High Power and Dynamic Wireless Charging of Electric Vehicles (EVs)

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2021 U.S DOE Vehicle Technologies Office Annual Merit Review
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ORNL is managed by UT-Battelle, LLC
for the US Department of Energy

Overview

Timeline
- Start Date: Oct 2019
- End Date: March 2022
- 78% Complete

Barriers
- **Power Density**: Developing a compact vehicle coil and power electronics assembly which can receive 200 kW power dynamically
- **Efficiency**: Achieving 90 % efficiency in a vehicle integrated dynamic wireless charging system
- **Controllability:** Identifying and implementing a control and communication system which can perform wide range power regulation without compromising efficiency or power density

Budget
DOE Total Share: $11,275K

FY $K	ORNL	INL	NREL
FY19	$3,075	$675	$250
FY20	$2,900	$875	$250
FY21	$2,900	$825	$250
Total	$8,875	$2,325	$750

Partners

National Laboratories

Oak Ridge National Laboratory: Veda Galigekere, Lincoln Xue, Rong Zeng, Gui-Jia Su, Omer Onar, Emre Gurpinar, Shajjad Chowdhury, Randy Wiles, Jon Wilkins, Larry Seiber, Cliff White, and Burak Ozpineci

Idaho National Laboratory: Richard Carlson and Bo Zhang

NREL Transforming ENERGY: Ahmed Mohamed, Andrew Meintz, and Cory Sigler

External Partners

Hyundai Motor Group: Hyundai Kia American Technical Center

American Center for Mobility (Connected. Automated. Validated.): American Center for Mobility

Virginia Tech Transportation Institute: Virginia Tech Transportation Institute

Any proposed future work is subject to change based on funding levels

Project Objectives and Relevance

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

Overall Objective: Design, develop, build, and validate vehicle integrated 200 kW dynamic wireless electric vehicle (EV) charging

- Conduct a high-level cost study → Feasibility targets for light duty (LD) vehicles
- Perform gap analysis of SOA systems → R & D required to realize a viable dynamic wireless power transfer (DWPT) solution
- Develop 200 kW DWPT and validate in a real-world application scenario:
  - Vehicle integrated validation at 55 mph
  - Mitigation of vehicle body impact on power transfer and achieving minimal power oscillation
  - Development of roadway embeddable coil structure

FY 2021 Objectives:

- Complete laboratory validation of 200 kW dynamic charging system
- Conduct EM-field safety analysis and validation, and develop data acquisition system for high power DWPT system and support on-track evaluation of 200 kW dynamic charging system
- Explore the impact of DWPT infrastructure on primary roadways that was optimized for LD vehicles on the driving performance of HD (Class 8) EV travel

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FY21 Milestones

Milestones

Lab	Date	Milestones	Status
ORNL	12/31/2020	Validate 200 kW power transfer capability of primary side power electronics, WPT coil, and resonant network.	Completed
ORNL	9/30/2021	Validate functionality of stationary high-power wireless charging with coil embedded on the vehicle.	In progress
INL	3/31/2021	Complete data acquisition system required for dWPT testing and evaluation	Completed
INL	9/31/2021	Assist with the evaluation and demonstration of ORNL DWPT system during dynamic operation	In progress
NREL	3/31/2021	Complete development of HD vehicle travel data	Completed
NREL	9/30/2021	Complete test cases for HD vehicles with different designs, allocations and EV models	In progress

Go/No-Go Decision Point

Lab	Date	Go/No-Go Decision	Status
ORNL	06/30/2020	If standalone test of 200 kW power electronics is successful, proceed with integration of PE and WPT coils	Go

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FY22 Milestones and Go/No-Go Decision

Milestones

Lab	Date	Milestones	Status
ORNL	12/31/2021	Validate functionality of the high-power dynamic wireless charging system.	Planned
ORNL	3/31/2022	Evaluate performance of dynamic wireless EV charging system based on performance.	Planned

Go/No-Go Decision Point

Lab	Date	Go/No-Go Decision	Status
ORNL	12/30/2021	If basic functionality of robust dynamic wireless EV charging is proven at low-speed tests, proceed with performance evaluation.	Planned

Any proposed future work is subject to change based on funding levels

Overall Approach

Goal: Validate a vehicle integrated dynamic wireless EV charging system with parameters which enable it to be economically viable in real world conditions

FY19: Determine Technical Targets for Feasibility

- High level cost and feasibility studies
- Review of SOA systems
- Technology gap analysis
- Analytical and simulation studies

FY20: Validate 200 kW DWPT System in Laboratory

- Power electronics and controls
- DWPT coils and resonant network
- EMI shielding
- Data acquisition

FY21: Validate 200 kW DWPT System in laboratory

- Vehicle body interference
- Control and communication system

FY22: Validate 200 kW Vehicle Integrated DWPT system in real world

- Real-world validation
- Performance assessment for use cases

Any proposed future work is subject to change based on funding levels

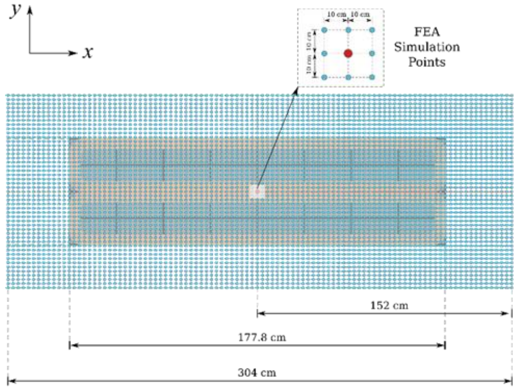
Approach: Proof of Concept Validation

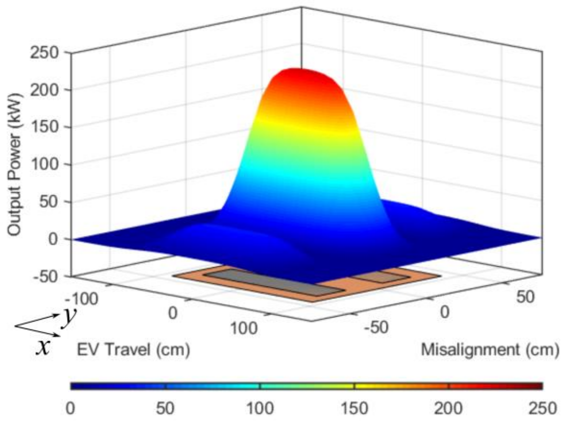
FY 19:
Analytical and simulation studies

FY 20:
Hardware design and development

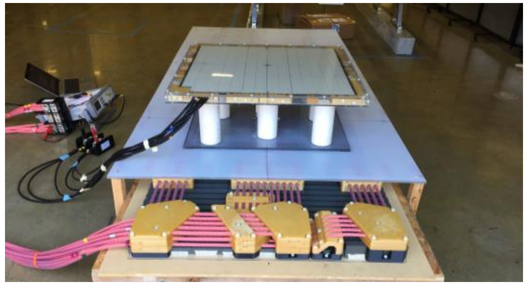
FY21:
Laboratory validation of 200 kW DWPT

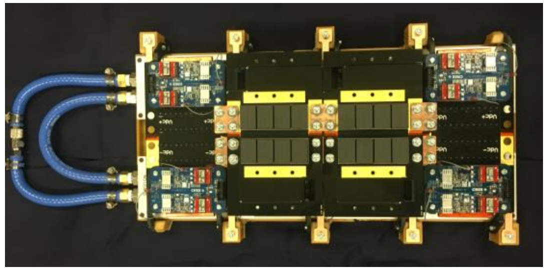
FY: 22
Real world validation of 200 kW DWPT





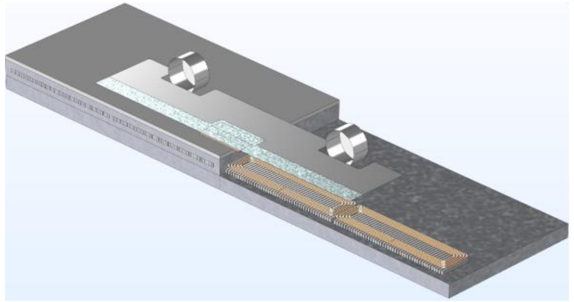
Detailed simulation and analytical design-oriented study





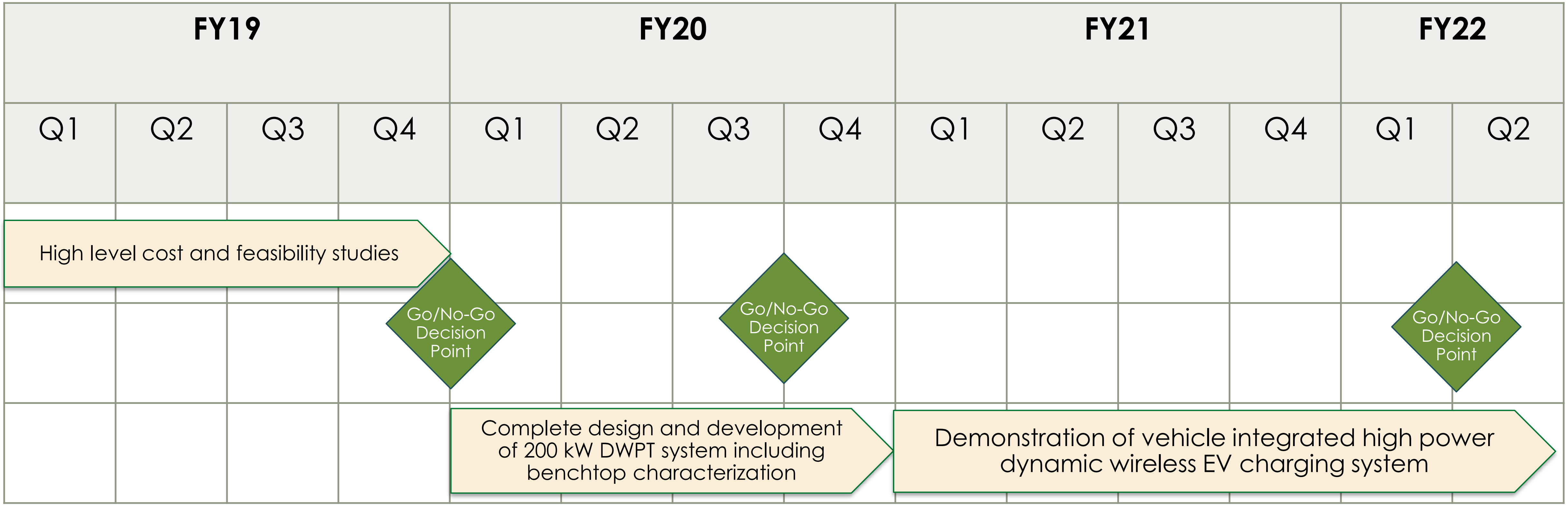
Hardware development and benchtop validation

Laboratory Validation of 200 kW DWPT using dynamic inductive charging emulator



Planned 200 kW 55 mph DWPT validation at ACM

Overall Project Timeline



FY20 Go/No-Go Decision Point: If standalone test of 200 kW power electronics is successful, proceed with integration of PE and WPT coils

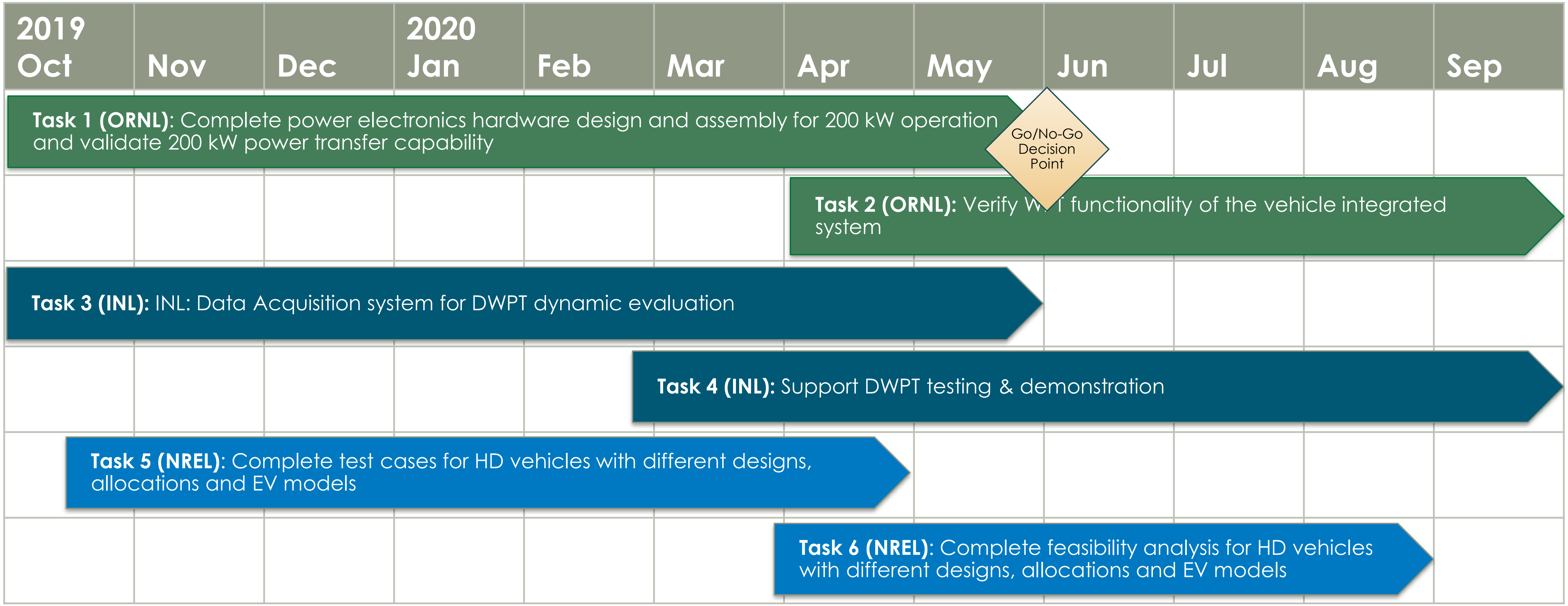
Outcome: Proceed with integration of PE and WPT coils

FY22 Go/No-Go Decision Point: If basic functionality of robust dynamic wireless EV charging is proven at low-speed tests, proceed with performance evaluation.

Outcome: In progress

Any proposed future work is subject to change based on funding levels

FY21 Timeline



FY20 Go/No-Go Decision Point: If standalone test of 200 kW power electronics is successful, proceed with integration of PE and WPT coils

Outcome: Proceed with integration of PE and WPT coils

Any proposed future work is subject to change based on funding levels

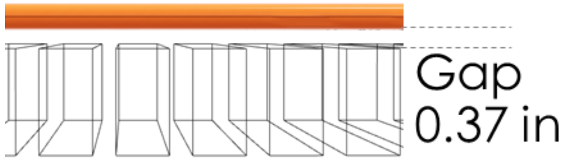
Technical Accomplishments FY20: Completed Benchtop Characterization of 200 kW DWPT Couplers

Goal: To design DWPT couplers to achieve the mutual inductance target for 200 kW power transfer
Challenge: High current density exasperates thermal challenges, and the required long lead length translates to significant additional inductance

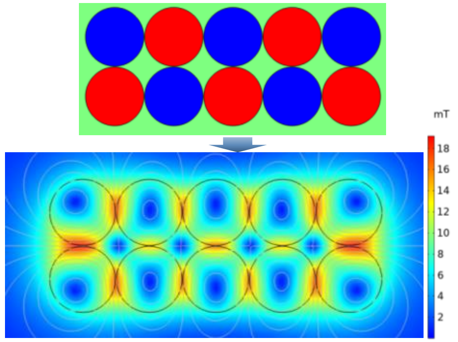
- Verified 200 kW power transfer capability
- Minimized lead-inductance by introducing wire-interleaving
- Optimized core-geometry to remove potential thermal hotspot
- Optimized ferrite and winding spacing which led to further increase in mutual inductance

Mutual inductance target for 200 kW DWPT at 9.3" gap – 1.7μH

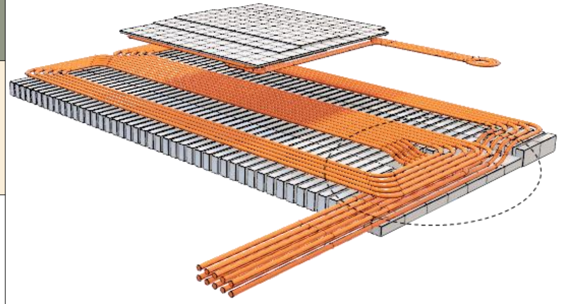
	Tx self inductance (μH)	Tx self inductance with interleaving (μH)	Rx self inductance (μH)	Mutual inductance (μH)
Preliminary benchtop measurement	8.2	7.1	22.79	1.67
FEA results based on proposed modifications	NA	7.6		1.96

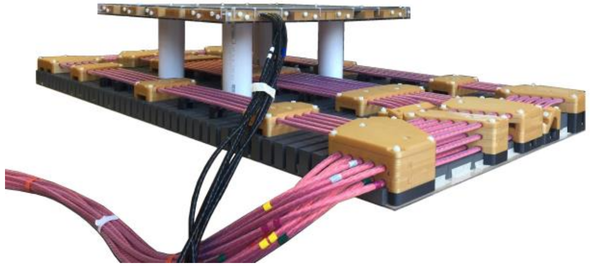


Optimized coil and ferrite spacing



Interleaving minimizes lead-inductance



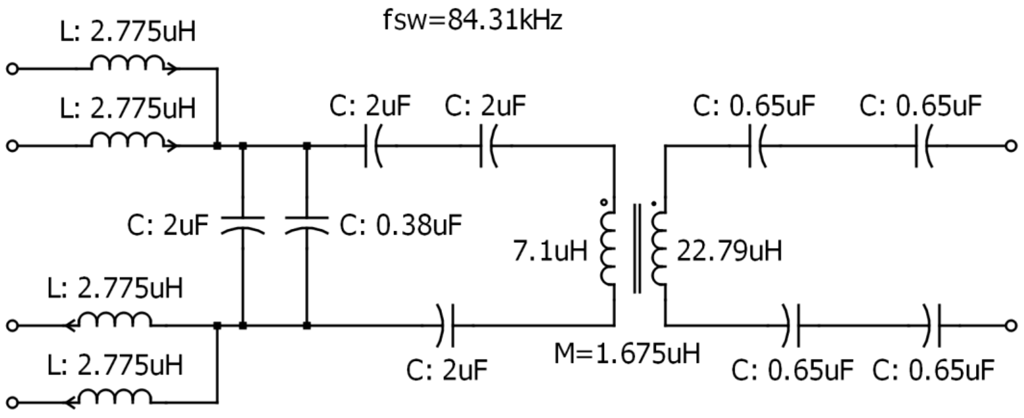


FEA coil and core model and prototype

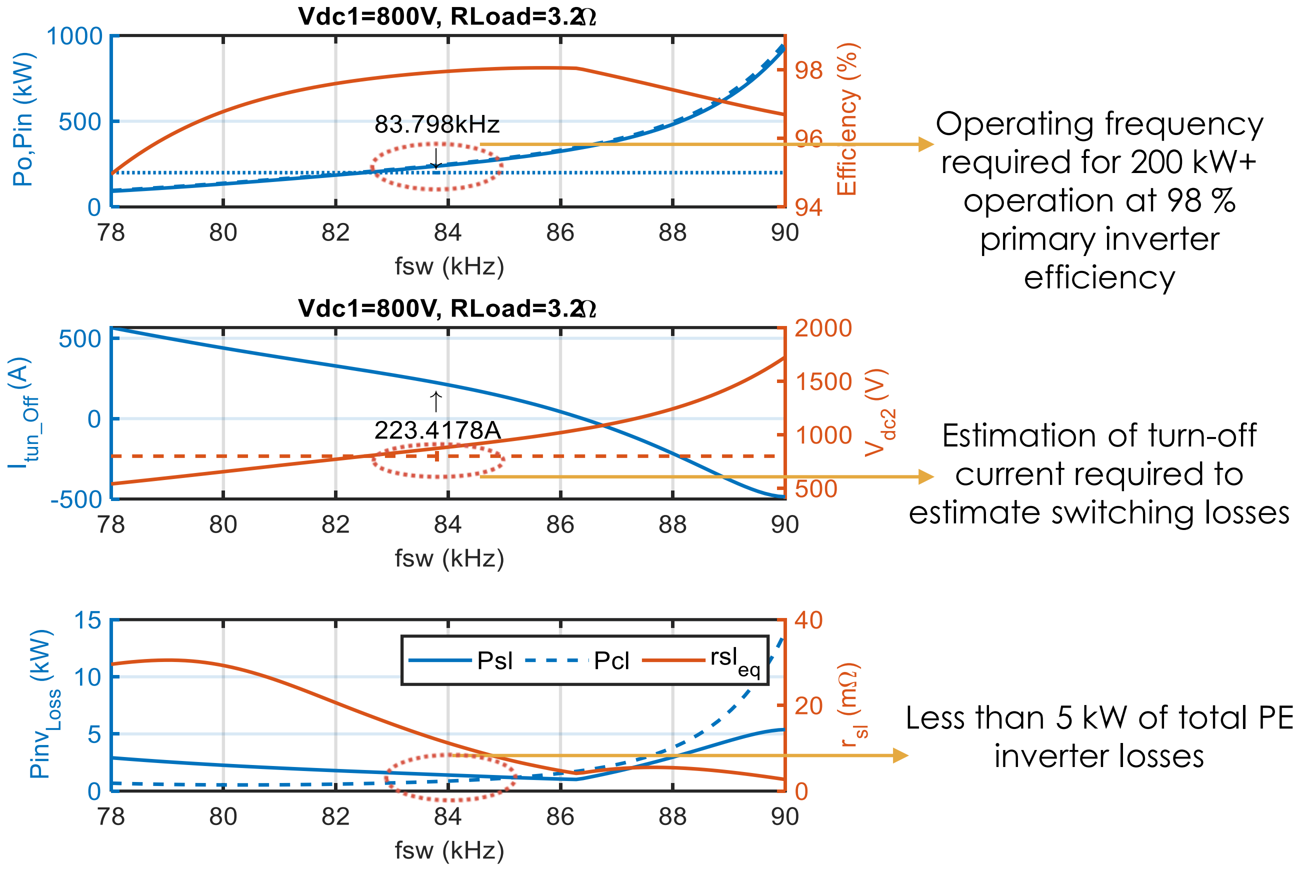
Technical Accomplishments FY20: Completed Resonant Network Analysis for 200 kW DWPT Operation

Goal: Design resonant network to enable efficient and controllable 200 kW DWPT
Challenge: Dynamic charging offers wide range of coupling variation and achieving soft-switching (for efficiency and safety) is critical

- Completed analysis and design of primary side LCC and secondary side series tuned 200 kW DWPT
- Design targets
  - 200 kW power transfer capability at 800 V
  - Reduced switching and conduction losses
  - Component values that can be practically realized



Primary side LCC and secondary side series resonant network for 200 kW DWPT



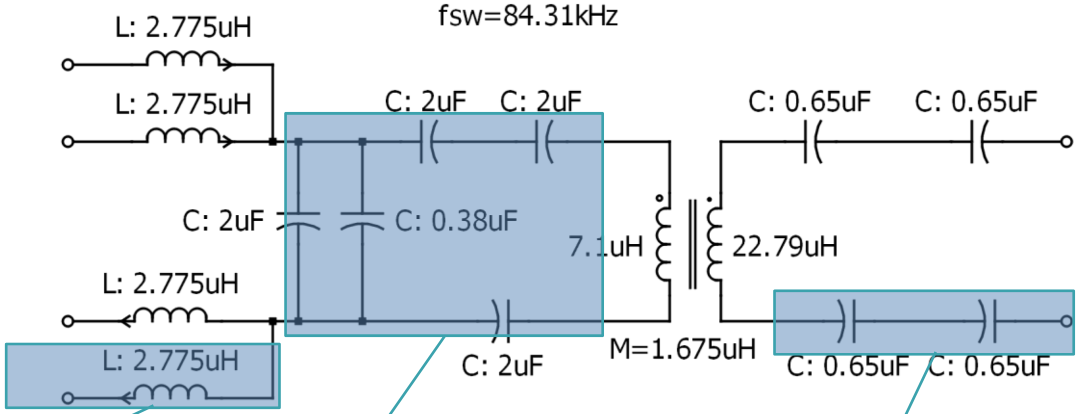
Analytical calculation of output power and losses for the designed resonant network configuration

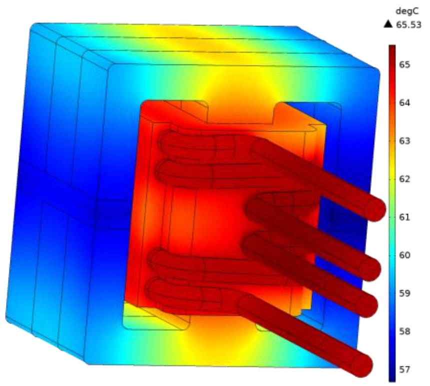
Technical Accomplishments FY21: Designed and Built Optimized Resonant Network for 200 kW DWPT

Goal: To design compact capacitor bank that meets current, voltage, and thermal requirements of 200 kW power transfer
Challenge: High voltage (~4kV), high current (~750A), and high frequency (~85 kHz) operation leads to power density and efficiency challenges

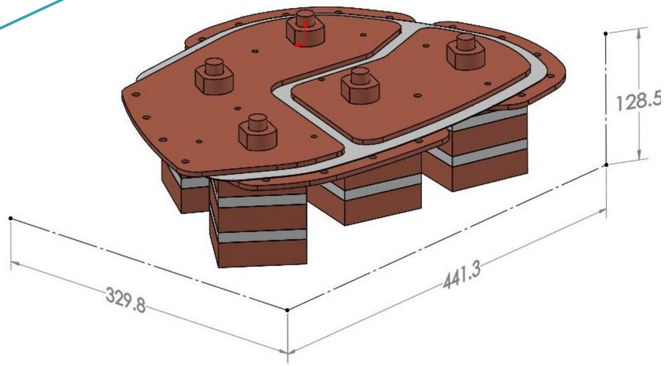
Identified optimized capacitance, busbar design, and cooling method for the high-power high-frequency capacitor bank

- Modified capacitances to compensate additional lead-inductance
- Optimized coolant and cooling channel to efficiently meet the thermal limit of capacitor
- Identified potential compact capacitor bank design that will reduce the size by ~40%
- Designed and built optimized resonant inductor with less than 25 Dec C.

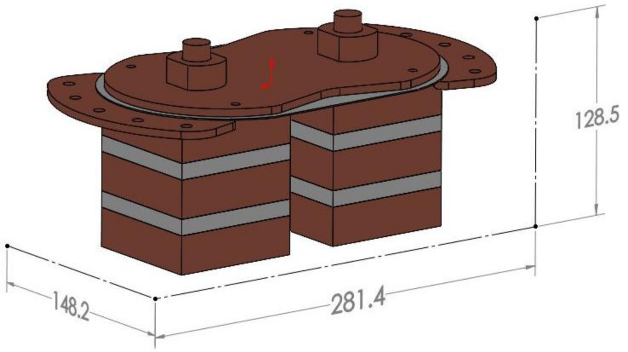




Primary-side resonant inductor



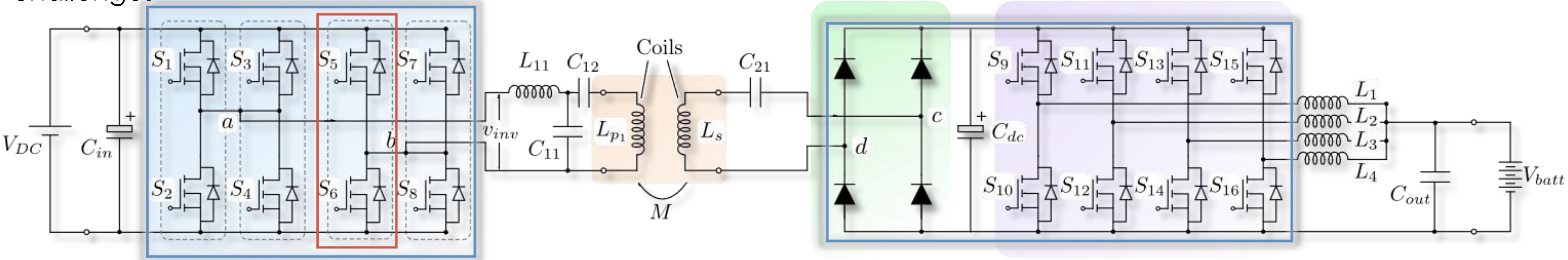
Primary-side capacitor bank

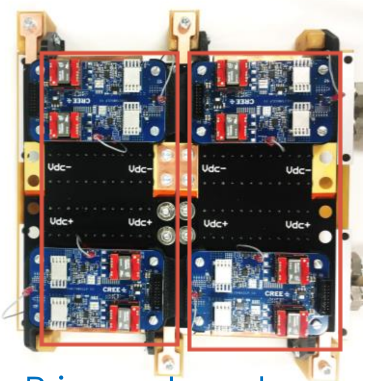


Secondary-side (half) capacitor bank

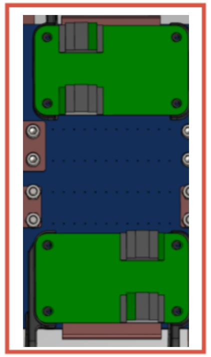
Technical Accomplishments FY21: Completed Development of Primary and Secondary Power Electronics

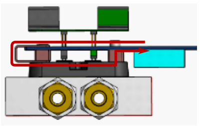
Goal: To develop efficient, compact, and reliable power electronics for high power operation
Challenge: Each power electronic stage has high frequency, high-voltage, and high current related design challenges

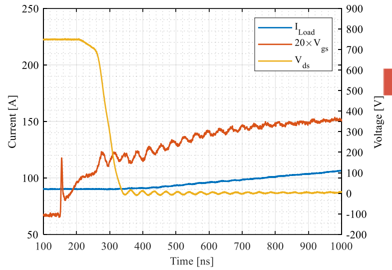




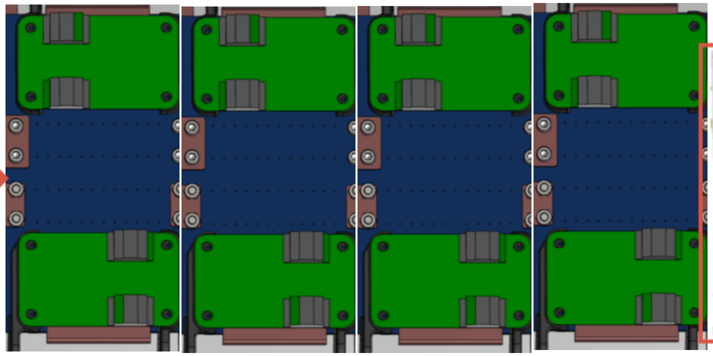
Primary Inverter:
2x building blocks



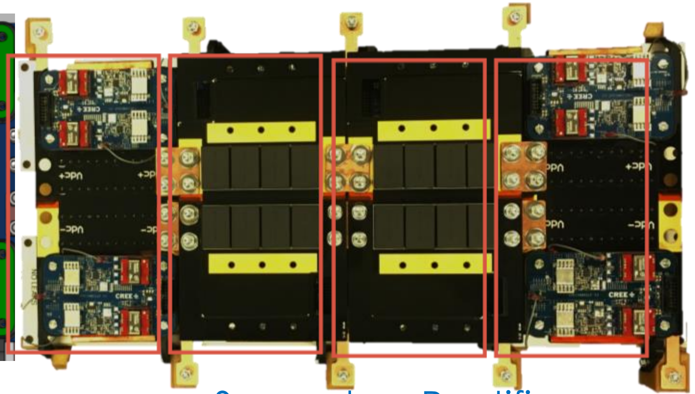




Compact, low noise building block with reliable and efficient switching



Modular up-scaling by horizontal cascading

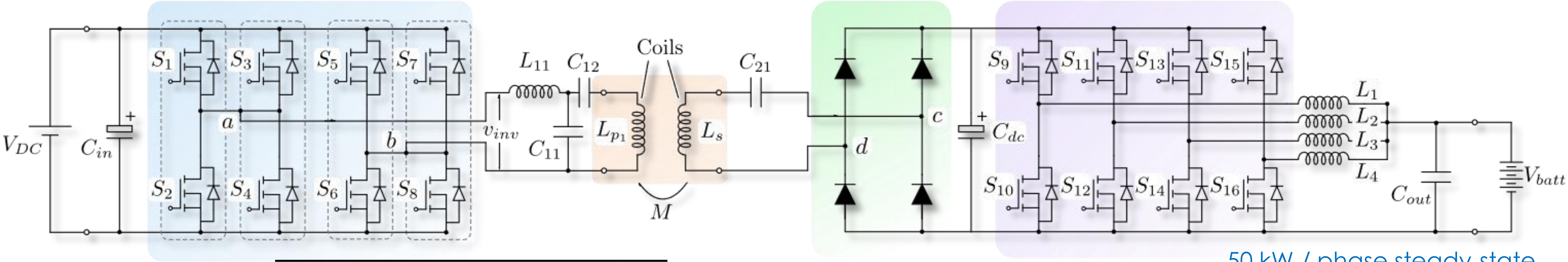


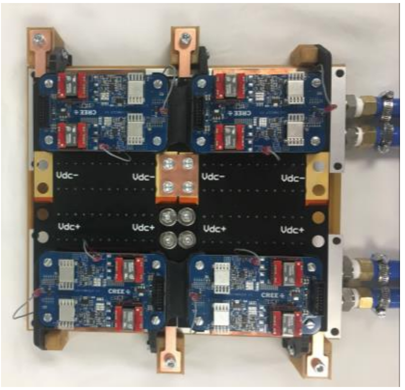
Secondary Rectifier and DC/DC:
4x building blocks

Modular approach enables high performance, fast prototyping, and reliable operation

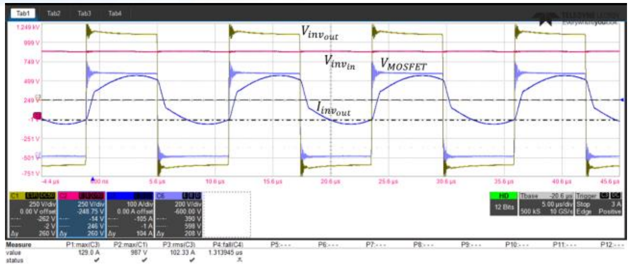
Technical Accomplishments FY21: Completed Validation of Primary and Secondary Power Electronics

Goal: Validate the operation of the power electronics in WPT setup

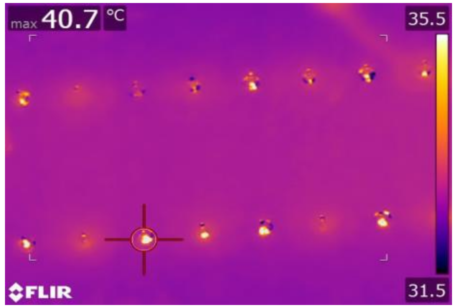




Primary Inverter

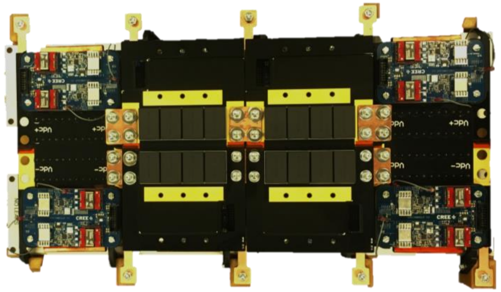


85 kW test waveforms



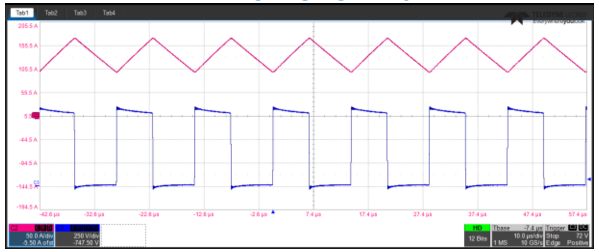
Thermal image of the PCB bus bar

- Tested inverter @ 85 kW, 800 V, 85 kHz, achieved 98.6% efficiency
- Low 41 °C high-current PCB temperature after 30 minutes continuous operation

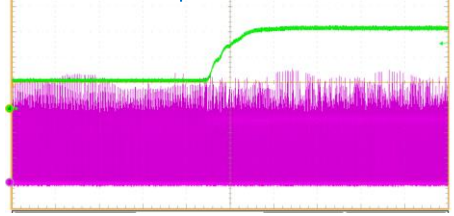


Secondary Rectifier and DC-DC converter

50 kW / phase steady-state waveforms

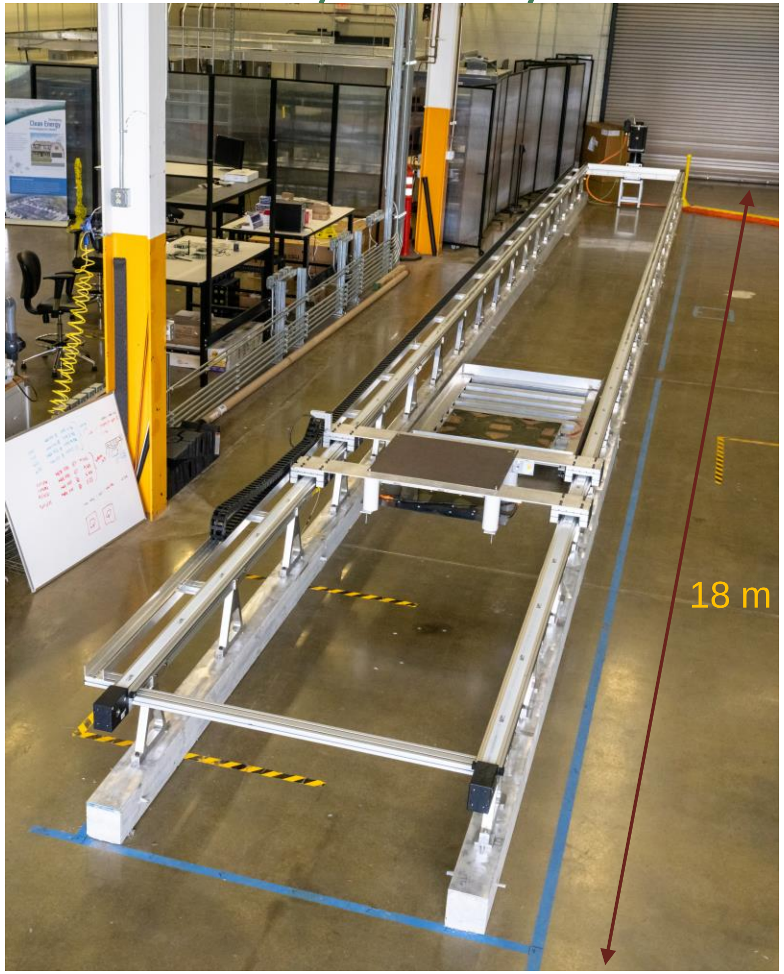


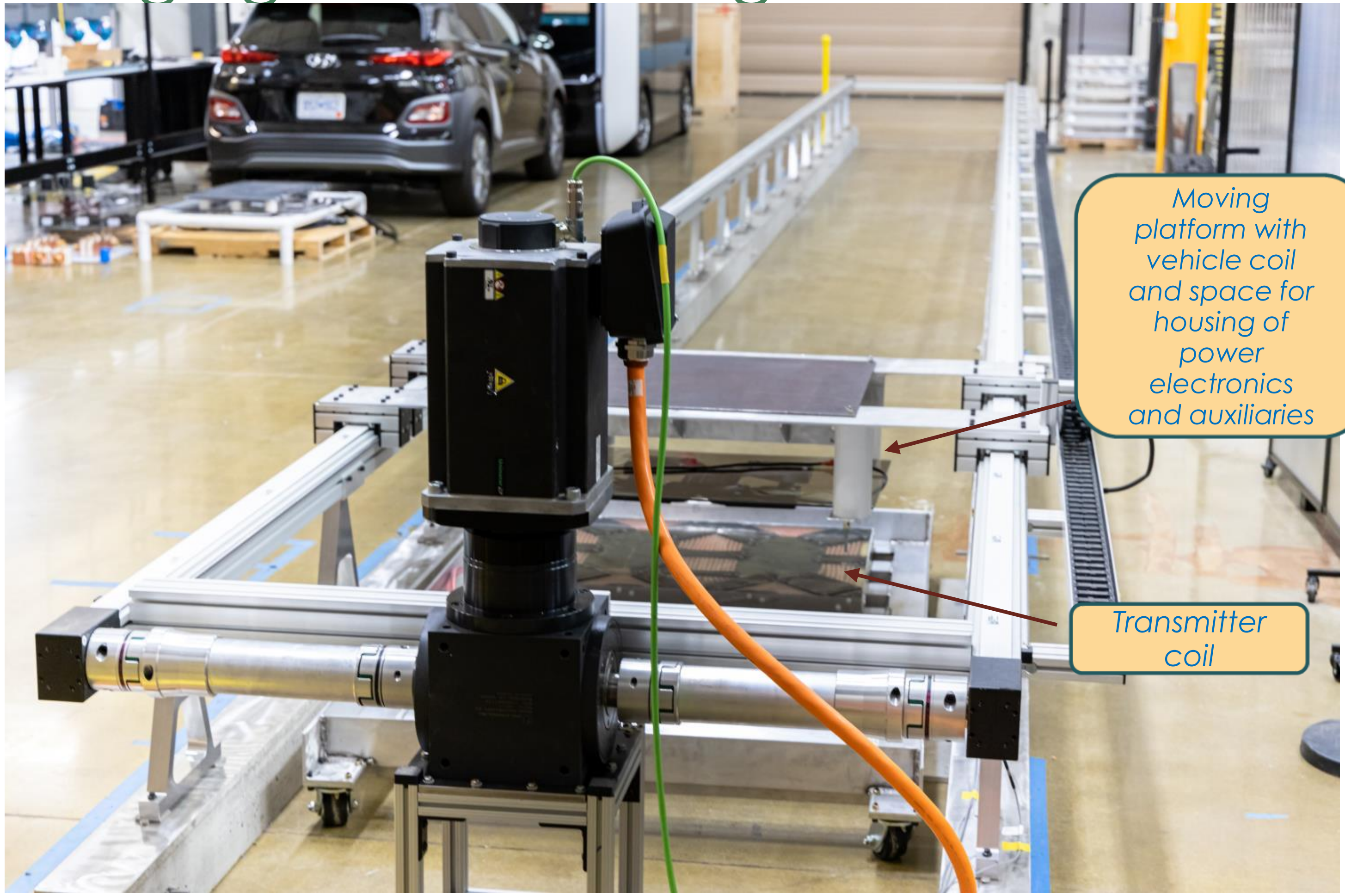
Closed-loop control waveforms



- Tested power stage @ 50kW/phase, 800 V, 70 kHz, achieved 98.3% efficiency
- Developed fast hardware protection with 4μs response time
- Verified closed-loop regulation at reduced power

Technical Accomplishments FY21: Installed and Verified Functionality of Dynamic Charging Evaluation Rig

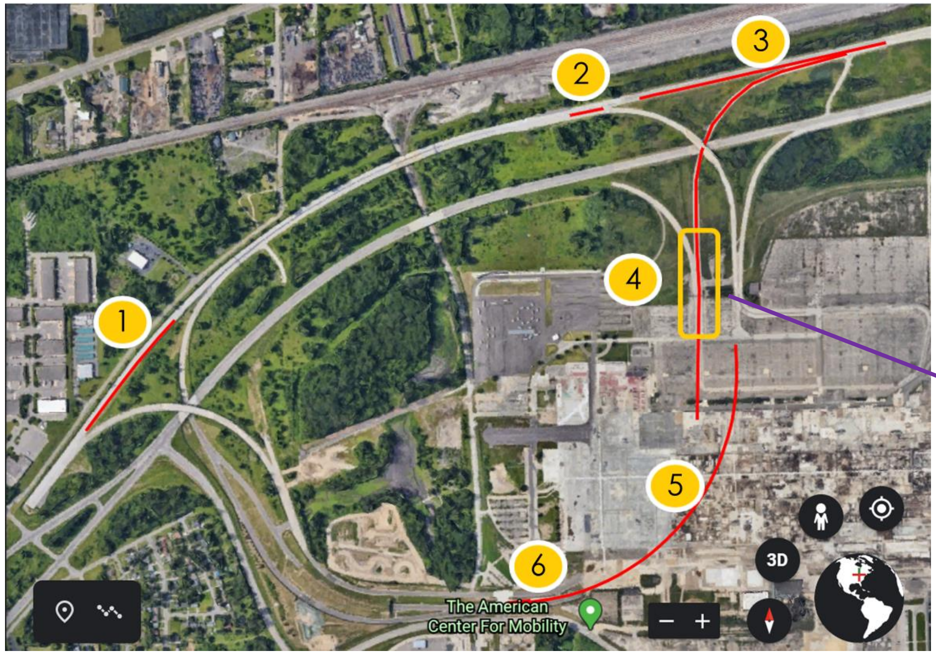


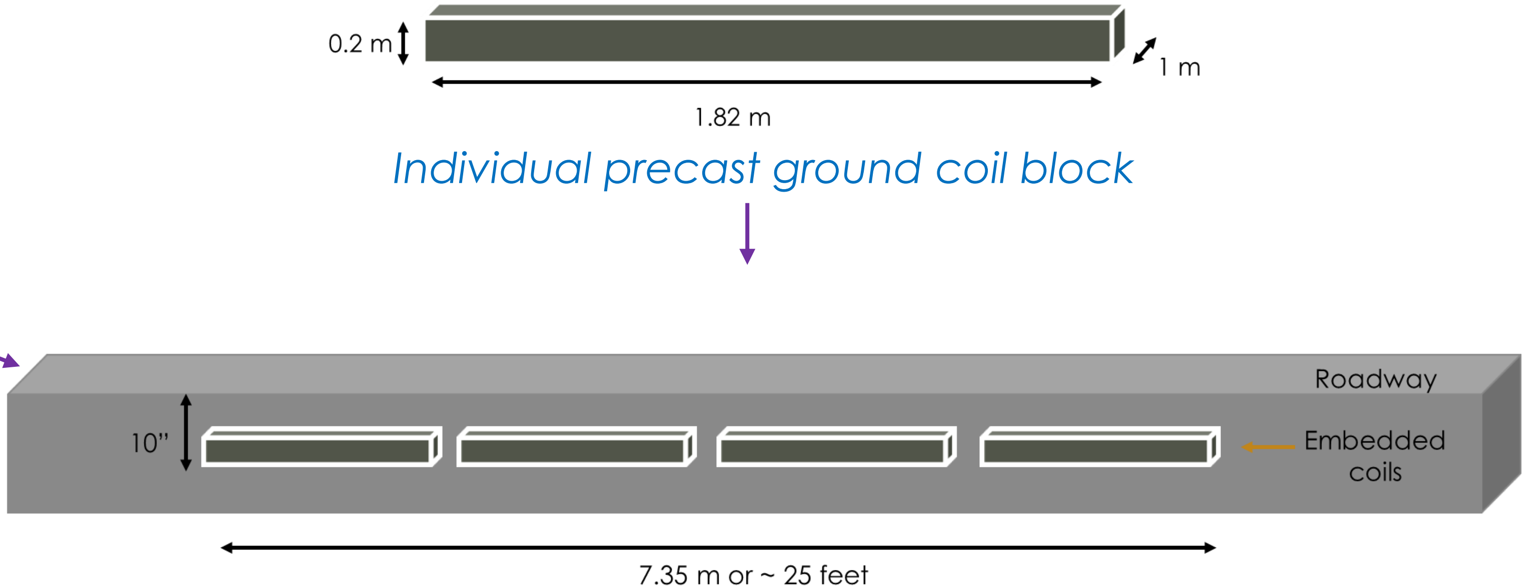


Dynamic inductive charging validation rig

- Track length - 18 m
- Payload capability – 100 Kg
- Speed ~ 9 m/s (20 mph)
- x, y, and z coil misalignment capability
- Automated and programable operation modes
- Capability to incorporate with HIL software

Technical Accomplishments FY21: Identified 200 kW Dynamic Charging Location





Individual precast ground coil block

Electrified Segment: Four precast ground coil blocks embedded in the roadway

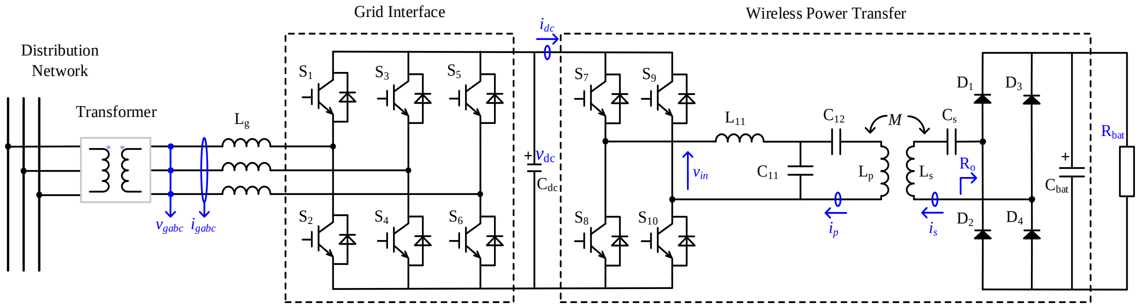
Demonstration site - ACM

- Four precast coil blocks to be embedded in roadway at ACM in location 4
- 13 KV electrical supply line to provide power for 200 kW DWPT evaluation
- Roadway with ample distance to get up to speed over the installed couplers.

Technical Accomplishments FY20: Completed Preliminary DWPT Grid Integration & Impact Analysis

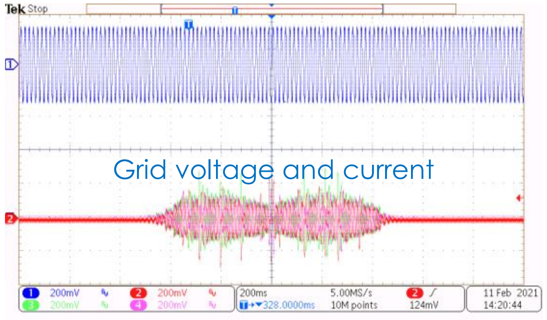
Accomplishment:

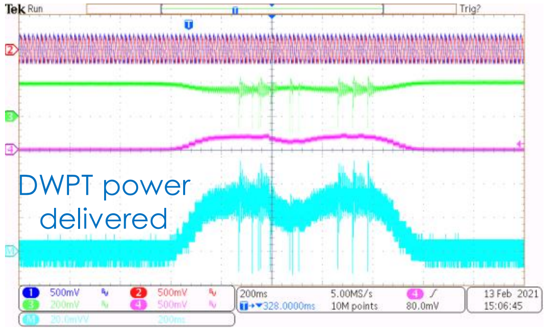
- Proposed and verified grid interface control strategy by detailed real-time emulation
  - Enhanced load transient response capability to address power pulsation from DWPT
  - Considered Imbalanced distribution network



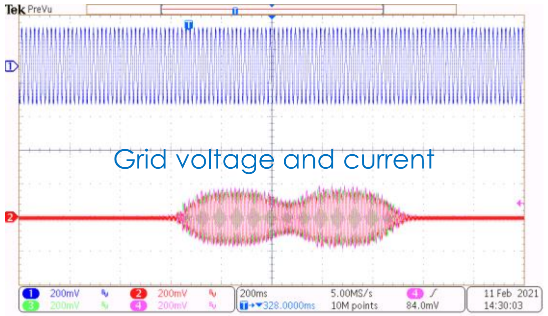
Architecture of Grid integrated 200 kW DWPT system

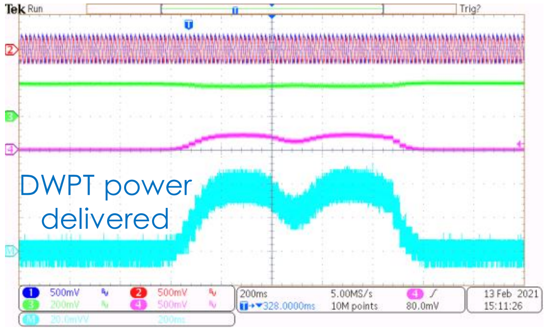
Conventional Grid-interface Control Scheme



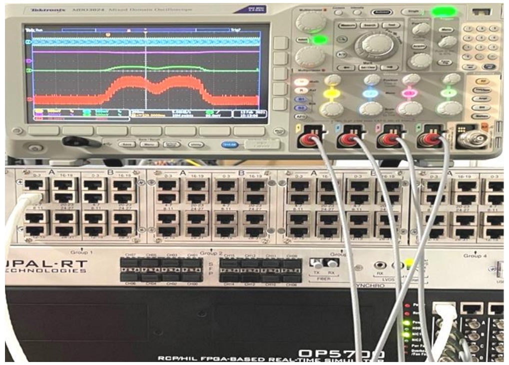


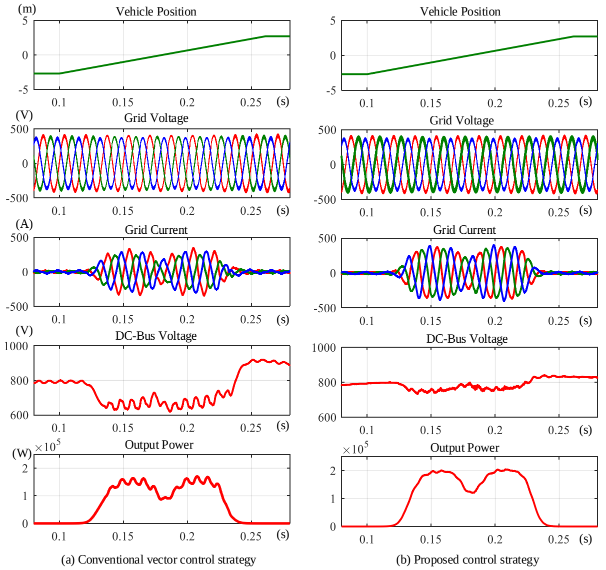
Proposed Grid-interface Control Scheme





Proposed Grid-interface Control Scheme implemented in OPAL-RT



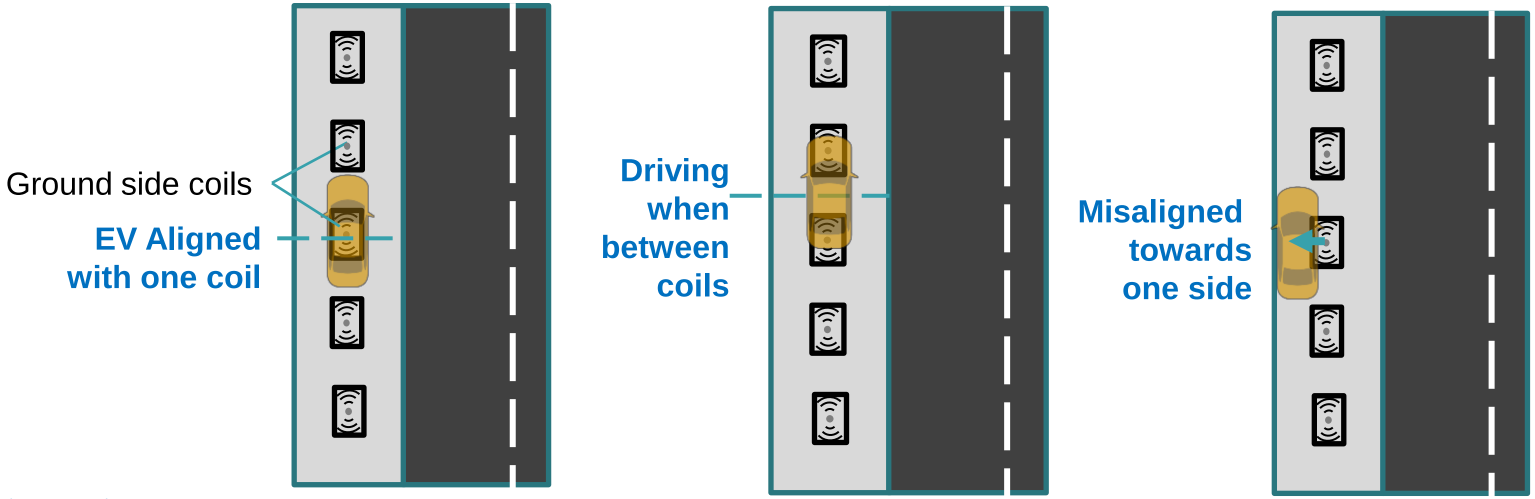


Comparisons of the conventional control strategy and the proposed control strategy for the grid interface converter

Technical Accomplishments FY21: EM-field Shielding Design for the 200kW DWPT

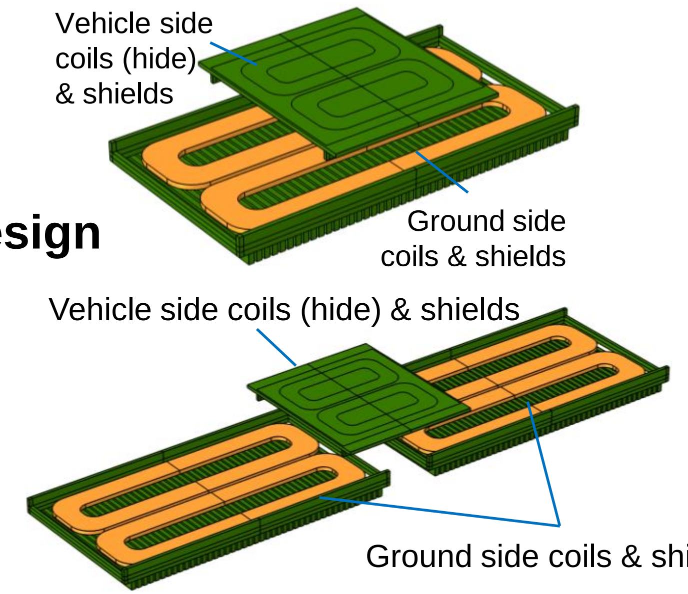
Goal: To ensure safety of 200kW DWPT system with respect to electro-magnetic safety
Issue: DWPT leads to more complicated charging scenarios. All typical wireless charging scenarios should be investigated to ensure EM safety.

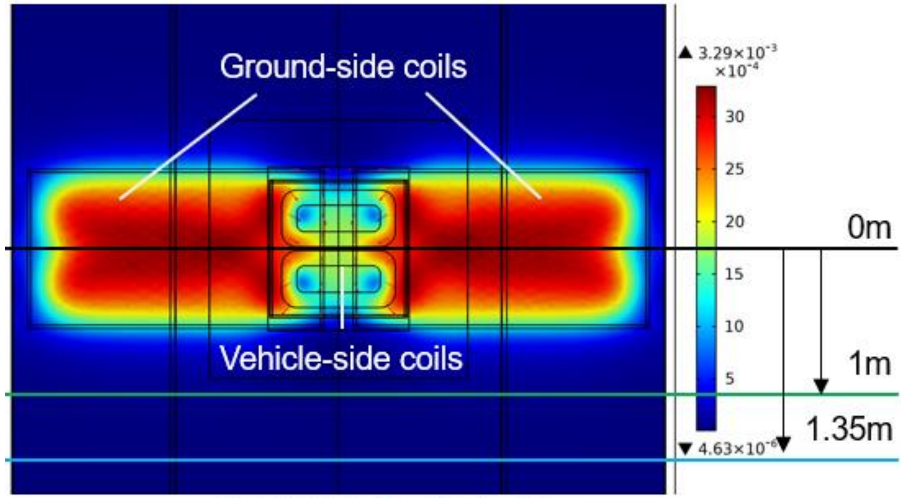
- **Scenarios**
  - A. EV is aligned with one ground-coil
  - B. EV is positioned between two ground-coils
  - C. EV is misaligned towards one side



- **Considerations**
  - The edge of the roadway lane is proposed as EM safety boundary for evaluation
  - Misalignment is considered
  - 200 kW in-motion operation

- **Completed: EM-field shielding design for the 200kW in-motion dWPT**
- **Final testing will be at ACM site**

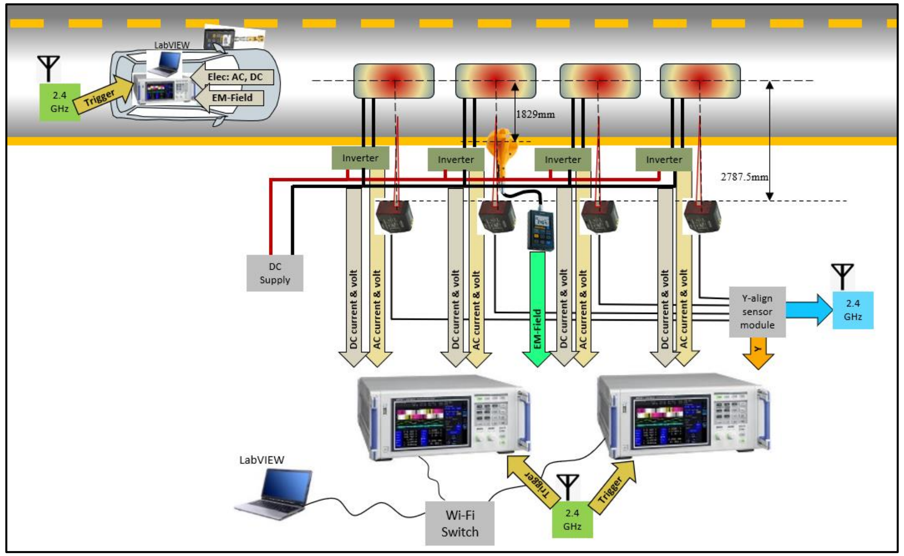




2-D EM field distribution

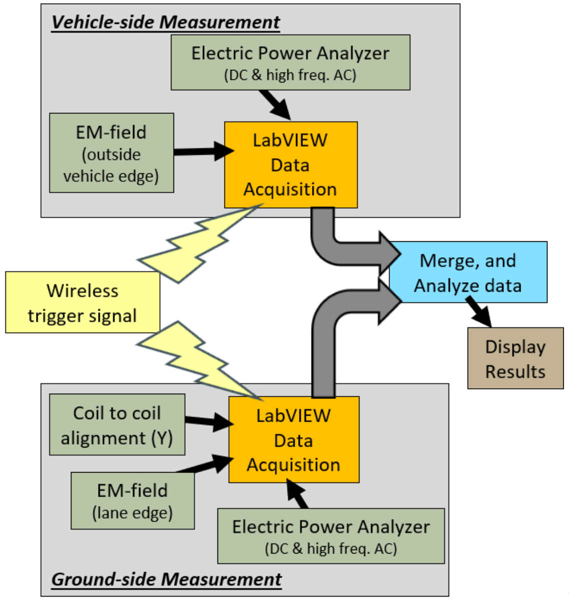
Technical Accomplishments FY21: DWPT Data Acquisition System Completed and Operational Functionality Verified

Goal: Complete data acquisition system for DWPT ground-side and vehicle-side measurements
Issue: Measurement of transient, high-speed in-motion power transfer requires synchronized high-speed data collection from many measurement sources (electrical, alignment, EM-field, veh. speed, etc.)



Data acquisition system <u>completed</u> and demonstrated functionality using a production EV

- **Data Acquisition Features:**
  - Power analyzers for electrical measurements of the ground-side and vehicle-side power flow
  - EM-field probes at the lane's edge and at the edge of the vehicle
  - Wireless synchronous trigger to align data capture
  - Non-contact distance sensors to measure the vehicle's lane alignment when traveling over each ground coil
  - Driver's Alignment Aid (DAA) to enable testing with repeatable lane alignment or misalignment (i.e. coil to coil Y-alignment)
- **Two rates of measurement**
  - 1MHz for waveform transient analysis, calibration tuning, and debug
  - 100Hz calculated measurement values for fast results of power transfer, efficiency, EM-field, & misalignment



Technical Accomplishments FY21

Overall Approach and Accomplishments

Year 1:
Developed high-level cost model and identified optimal solutions for dynamic charging for LD EVs on Primary Roadways

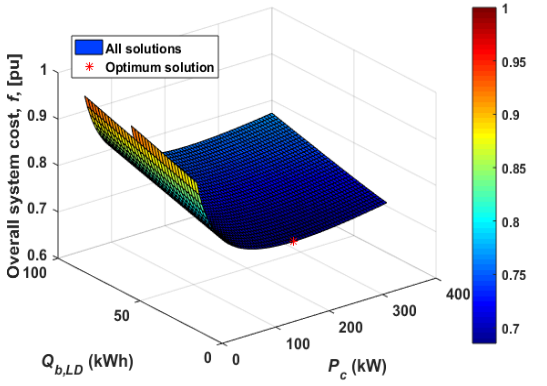
Year 2:
Develop and used EVI-InMotion tool to evaluate impact of DWPT system on LD EV travels (intercity and intracity) in Atlanta

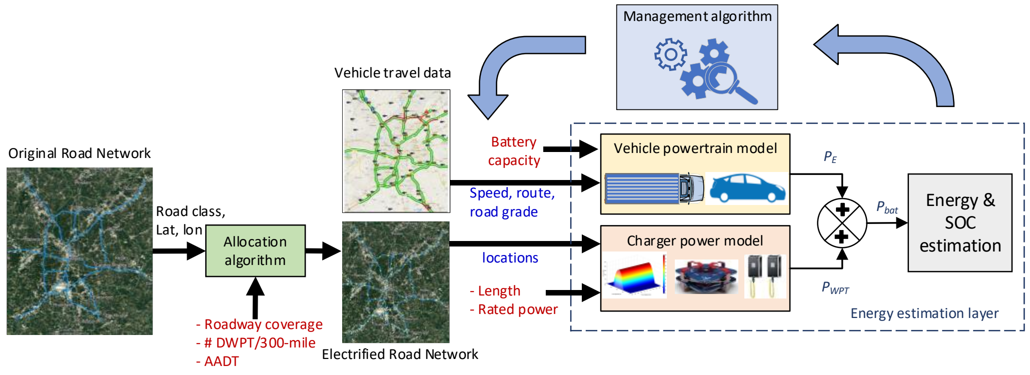
Year 3:
Evaluated impact of DWPT system on HD Class 8 EV travels (local, regional, and long-haul) in Atlanta, considering multiple receivers per vehicle

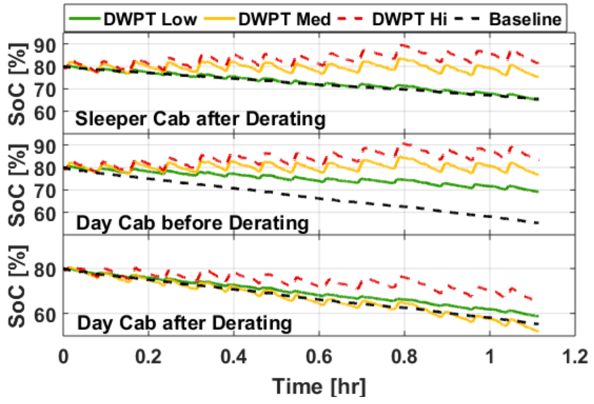
High-power (200-250 kW) and low-coverage (8-20%) DWPT with small battery (30-60 kWh for LD Evs and 200-500 kWh for Class 8 EVs) has the potential to allows CS operation on primary roadways (unlimited range)

Besides CS on primary roadways, DWPT system provides >2x range extension for ~33% of LD EVs, > 4x for 24% of LD EVs, and > 6x for 19% LD EVs in Atlanta metro area.

- Scaling DWPT system for class 8 EVs by using multiple receivers (4-6) per vehicle has the potential to provide CS operation on primary roadways with a much smaller battery size (up to 80 reduction).
- Exploring large scale impact in Atlanta??







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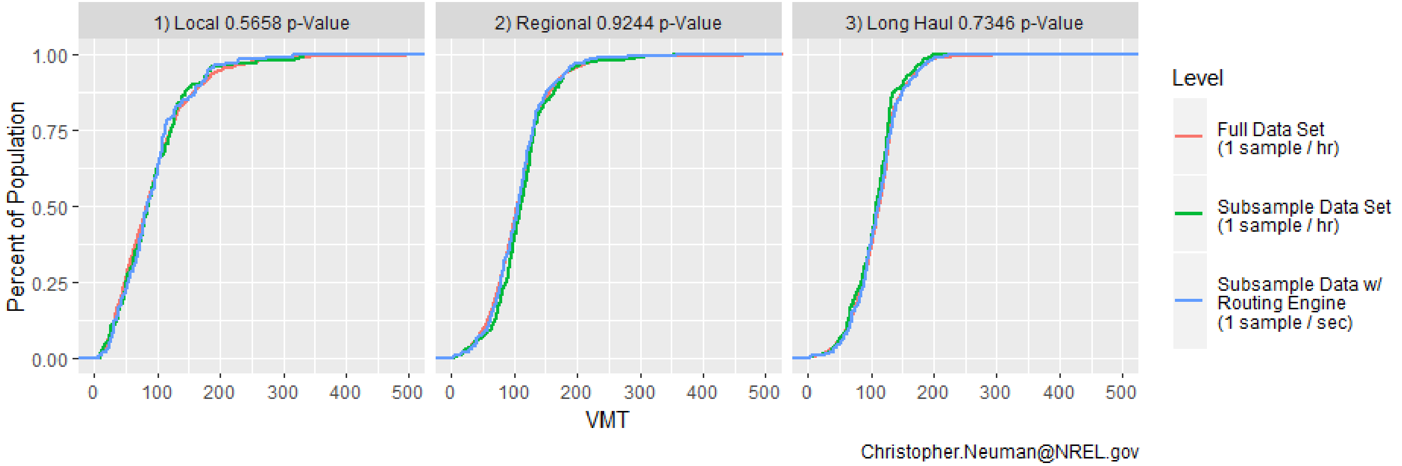
Technical Accomplishments FY21

Development of High-Resolution HD Vehicle Travel Data using 1 Sample/Hour Waypoints

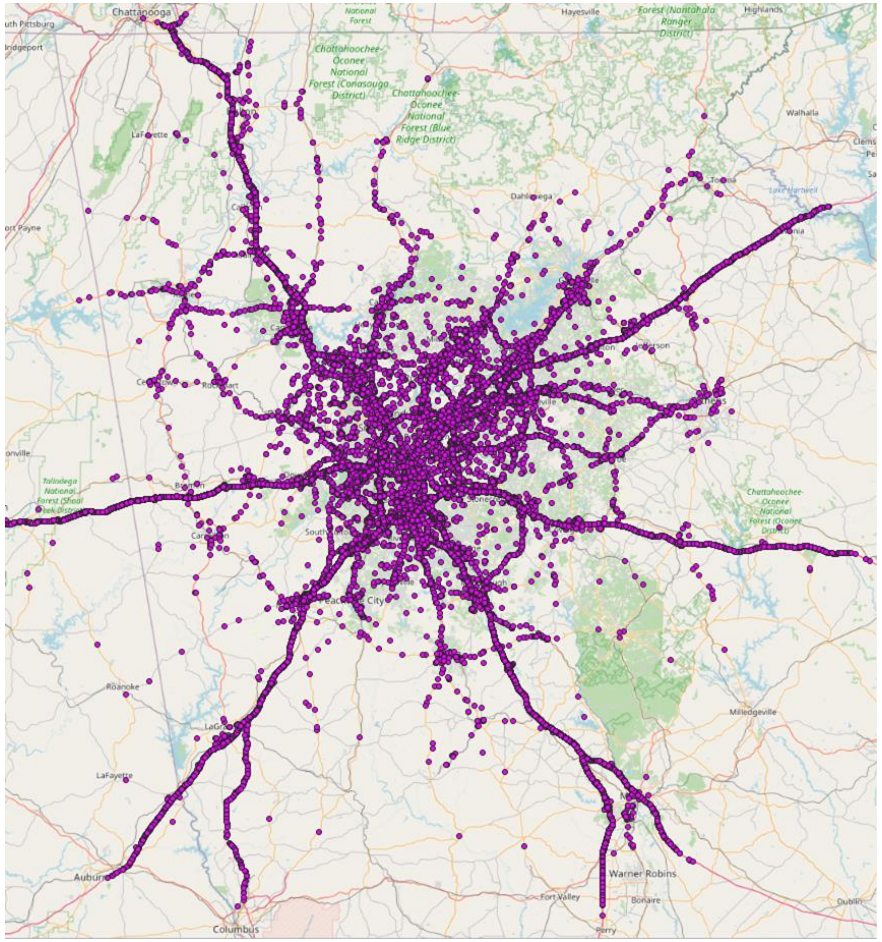
Goal: To develop high-resolution HD vehicle travel data (route and speed) to be used in exploring the impact of DWPT system on HD vehicle travel
Challenge: Available data set is low resolution (1 sample/hour)

Data Methodology:

- **Classification**: classify HD travel data into local, regional, and long-haul based on the radius of operation
- **Subsampling**: select a representative subset of the total data set to reduce computational time
- **Route generation**: generate and validate route data using 1 sample/hour waypoints (Inverse weighted Dijkstra's algorithm)
- **Route discretization (1 Hz)**: develop 1 Hz route and speed profiles



Probability indicator (p-value) > 0.05 indicates the sub-sample is an acceptable representation of the population



Snapshot of real-world HD way-points in Atlanta

- The HD data set makes up ~4% of all VMT for national freight.
- 7.6K unique HD vehicles within the Atlanta region.
- ~30K unique trips within the Atlanta region.
- Original data set 1 Sample per hour.

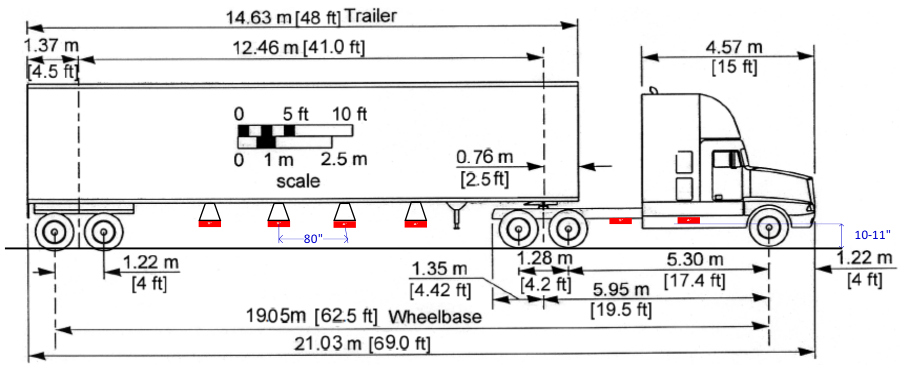
Technical Accomplishments FY21

Identified HD Vehicle Models and Parameters Associated with DWPT System

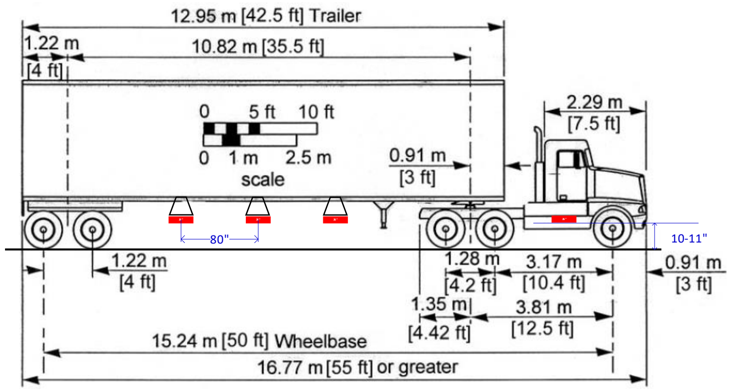
Goal: Identify representative class 8 EV models with the associated battery size and number of receivers

Class 8 EV Models:

- Two EV class powertrain models are considered:
  - Sleeper Cab: used with long-haul travel data
  - Day Cab: used with regional and local travel data
- Maximum number of receivers in each models is identified based on DWPT system and vehicle dimensions.
- Sleeper Cab (Models A: 2.4 kWh/mile): fit 6 receivers
- Day Cab (Models B: 2.3 kWh/mile): fit 4 receivers
- Receivers can be installed at lower level in the trailers



Model A



Model B

DWPT Receivers in Different Class 8 Vehicles

Test Cases:

		Low requirements for LD EVs	Medium requirements for LD EVs	Hight requirements for LD EVs
Approach based on LD vehicles		- CS for intercity travels, - min road coverage, - low travel requirements (65 mph, 270 Wh/mile)	- CS for intercity travels, - min overall system cost, - medium travel requirements (74 mph, 310 Wh/mile)	- CS for intercity travels, - min overall system cost, - high travel requirements (86 mph, 350 Wh/mile)
Roadway coverage (%)		8.2	14.56	16.6
Transmitter power (kW)		235	200	225
Sleeper Cab EV	Battery size (kWh)	497.8	222.2	196.4
	# receivers	7→6	6	5
	Received Power (kW)	~235 x 7/6 = 1,645/1,410	~200 x 6 = 1,200	~225 x 5 = 1,125
Day Cab EV	Battery size (kWh)	494.2	220.6	195
	# receivers	7→4	6→4	5→4
	Received Power (kW)	~235 x 7→4 = 1,645→940	~200 x 6→4 = 1,200→800	~225 x 5→4 = 1,125→900
#DWPT/300-mile		20, 40, 60, 80, 100, optimized	20, 40, 60, 80, 100, optimized	20, 40, 60, 80, 100, optimized
Elec. Segment (mile)		1.23, 0.62, 0.41, 0.31, 0.25, x1	2.18, 1.09, 0.73, 0.55, 0.44, x2	2.49, 1.25, 0.83, 0.62, 0.5, x3
Non-elec. Segment (mile)		13.77, 6.88, 4.59, 3.44, 2.75, y1	12.82, 6.41, 4.27, 3.2, 2.56, y2	12.51, 6.25, 4.17, 3.13, 2.5, y3

Comparable 600-mile non-DWPT vehicle could require up to ~1.4 MWh battery

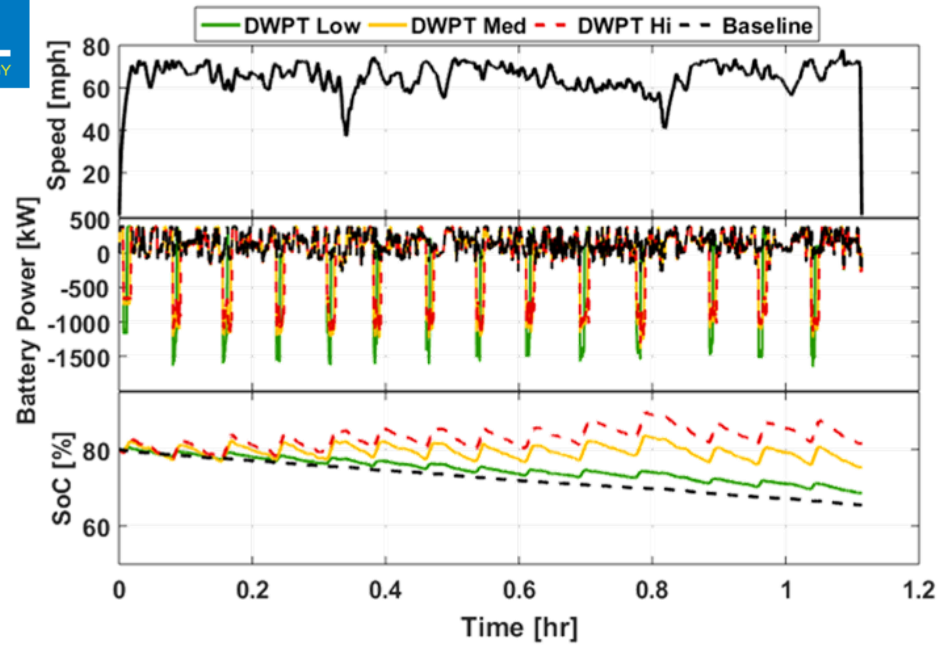
Technical Accomplishments FY21

Preliminary Results: Analyzed Class 8 EV Performance on Primary Roadways in Atlanta with DWPT system

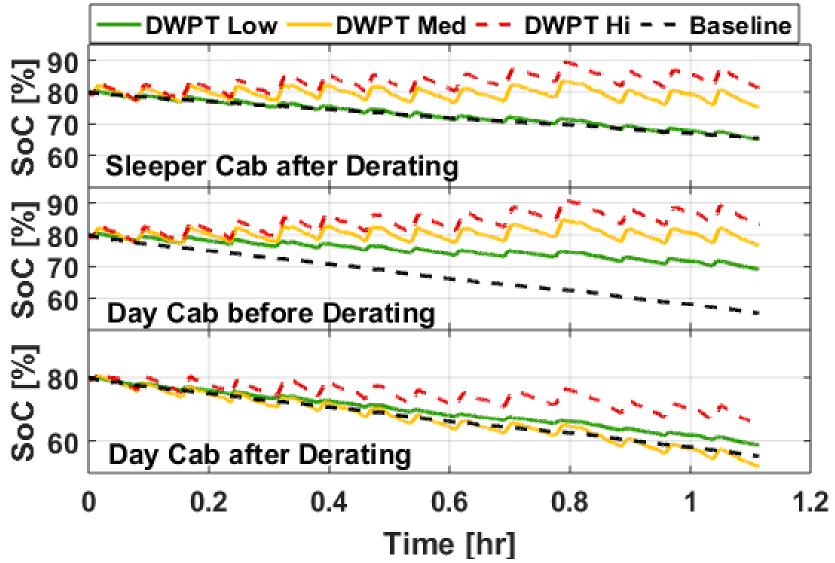
Goal: Test the travel performance of class 8 vehicles in primary roadways

- Small sample of real-world trips for class 8 trucks on primary roadways in Atlanta from NREL's FleetDNA are used.
- In most cases DWPT system is able to compensate for vehicle consumption leading to near zero kWh/mile on primary roadways
- DWPT system design with higher road converge (DWPT Hi) shows consistent charge-sustaining (CS) in sleeper and day cab EVs.
- Space constraint on vehicles leads to lowering the number of receivers and impacts the CS performance

Energy Consumption [kWh/mi]			DWPT Low	DWPT Med	DWPT Hi
Sleeper Cab	Original	min	0.635	0.029	-0.135
		mean	**0.763**	**0.171**	**-0.003**
		max	0.926	0.339	0.187
	Derated	min	0.869	0.029	-0.135
		mean	**0.994**	**0.171**	**-0.033**
		max	1.143	0.339	0.187
Day Cab	Original	min	0.586	-0.021	-0.179
		mean	**0.713**	**0.124**	**-0.049**
		max	0.875	0.312	0.161
	Derated	min	1.287	0.713	0.301
		mean	**1.407**	**0.848**	**0.418**
		max	1.525	0.995	0.6



Sleeper cab EV performance on primary roadway with and without DWPT system (60 segment/300- mile)



Sleeper and Day cab EV performance on primary roadway before and after derating

Response to Previous Year Reviewers' Comments

Reviewer Comment: There is a good approach, but some intermediate verification of the dynamic aspect would be helpful.

Reply: Dynamic inductive charging evaluation rig has been installed to aid in dynamic testing before vehicle implementation

- Can emulate vehicle movement across 20 m track with velocity up to 8 m/s
- Can emulate vehicle misalignment and different magnetic airgap

Reviewer Comment: The future research looks appropriate and logical. It would be good to hear more about the work needed on the pavement side of the system and the implications (both technical and cost) to the roadways when that information is ready to be presented.

Reply: We have initiated discussions with Virginia Tech Transportation Institute to leverage their expertise in evaluation and preparation for roadworthiness.

Reviewer Comment: More focus on the dynamic aspects is needed.

Reply: The control and dynamics of the secondary side dc-dc converter and the 200 kW DWPT system is being analyzed with a design-oriented approach. The dynamic inductive charging evaluation test rig will also be used extensively for experimental validation.

Collaboration and Coordination with Other Institutions

Laboratory partners:

Oak Ridge National Laboratory	• Project lead • 200 kW power dynamic EV charging system design, simulation, hardware development, vehicle integration and validation
INL Idaho National Laboratory	• Design of active and passive shielding and data acquisition system for 200 kW dynamic EV charging system
NREL Transforming ENERGY	• High level cost study of high-power dynamic wireless EV charging • Study of large-scale deployment scenarios of high-power dynamic EV charging

Coordination with Other Institutions:

HYUNDAI MOTOR GROUP	• Kona EV for high power dynamic wireless EV charging demonstration • Engineering support and guidance for integration of DWPT system with the vehicle
American Center for Mobility CONNECTED. AUTOMATED. VALIDATED.	• Site for 'electrified mile' dynamic charging demonstration (FY21) • Infrastructure and support for demonstration
VT VIRGINIA TECH TRANSPORTATION INSTITUTE	• Evaluation and guidance of making the ground side coils and power electronics roadworthy

Remaining Challenges and Barriers

- Evaluate and overcome the effect of vehicle body interference on power transfer efficiency
- Evaluate the effect of embedding couplers in roadway has on power transfer efficiency

Any proposed future work is subject to change based on funding levels

Proposed Future Research

Research:

- Evaluate performance of WPT couplers embedded in roadway and plan for road-worthiness from both civil engineering and electrical performance perspectives
- Explore the possibility of replacing secondary passive rectifier and DC-DC converter with a single active rectifier

Tasks/Milestones:

- **FY 2021**
    - Validate 200 kW dynamic wireless charging capability in laboratory using dynamic inductive charging emulator
    - Complete vehicle integration and validation of 200 kW dynamic wireless EV charging system
    - Integrate INL's passive EM-field shielding solution with ORNL's 200kW DWPT system
    - Complete analysis of impact of DWPT system on HD class 8 vehicle travel in Atlanta.
- **FY 2022**
    - Validate and map performance of vehicle integrated 200 kW dynamic charging system at ACM

Any proposed future work is subject to change based on funding levels

Summary

- **Relevance:** Dynamic EV charging can significantly alleviate range anxiety and concurrently reduce the on-board battery requirement (weight and cost reduction)
- **Approach**:
  - Optimal range of power transfer level for feasible dynamic wireless EV charging system has been identified (150 kW – 235 kW)
  - Key R & D necessary to realize a practicable 200 kW dynamic charging system have been identified and being pursued for hardware development
  - Benchtop validation of power electronics and couplers validated to rated power thereby validating 200 kW power transferring capability
  - Dynamic inductive charging is operational and will be used to perform controlled dynamic charging tests to optimize control and efficiency
- **Technical Accomplishments:**
  - Completed high-Level cost and feasibility studies and identified architecture suitable for 200 kW DWPT
  - Completed design, development, and laboratory benchtop validation of primary and secondary side power electronics design of 200 kW DWPT system
  - Completed design, development, and validation of DWPT coils and tuning network
  - Planned for 200 kW dynamic charging tests in laboratory and for real-world validation at ACM
  - Identified and developing active and passive EM-field shielding solutions for 200kW DWPT system
  - Developing data acquisition system necessary for real-world implementation of 200 kW DWPT system
  - Analyzed Feasibility of Large-Scale Deployment of DWPT system on Primary Roadways in Atlanta
  - Developed E-Roads Tool for Analyzing Large-Scale Deployment of DWPT system on Roadways in a Region
- **Collaborations and Coordination with Other Institutions**:
  - HATCI providing an EV and support and guidance on vehicle-integration of DWPT system
  - ACM providing infrastructure and physical proving grounds for validation of 200 kW DWPT system
  - VTTI providing guidance and support to develop roadworthy DWPT coils
- **Future Work**:
  - Validate functionality of 200 kW DWPT system in laboratory
  - Demonstrate practicability by means of vehicle integrated demonstration at ACM

Any proposed future work is subject to change based on funding levels