EV Charging

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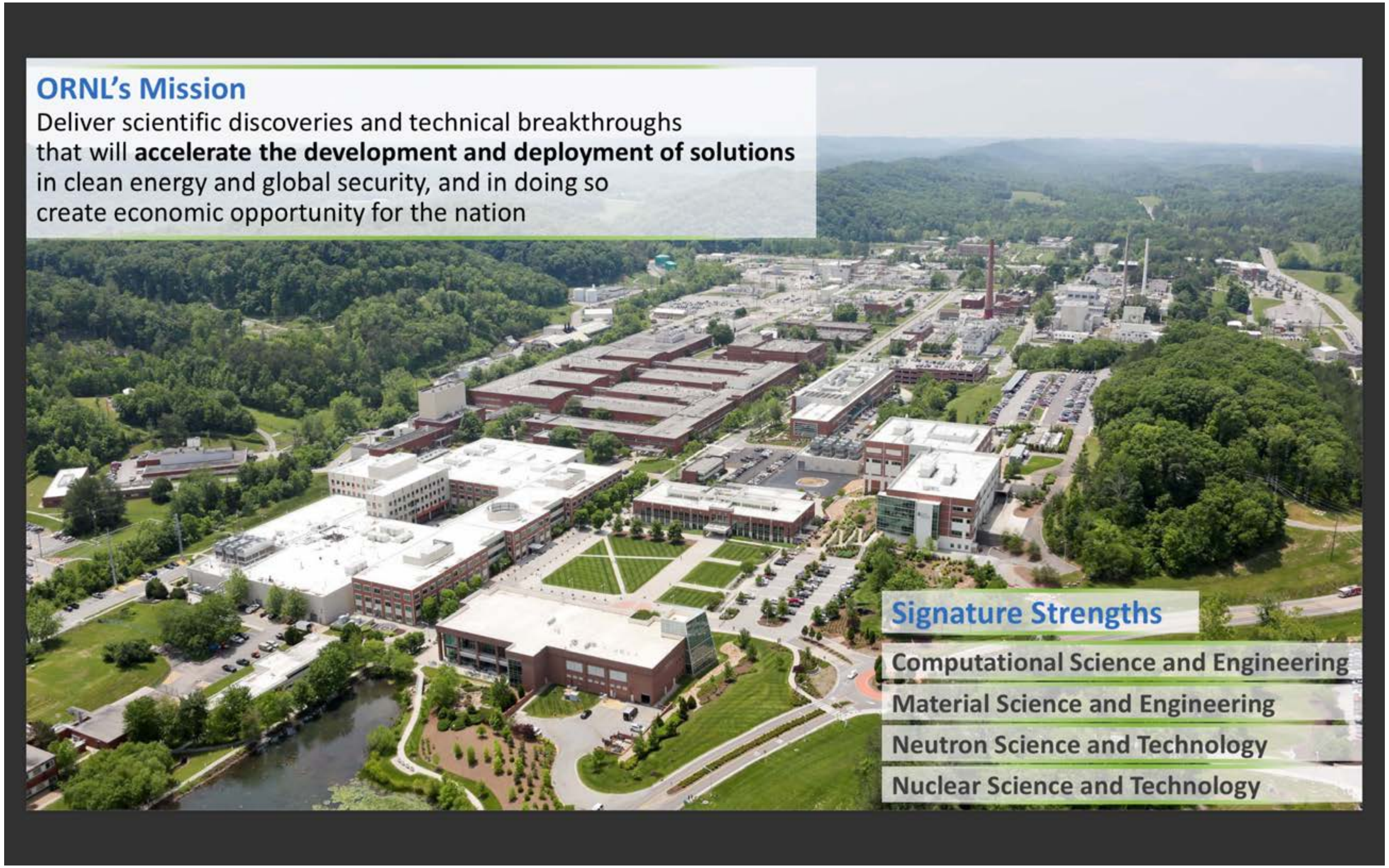
ORNL is managed by UT-Battelle, LLC for the US Department of Energy

Oak Ridge National Laboratory



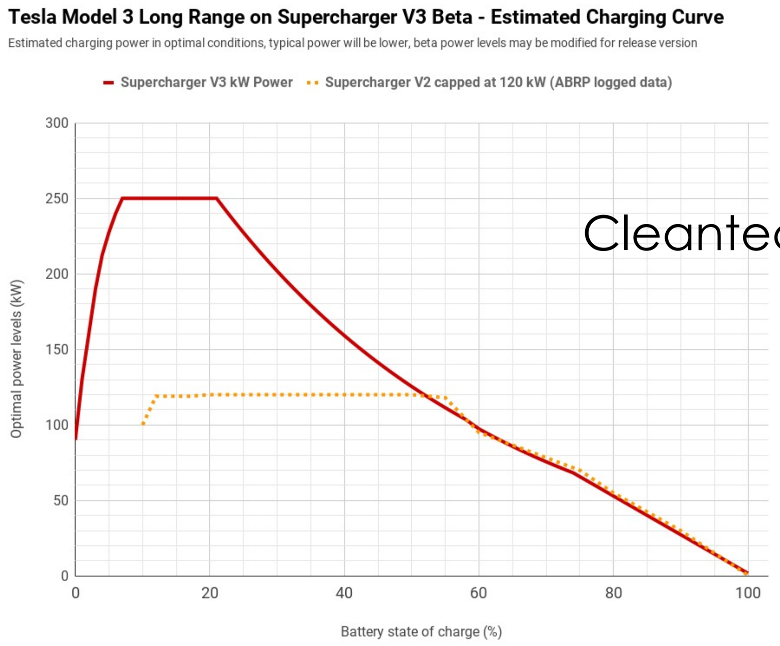
- **DOE national laboratory (one of 17)**
- **>$1.65B budget**
- **~5,000 employees**
- **~3,000 research guests annually**

Common Chargers today

- Level 1 – 110V ~1.5kW: on board. No Power Electronics.
- Level 2 – 220V 3.3kW, 6.6kW, 11kW: on board. No Power Electronics
- DC Quick Chargers – 50kW
- Tesla – 150-250kW
- Electrify America – up to 350kW

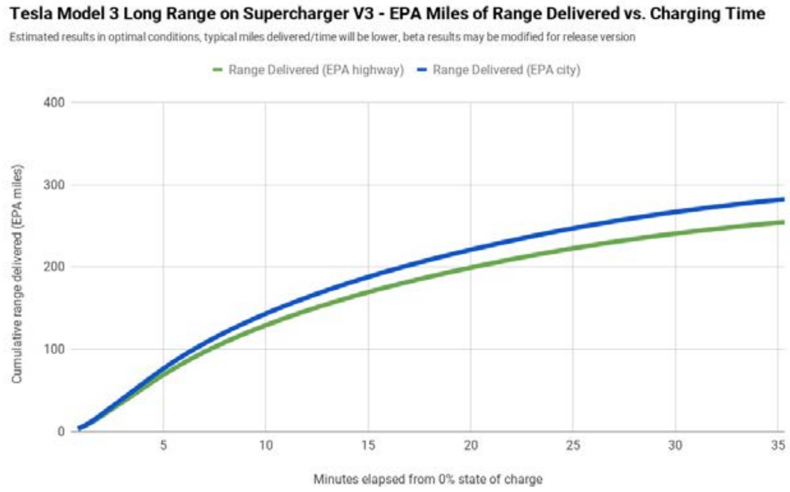
Range Anxiety

- EV range is increasing - >300 miles
- Range anxiety still exists
- More fast charging stations needed – 5-minute charging?



Cleantechnica.com

355V battery
High currents



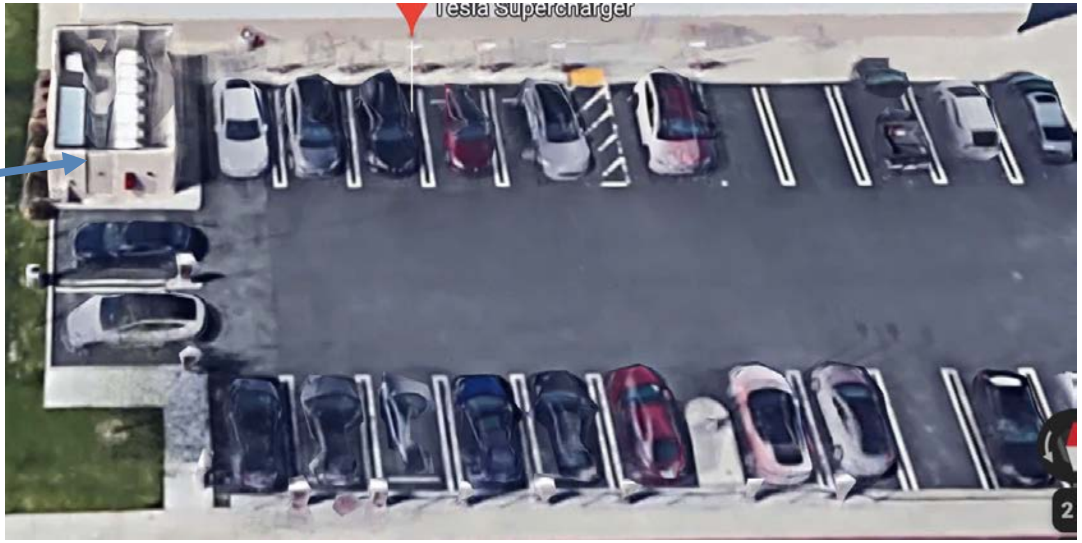
5 mins – 75 mile range

Extreme Fast Charging (XFC)

- 350kW+ at 800V+ → the numbers will increase in the future
- 800V battery. 800V electric drive.
- Medium Voltage Connection
  - Transformer
  - Solid-state transformer

Tesla.com

Transformer and PE

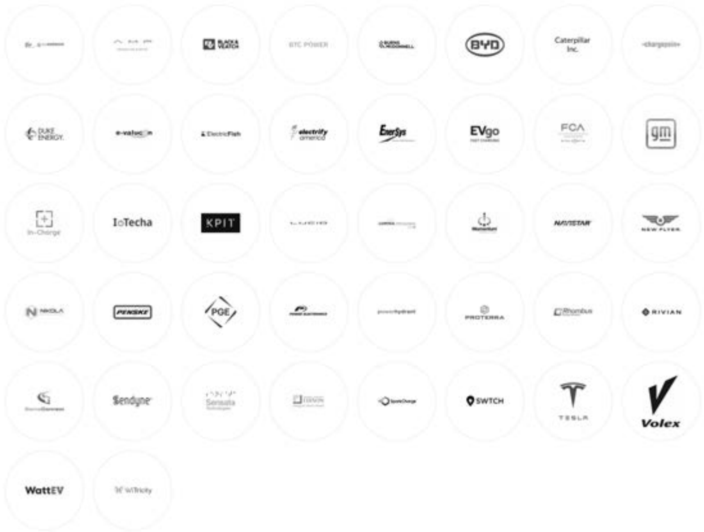


Google Maps
Anaheim Superchargers

CharIN

https://www.charin.global

- The standard focuses on Class 6, 7, & 8 commercial vehicles, but could easily be used for buses, aircrafts, or other large battery electric vehicles (BEVs) with huge battery packs and ability to accept a >1MW charge rate.



- Single conductive plug
- Max 1.250 volt & 3.000 ampere (DC)
- PLC + ISO/IEC 15118
- Touch Safe (UL2251)
- On-handle software-interpreted override switch
- Adheres to OSHA & ADA (& local equivalent) standards
- FCC Class A EMI (& local equivalent)
- Located on left side of the vehicle, roughly hip height
- Capable of being automated
- UL (NRTL) certified
- Cyber-Secure
- V2X (bi-directional)

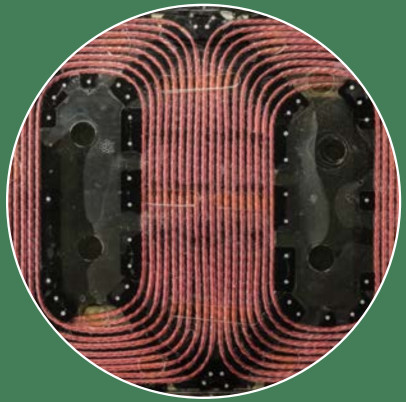
https://www.charin.global/technology/mcs/

Wired and Wireless Chargers

ORNL Wireless Charging animation
https://www.youtube.com/watch?v=Gw6XtzEOlyI

ORNL Wireless Charging Activities

Wireless power transfer (WPT) work at ORNL started in 2008



120kW WPT (2018)

- 97% efficiency @ 6-inch gap
- Fast charging for LD EV

300kW XFC (2021)

- ORNL polyphase coil technology
- Extreme fast charging for LD/MD

High Power DWPT (2021)

- Partners: Hyundai and ACM
- 200 kW @ 55 mph+

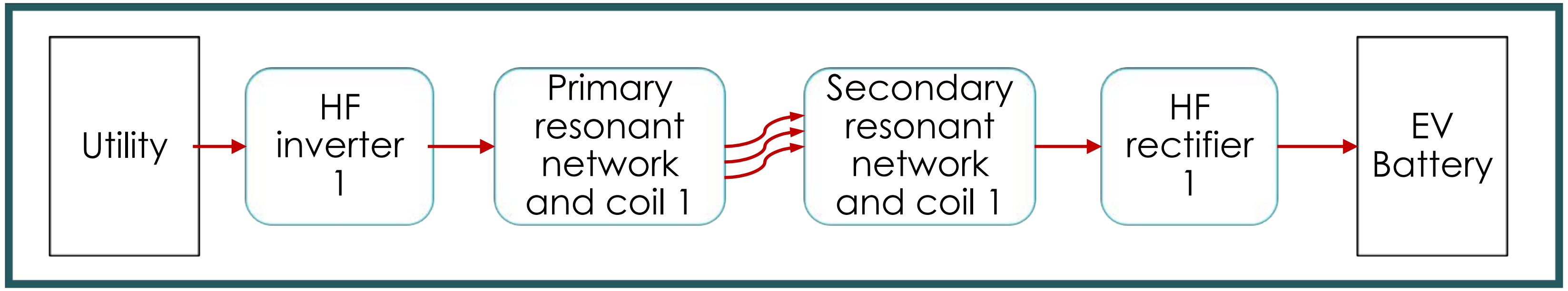
20 kW Bi-directional WPT (2020)

- Partner: UPS
- 20 kW Grid-to-EV
- 6.6 kW EV-to-grid

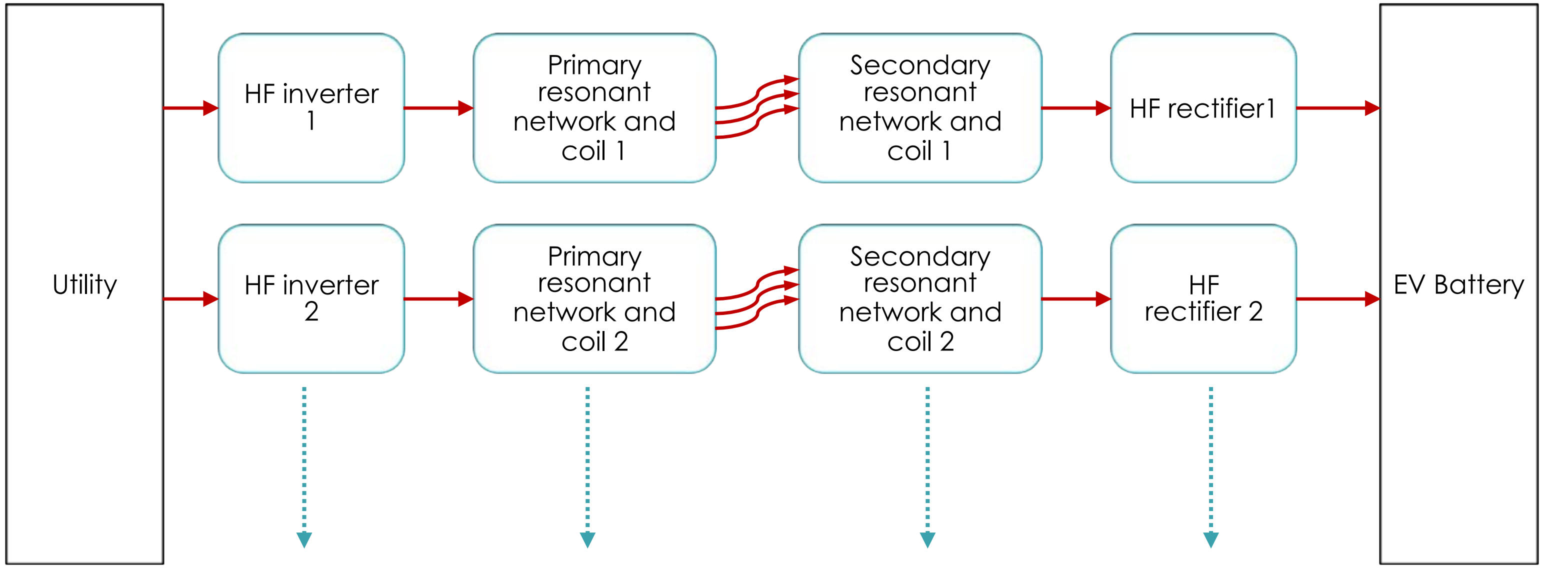
Wireless EV Charging to Enable Electrified Transportation

ORNL's Wireless Power Transfer Approach

Single line power flow



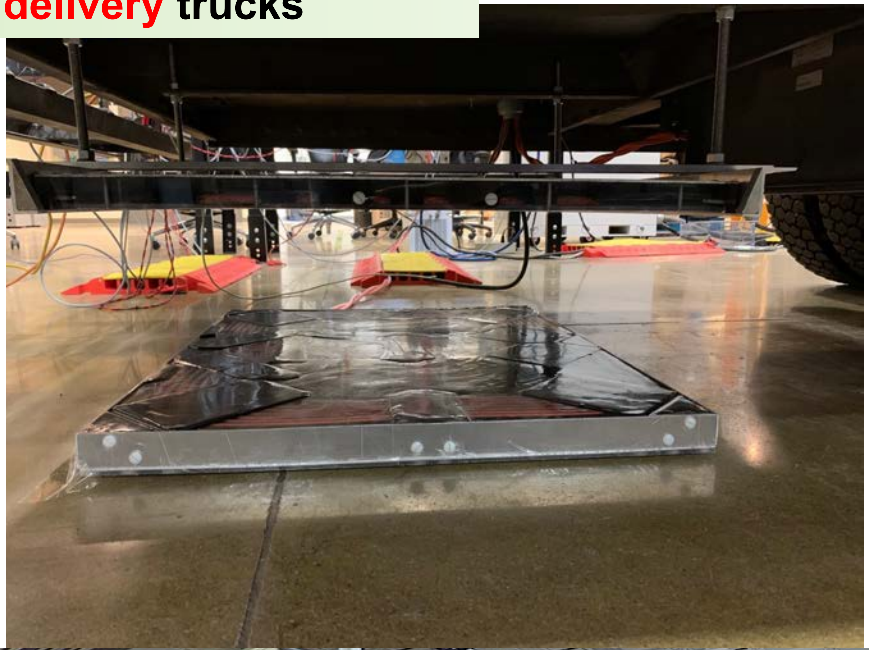
Not a paralleled approach



Bi-Directional Wireless Charging – UPS Demonstration

Developing high-power, bidirectional wireless charging for electric delivery trucks

- **Target:** Design, model, simulate, build, integrate, and test a bi-directional wireless power transfer (BWPT) system for medium duty delivery trucks
  - A vehicle integrated ≥20 kW wireless power transfer system with bi-directional operation
  - High-efficiency with a nominal magnetic airgap of **11 inches**
  - Vehicle-to-grid mode wireless power transfer to building or grid loads (grid support or ancillary services)



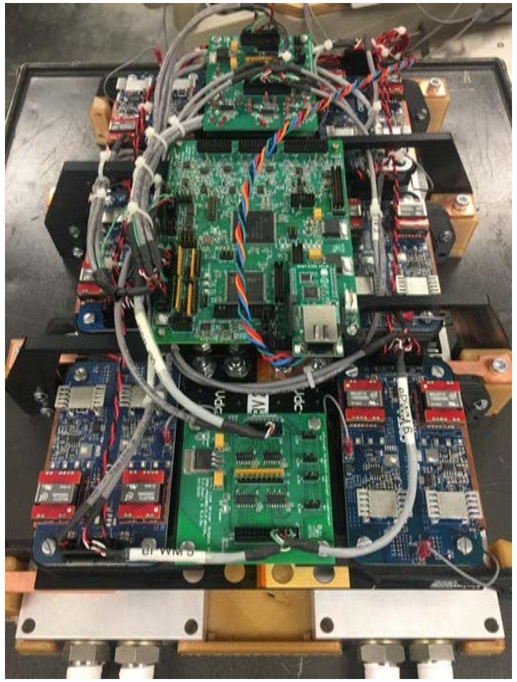
- **Demonstrated:**
  - **Grid-to-Vehicle:** 20.36 kW at 93% efficiency
  - **Vehicle-to-Grid:** 12.8 kW to 480V power grid at 89.1% efficiency

- Vehicle and charging system will be deployed at a UPS facility in Roswell, GA for 6 months of data collection and evaluation

Wireless Extreme Fast Charging (XFC): 270 kW

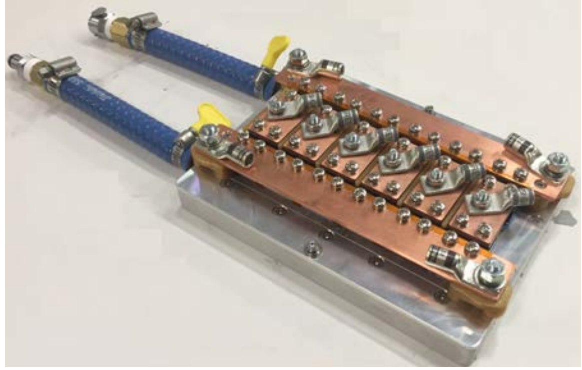
100kW and 270kW power transfer (50% increase in SOC in 10 minutes) with 90% efficiency (end-to-end)

- Partnering with Hyundai-Kia North America Technical Center (HATCI) and VW Innovation Hub
- Targeting 3C charge rates
- Hyundai KONA EV (100 kW power transfer) and Porsche Taycan (270 kW power transfer) research vehicles
- Achieved 0.905 and 1.53 MW/m^2 surface power density with 100 kW and 270 kW receivers
- Open-ended winding dual three-phase inverter design for the primary side,
  - 500 kW design, 9.16 liters, ~55 kW/liter specific power



Primary-side high-frequency inverter – 500 kW peak power

Laboratory development of the 100-kW receiver for Kona EV (375 mm diameter)



100-kW HF open-ended winding rectifier for Kona EV

Laboratory development of the 100/300-kW interoperable ground coupler (750 mm diameter)

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High Power and Dynamic Wireless Charging of Electric Vehicles

Relevance

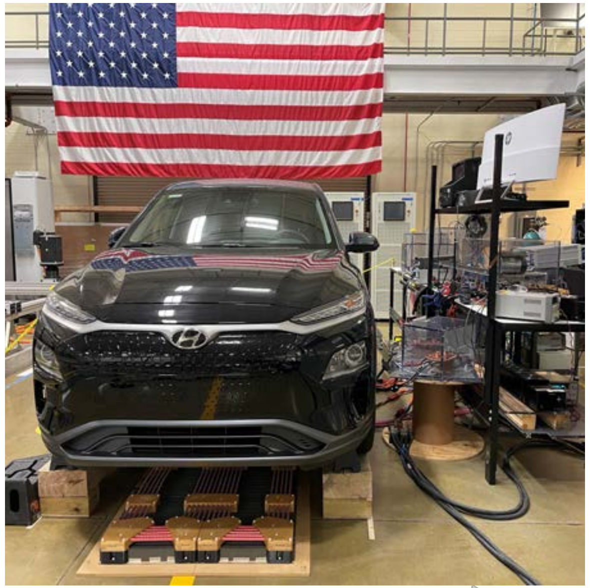
- Dynamic EV charging can significantly alleviate range anxiety and concurrently reduce the on-board battery requirement (weight and cost reduction)

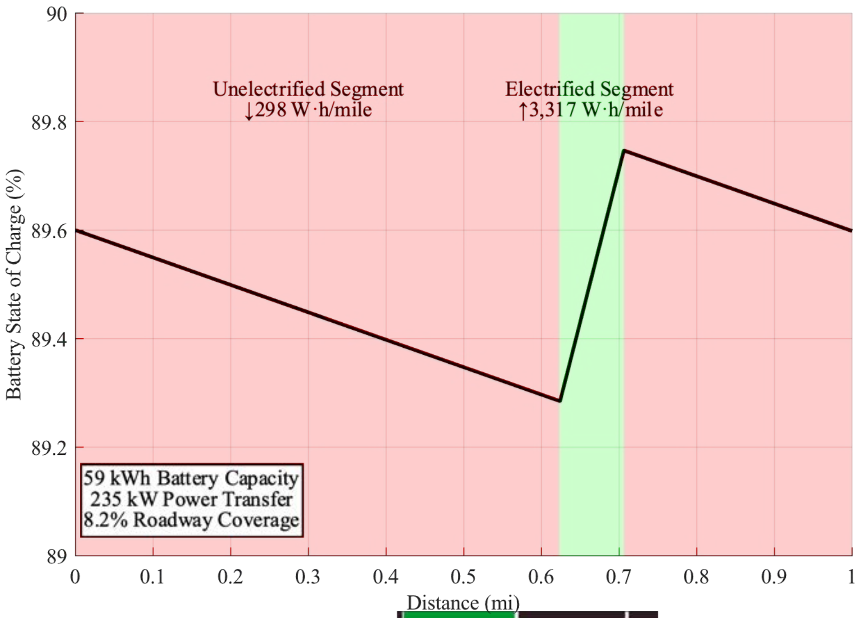
Objective

- Design, develop, build, and validate vehicle integrated **200 kW** dynamic wireless electric vehicle (EV) charging
- Charge sustaining mode of operation
- **8.2%** roadway coverage

Status

- **186 kW, 93.3%** efficient, in-lab wireless power transfer validated;
- Field demonstration planned for **Spring 2022** at American Center for Mobility in Michigan





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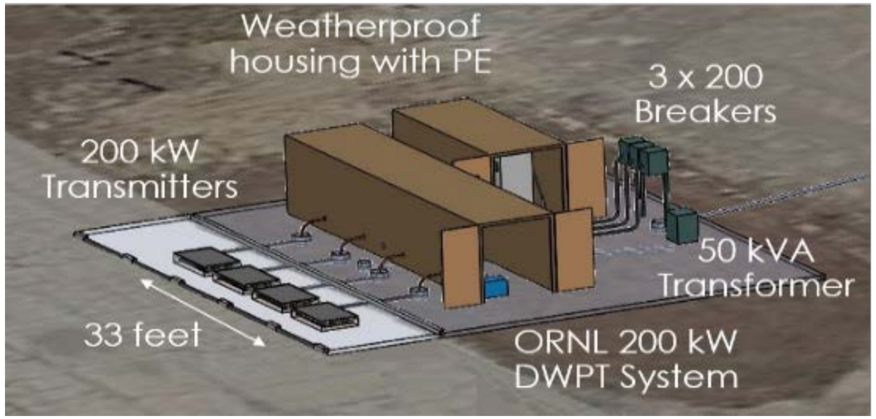
Integrating Dynamic Wireless Power Transfer Systems in Roadways

Validate technologies and solutions to transition high-power dynamic wireless (HPDW) charging of electric vehicles (EVs) from an early-stage proof-of-concept system to a practical roadway-integrated dynamic wireless power transfer (DWPT) system suitable for deployment at-scale.

- Characterize HPDW charging system both **in the lab and on the road at ACM.**
- Analyze the power transfer characteristics including
  - efficiency, power & energy profiles,
  - misalignment tolerance,
  - thermal profiles,
  - emissions and shielding,
  - impact of different vehicle classes,
  - impact on the grid,
  - use cases,
  - scalability, and
  - **environmental factors**.

Laboratory development of 200 kW, 20 MPH dynamic wireless charging emulator



ACM deployment of 200 kW DWPT system with 4 roadway integrated transmitters and roadside equipment

- Identify and develop solutions to challenges of **roadway integration of high power DWPT** components and different **roadway materials**.
- Perform system-level cost study and analysis of deployable scenarios for integration of DWPT system for **light-, medium-, and heavy-duty EVs**

Failure Modes and Effects Analysis for Wireless and Extreme Fast Charging

- NHTSA funded FMEA report
- Review of wired and wires charging technologies in a 230-page report along with conceptual FMEA for different charging levels
- 3 different charging levels (3.3-22kW, 22-120kW, 120-350kW) with wired and wireless charging were considered for conceptual FMEA study

U.S. Department of Transportation
National Highway Traffic Safety Administration

NHTSA

DOT HS 813 137 August 2021

Failure Modes and Effects Analysis for Wireless and Extreme Fast Charging

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https://rosap.ntl.bts.gov/view/dot/57152

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Questions