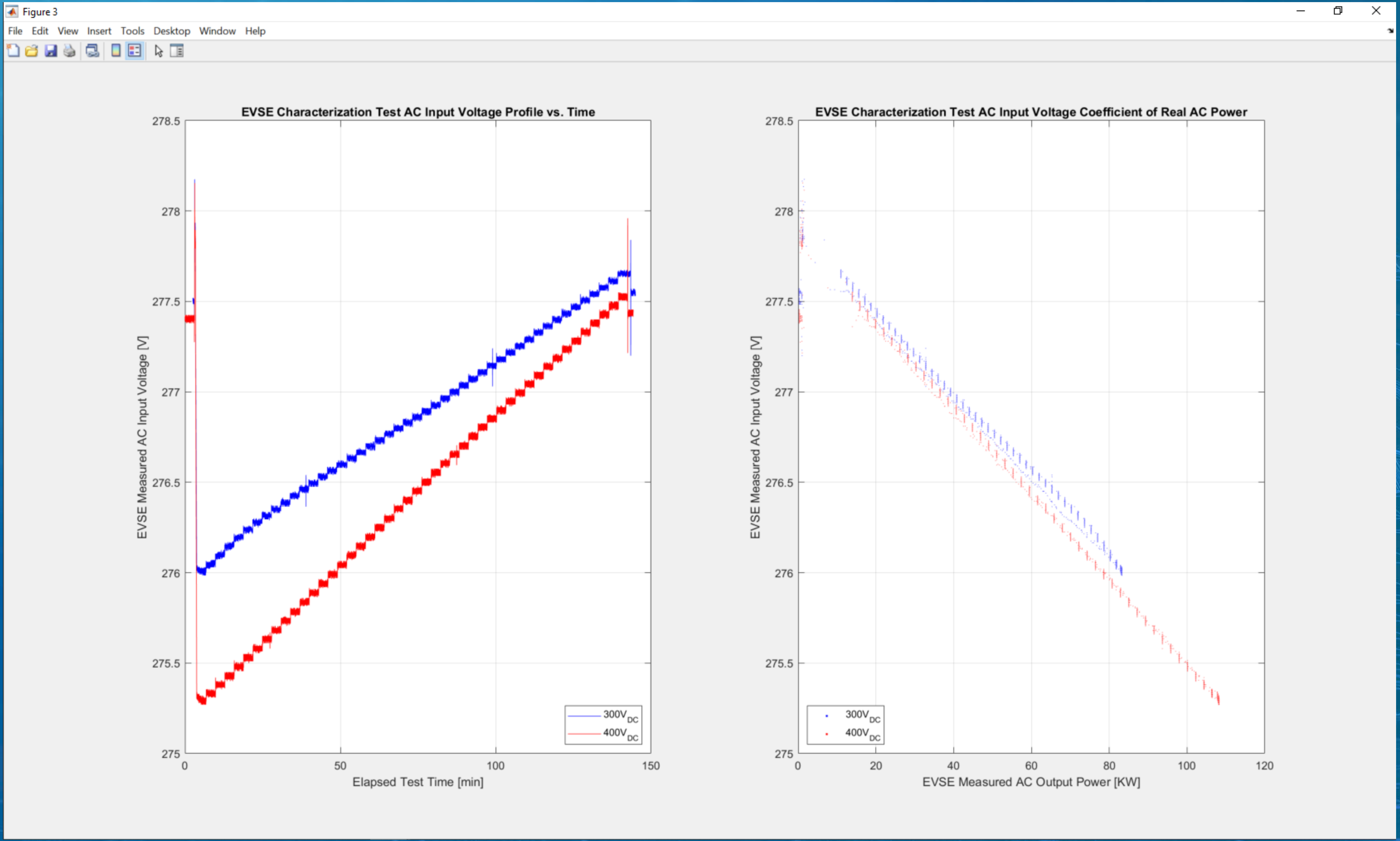

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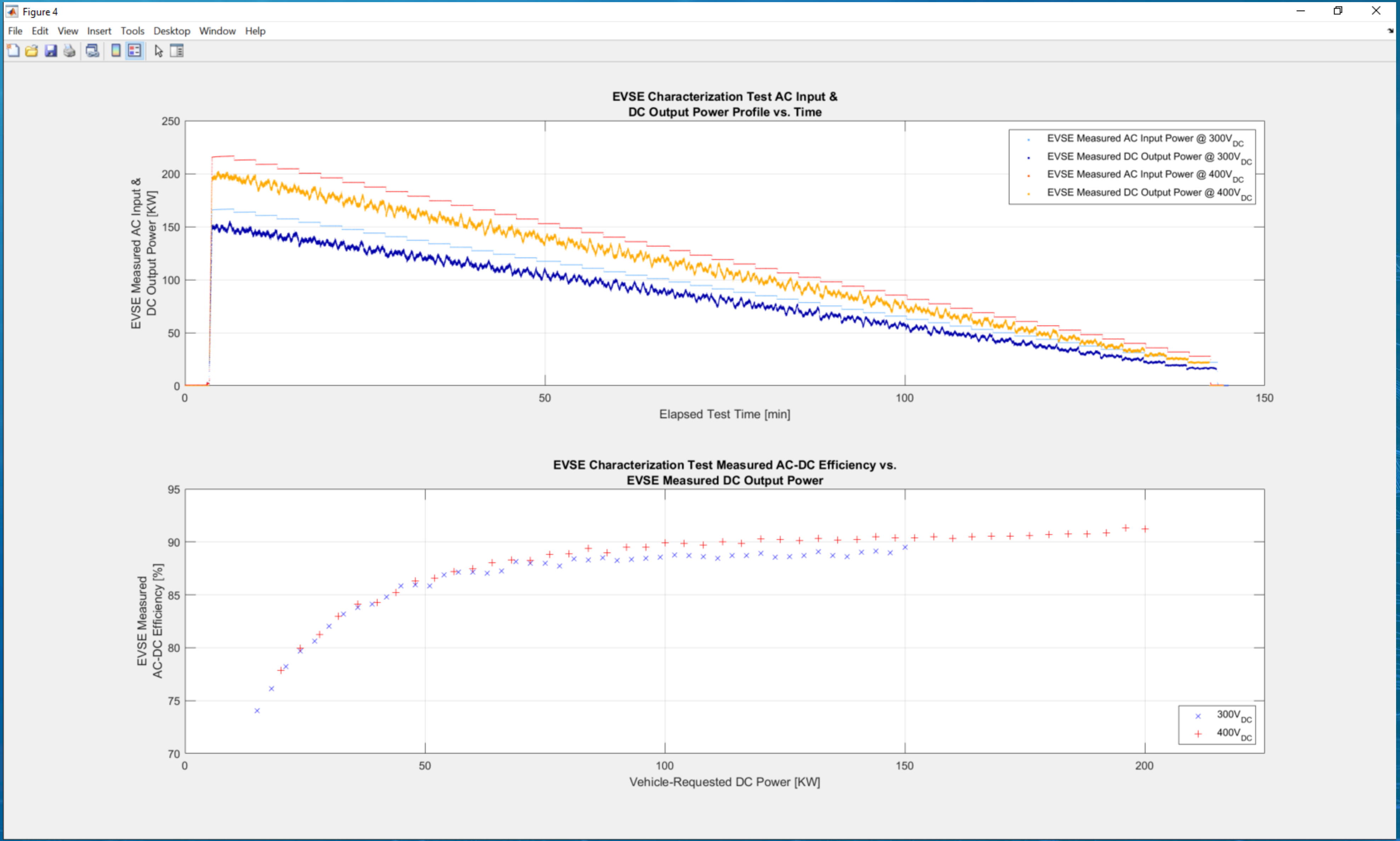

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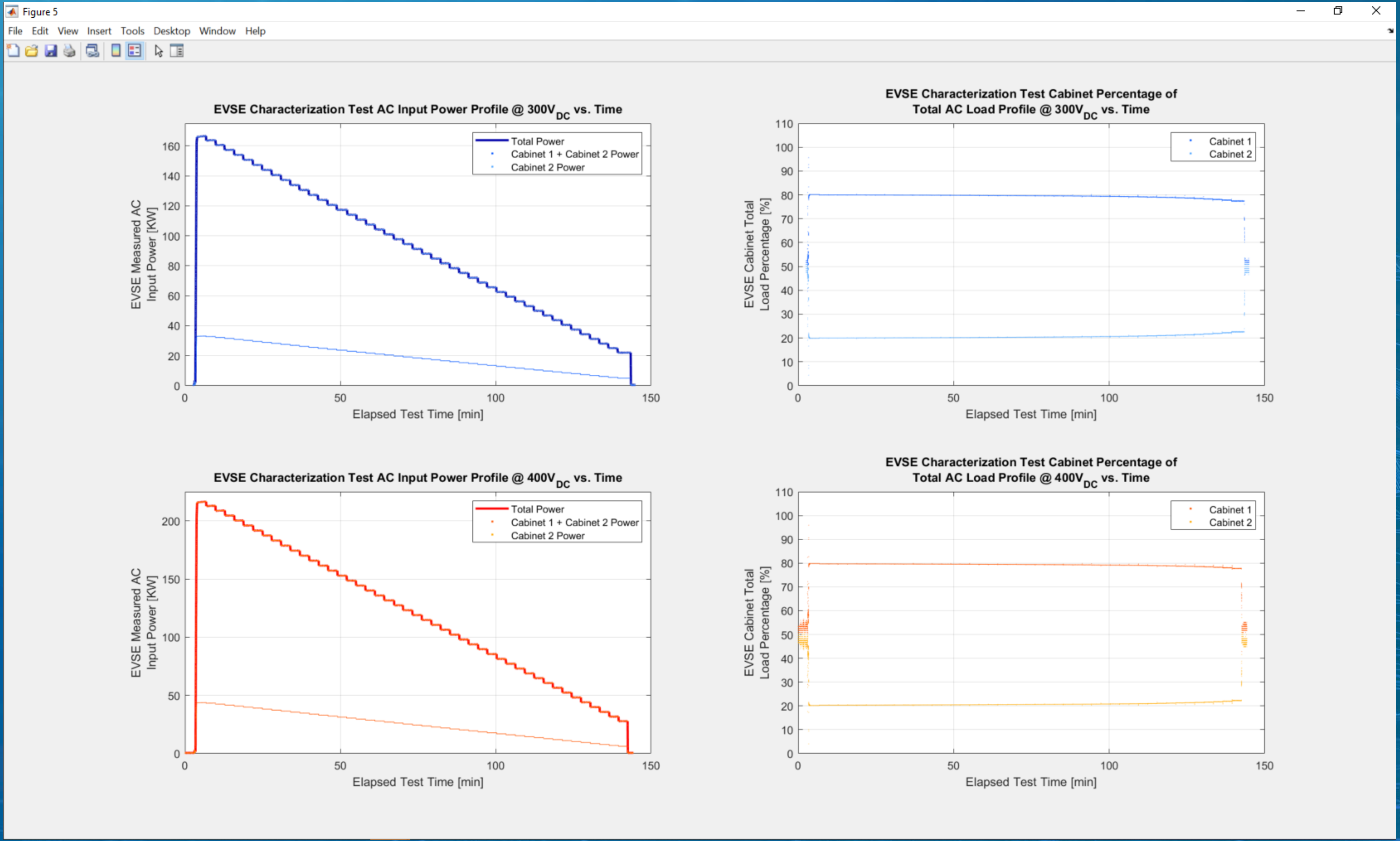

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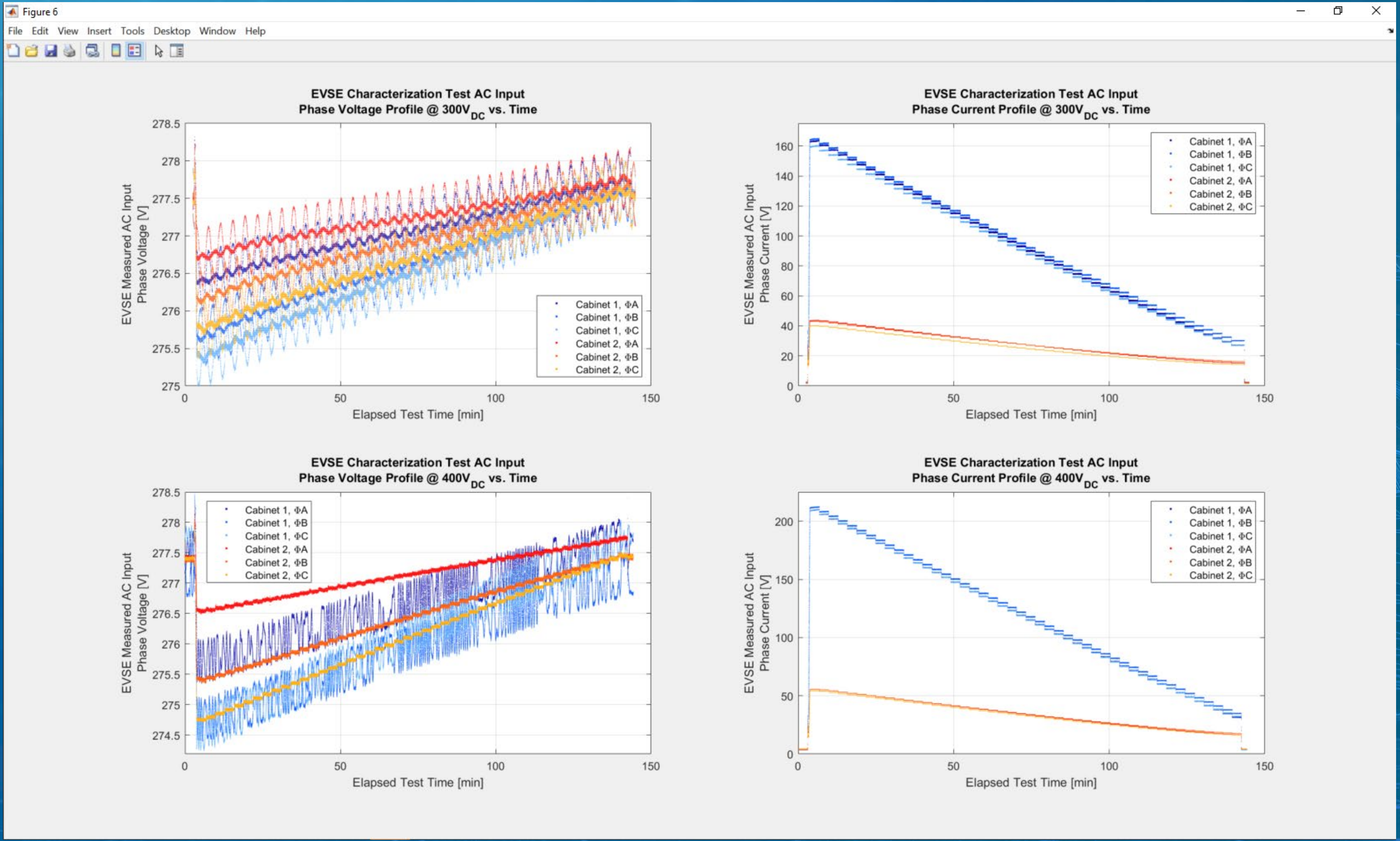

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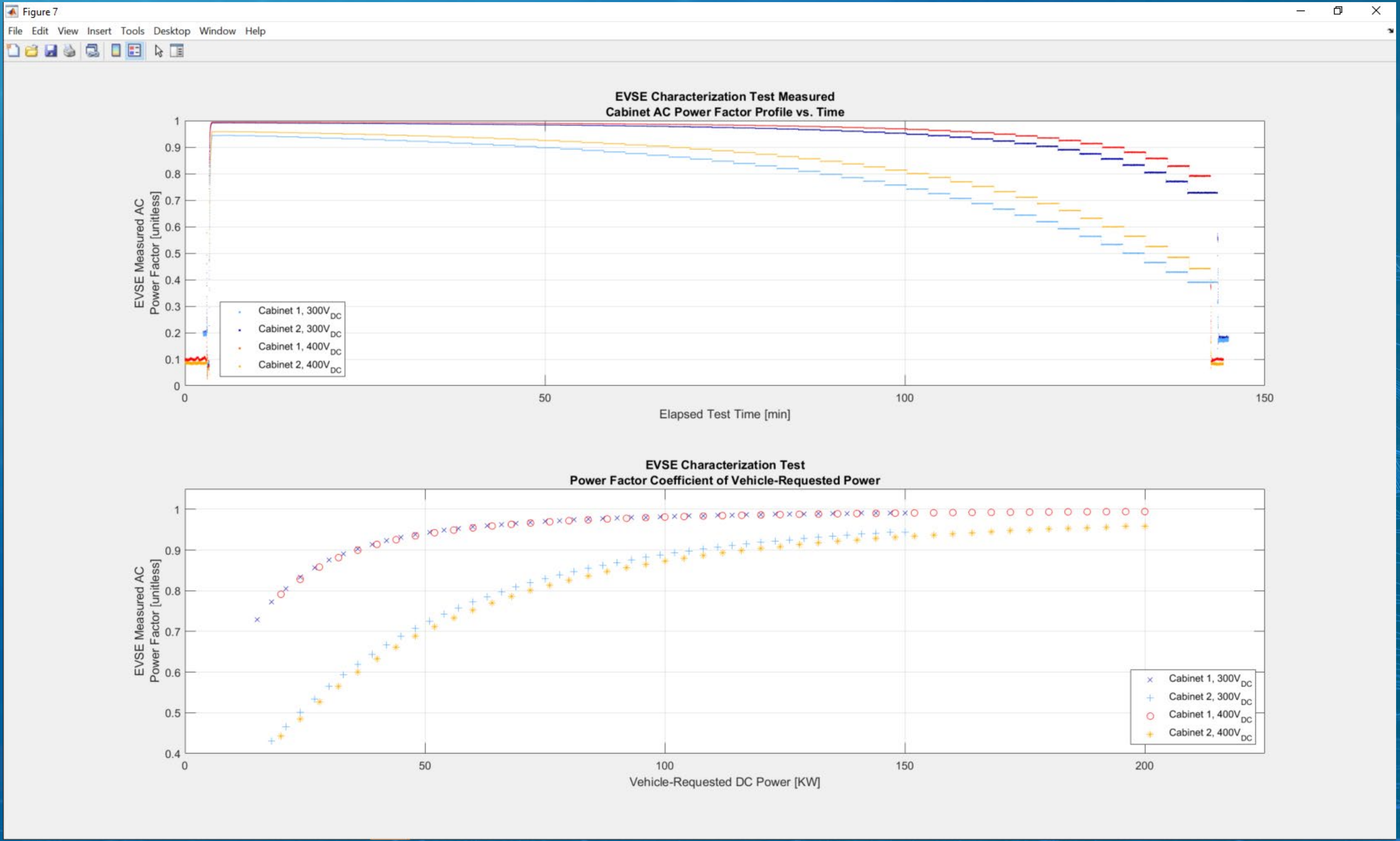

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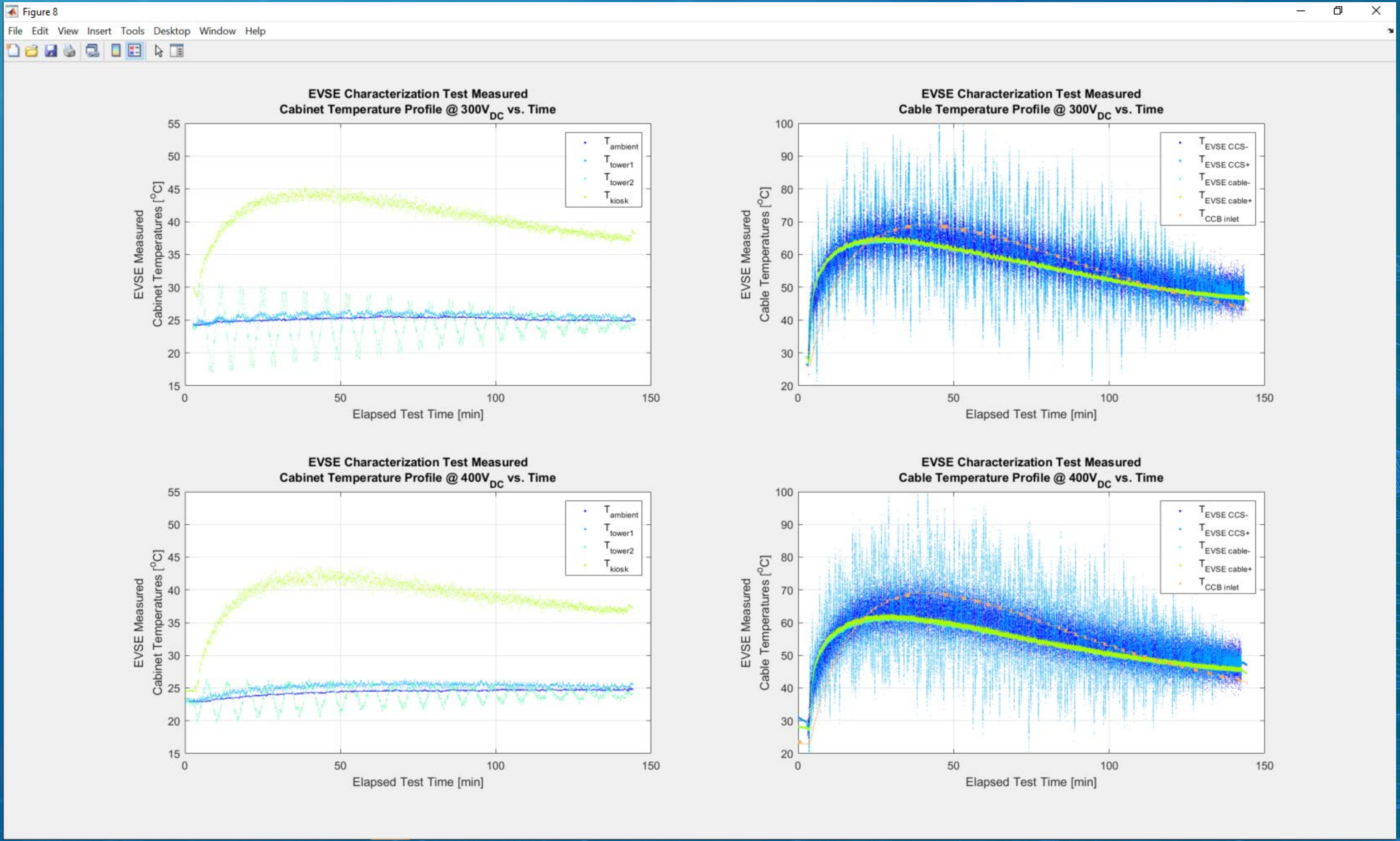


Project Outcomes:

Data Reporting & Distribution

Your Participation

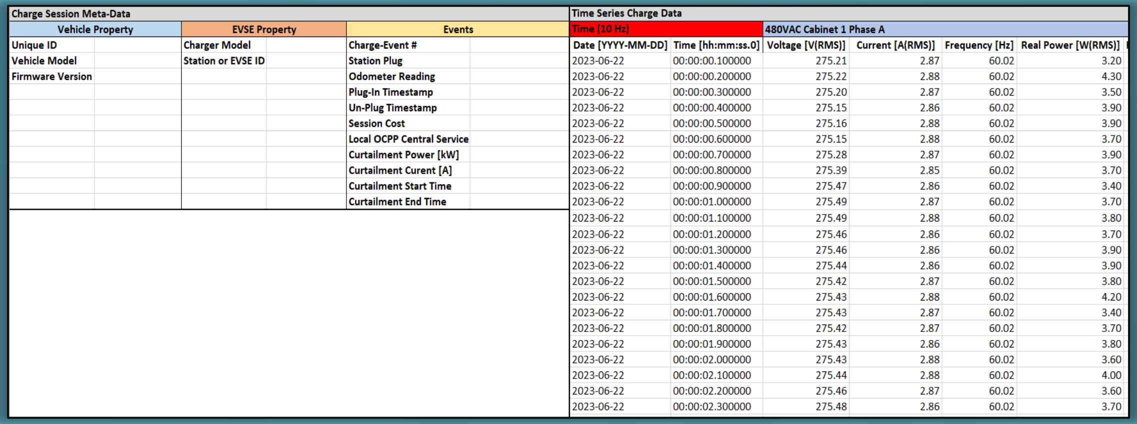
Reporting

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

In Closing

- OP4512 is a capable and critical piece of hardware that enables NREL's EV charging and EVSE infrastructure research
- Your Participation in the NextGen Profiles project is welcome
- Project is funded through FY2025
  - Vehicle Profile Capture (≥200KW)
    - Light Duty
    - MD/HD vehicles of interest
  - *EVSE Performance Characterization (≥200KW; ≥350KW preferred)*
    - *NACS systems of interest*
  - *NACS Adapter Performance*
  - Vehicle Boost Converter Performance
  - *MCS*
  - V2X
  - keith.davidson@nrel.gov
- NREL is hiring!
  - https://www.nrel.gov/careers/
- Thank you Ben Ouaglal

Questions?

Thank you

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