NREL
NATIONAL RENEWABLE ENERGY LABORATORY

HEV TCP Task 26 Workshop 9: Wireless Charging for EVs (6-7 Nov. 2018 in Detroit, Michigan USA)

“NREL’s Managed WPT Experiences and Lessons Learned”

Presenter

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Outlines

- Introduction/NREL's Vision for Demonstrating WPT for EV
- Description of 25 kW WPT system at NREL's Shuttle
- EMF Testing of On-Vehicle WPT System
- Monitoring and Control of the Wireless Charging
- Description of WPTsim Tool for WPT design
- Design of Greenville AMD Project using WPTsim
- Conclusions/Opportunities

Visions of WPT for EV

Quasi-dynamic WPT

Stationary WPT

Dynamic WPT

https://www.nbcnews.com/mach/mach/futuristic-roads-may-make-recharging-electric-cars-thing-past-ncna766456

Stationary Wireless Charging: 25 kW Wireless Charger at NREL's Shuttle

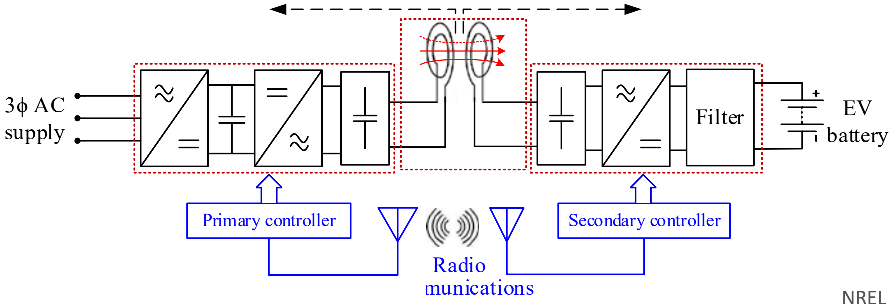
WPT on NREL's Campus

✓ Wirelessly Charged Electric Shuttle

- Full electric on-demand service
- 16 passenger
- 62.1 kWh battery capacity
- 100 miles range
- 7600 curb weight, including VA
- 6.6 kW on-board conductive charger

✓ Momentum Dynamics WPT system

- 35.5"x35.5"x2.25" (900x900x57 mm) symmetrical square pads
- 25 kW maximum power transfer
- 20 (19-21) kHz nominal operating frequency.
- Automatic alignment capability.
- 5"-9.5" (125-240 mm) airgap



EMF Testing for In-Vehicle WPT System

✓ Test Methodology

1. Define coordinates.
2. Define a marked safety perimeter.
3. Identify the worst misalignment condition (X, Y, Z, pitch, roll and yaw).
4. Define test zones and points

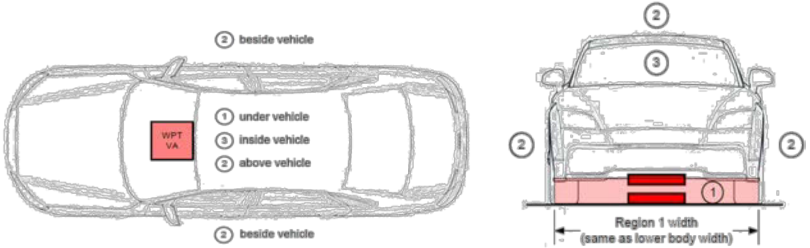
   Region I: Under the vehicle
   Region II: Around and above the vehicle
   Region III: Inside the vehicle

5. Define the standard limits for each zone (2010 ICNIRP)

EHP-50D, Narda

https://www.narda-sts.com/en/
http://www.eenewsautomotive.com/news/one-test-system-analysing-electromagnetic-fields-5-hz-60-ghz

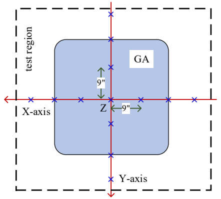
Coupler Offset & Gap			Max Magnetic Field		Max Electric Field	
dX	dY	dZ	Location	B (µT)	Location	E (V/m)
+max	+max	max				
+max	-max	max				
-max	+max	max				
-max	-max	max				

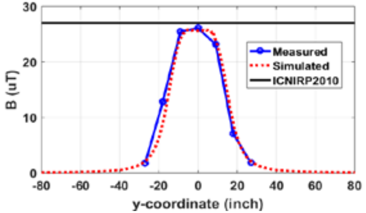


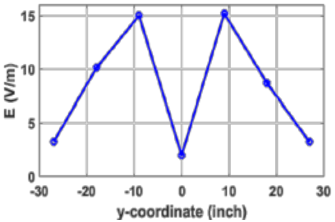
"J2954A (WIP) Wireless Power Transfer for Light-Duty Plug-In/ Electric Vehicles and Alignment Methodology - SAE International."

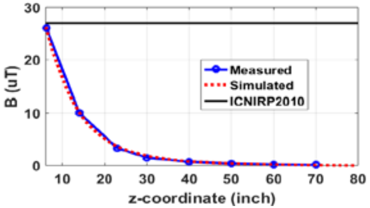
EMF Test Results

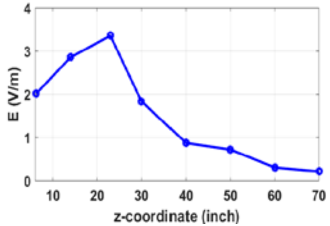
EMFs before/during alignment (Low Power Excitation)



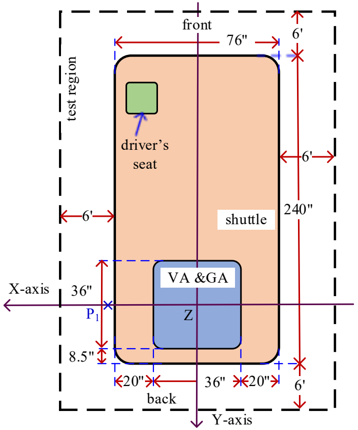


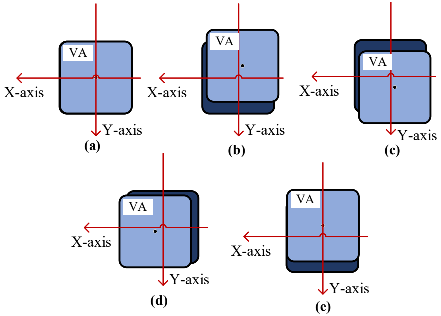


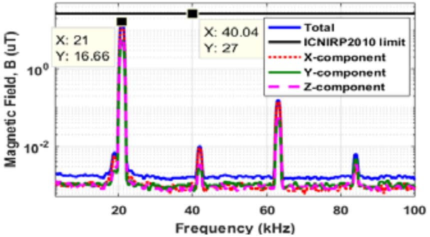


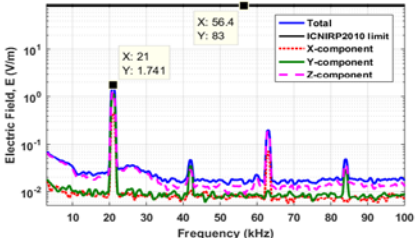


EMFs around the vehicle (zone II)









Misalignment	Max B_{rms} (μT)	Max E_{rms} (V/m)
Position I	16.661	1.7414
Position II	18.380	2.4091
Position III	17.696	2.5345
Position IV	17.152	1.7147
Position V	18.526	2.0853

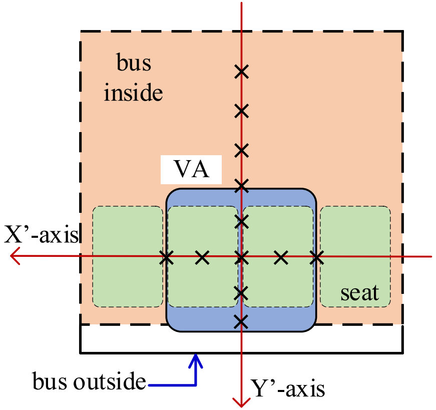
EMF Test Results

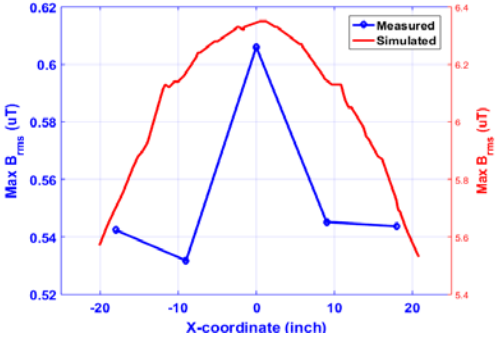
EMFs inside the vehicle (zone III)

Driver seat test points

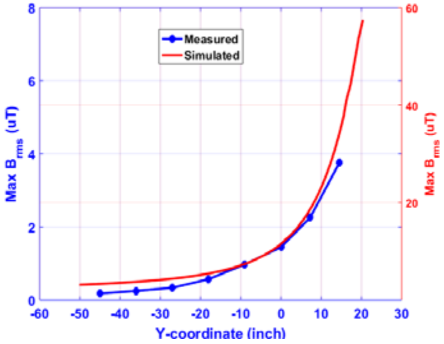
Test Point	Max B_{rms} (µT)	Max E_{rms} (V/m)
P_A	0.0328	0.0633
P_B	0.0068	0.0380
P_C	1.0362	0.0257

Over VA test points



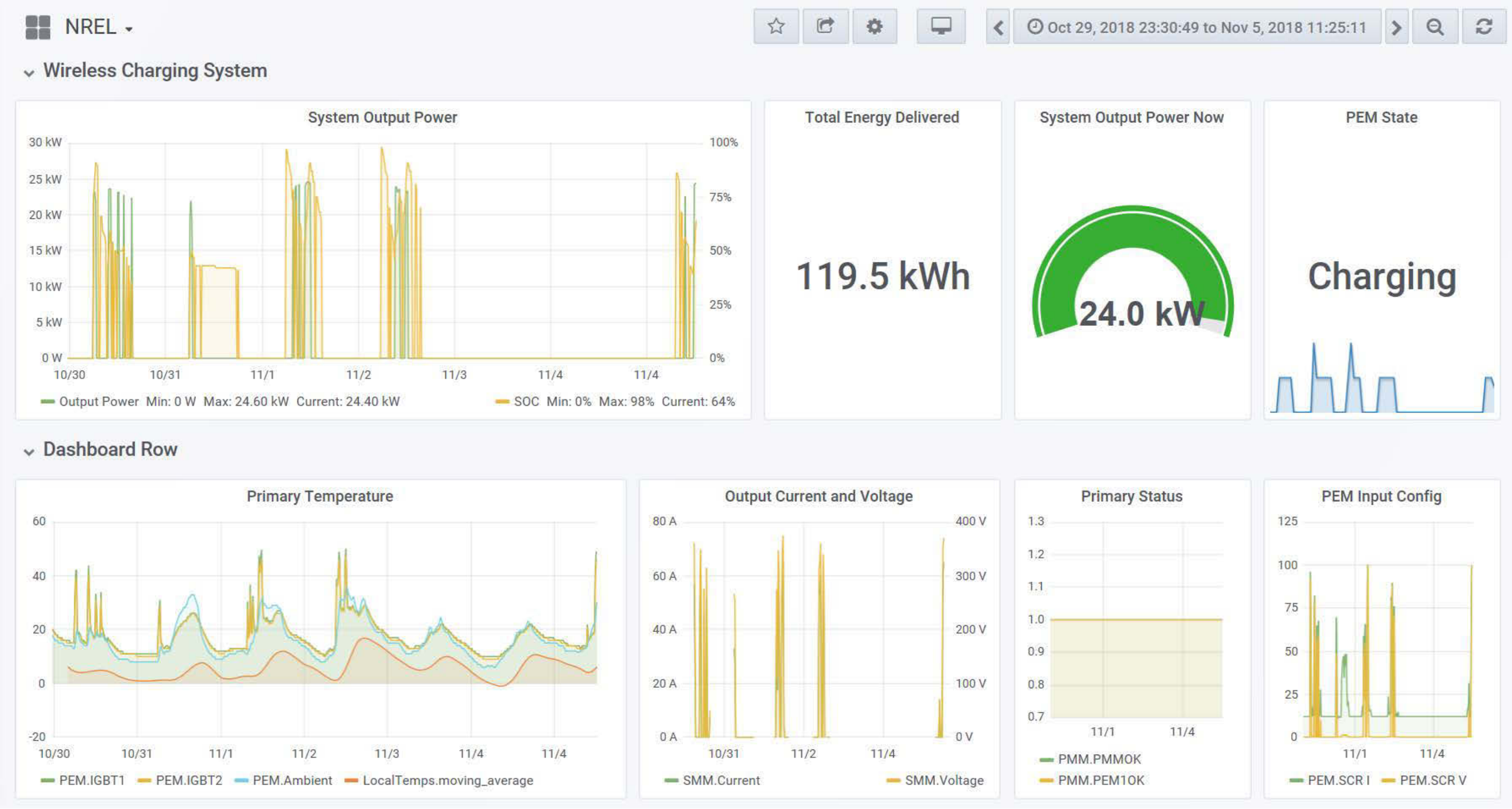


Magnetic field along Y'-axis at a height of 6.25" from the floor of the bus



Magnetic field along X'-axis at a height of 27.25" from the floor of the bus

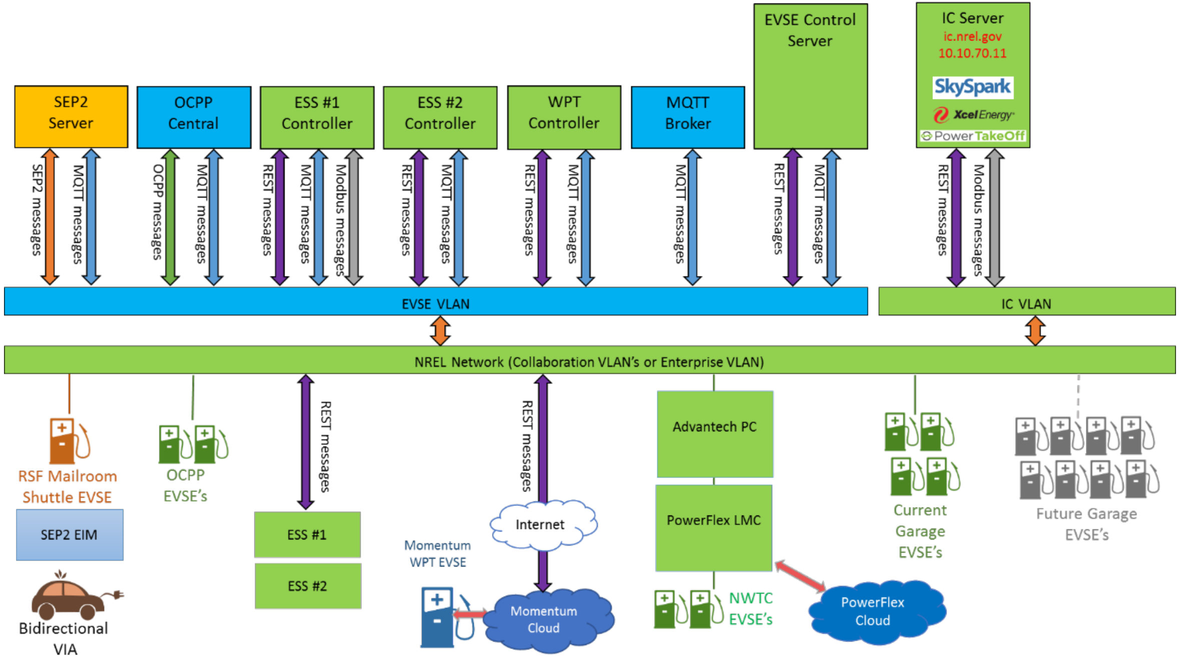
Wireless Charger Operation: Monitored and Managed



NREL's Intelligent Campus Energy Management Plan

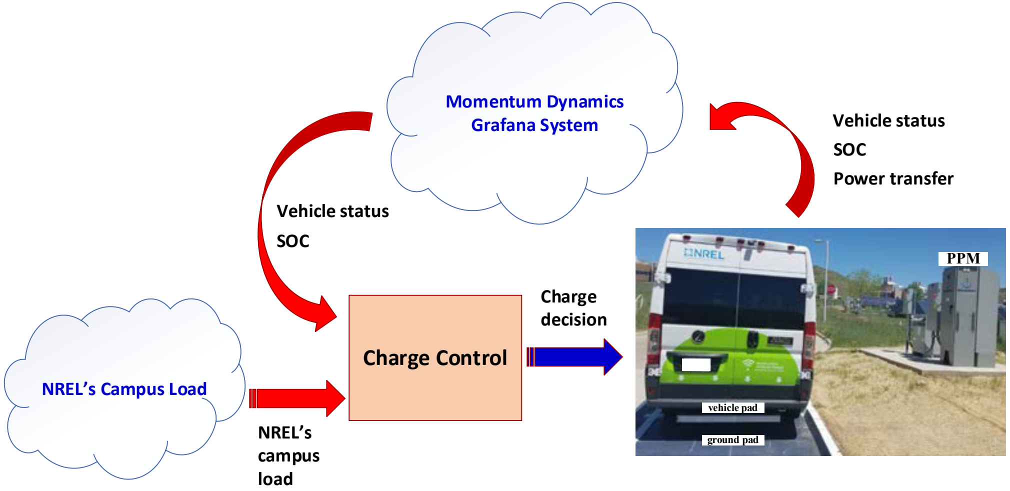
NREL Intelligent Campus Integrates:

- RESs
- ESSs
- Building loads
- EVSEs
  - AC level 2
  - DC FC (50 kW)
  - Wireless Charger (25 kW)
  - Bidirectional EV



Wireless Charging Operation: Control

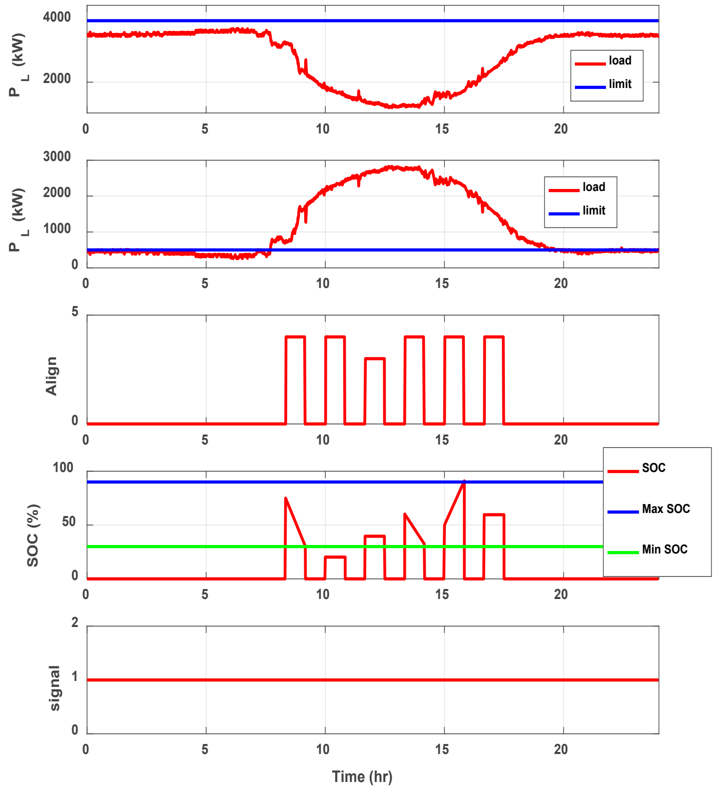
- Objective: ‘smart’ integration of wireless charger with surrounding infrastructure on NREL campus (e.g. Renewable Generation, Loads, other EVSEs, etc.)



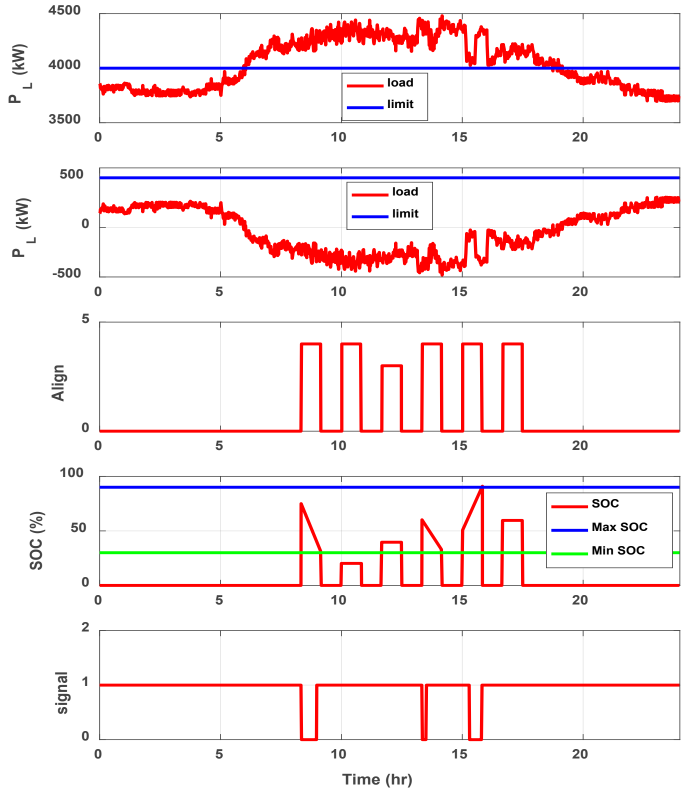
Block diagram for the data-flow of the wireless charging control

Results of the Wireless Charging Control

Nice day results: lots of PV generation



Cloudy day results: lack of PV generation



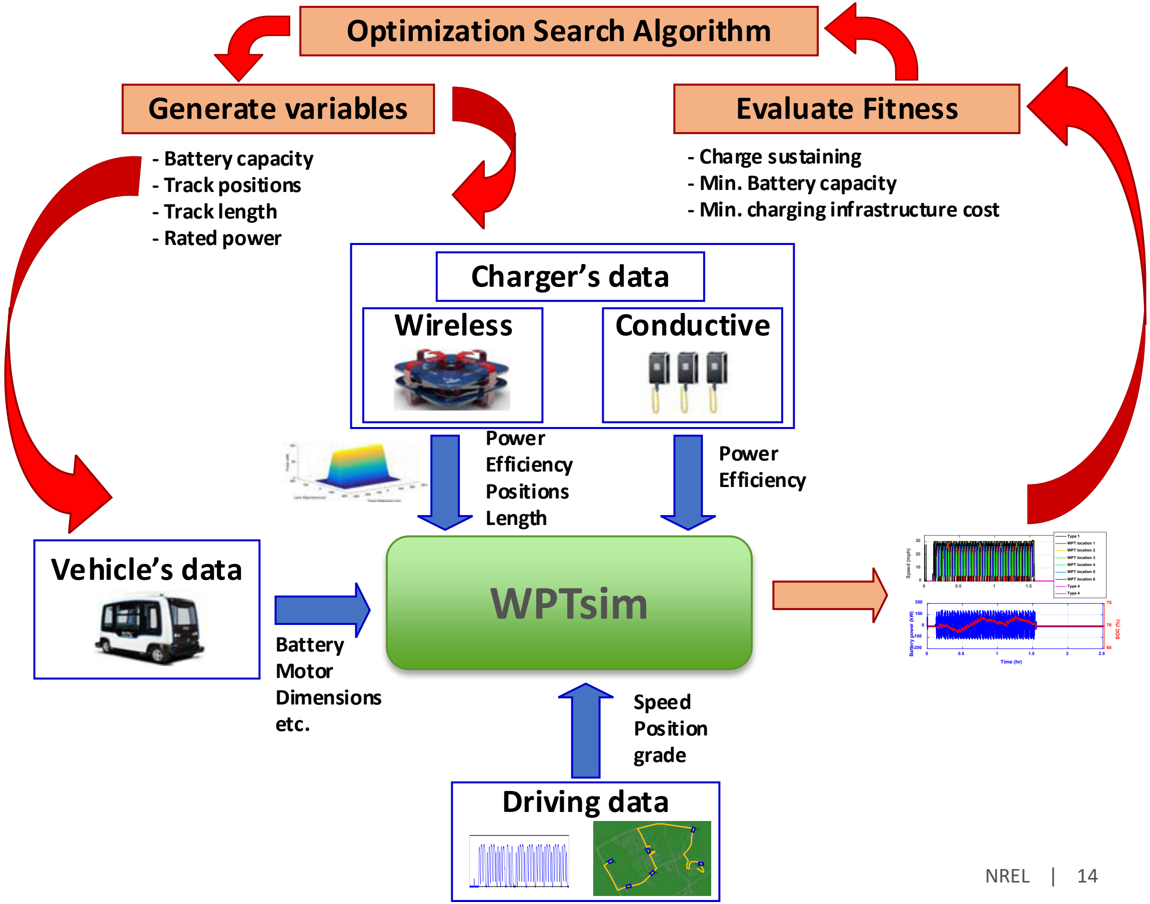
Dynamic Wireless Charging: Feasibility Analysis of DWPT for Autonomous Vehicles at AMDs

WPTsim Tool: Wireless Charging Design

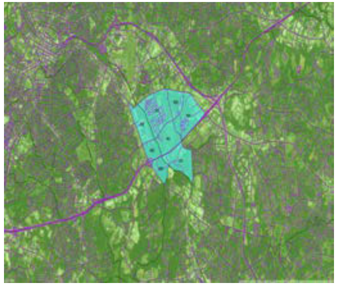
- It is a design optimization tool that incorporates driving data, vehicle data with charging infrastructure parameters (conductive or wireless).

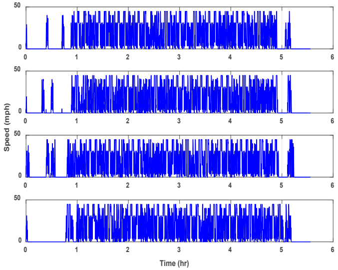
- It is capable of providing optimum design of wireless infrastructures (stationary, dynamic and quasi-dynamic) for certain road scenario.

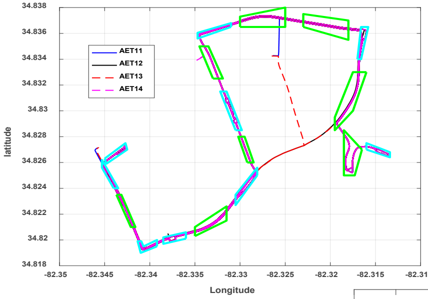
- It is utilized to provide designs for multiple scenarios such as:
  - NREL's circulator shuttle.
  - Greenville AMD Project



Greenville Automated Mobility District (AMD): WPTsim Scenario Analysis





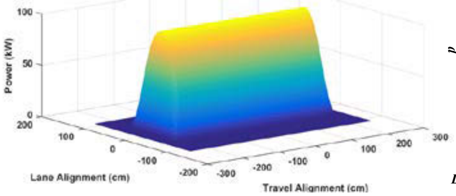


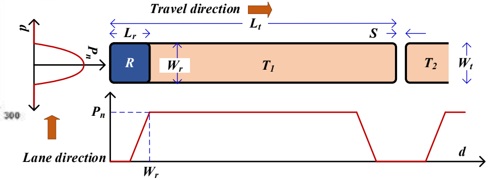
GRT, AET11 with 17 WPT positions (60 kW and 155 m track at each position).

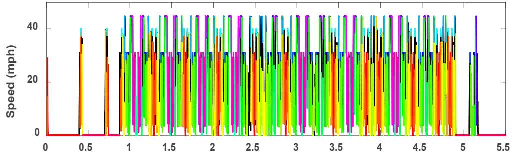
GRT AES

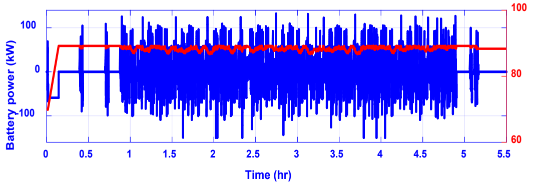
16 passenger, curb weight 3500 kg, 36 kWh battery capacity and about 45 mph maximum speed

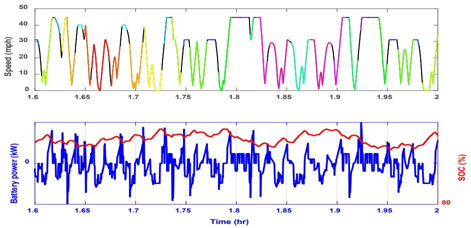
WPTsim











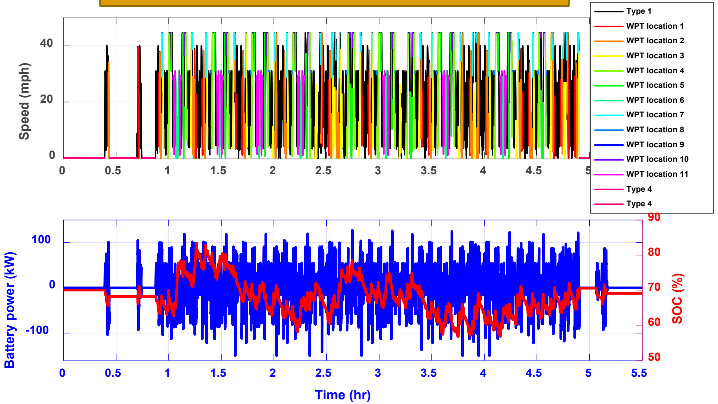
Optimization Results of Greenville AMD

- **Optimization Variables:**
  - Position of each wireless charger.
  - Wireless charger power.
  - EV's battery capacity.
  - Number of track segments (track length).
- **Optimization Objectives:**
  - Minimum battery capacity.
  - Minimum charging infrastructure cost.
  - Achieve charge sustaining operation.

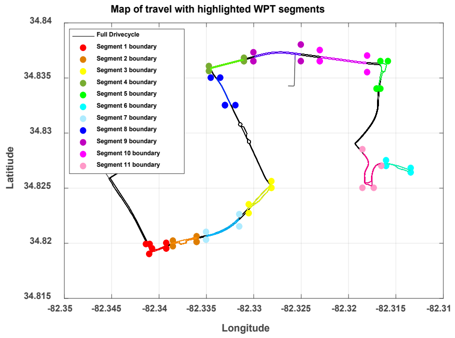
Optimal key design parameters

Parameter	Optimal value
# wireless chargers	11 out of 17
Positions	[3 4 5 7 8 9 11 13 14 15 17]
Power	80 kW
Battery capacity	12 kWh
# segments per Track	25 (125-meter track length)

Optimal driving performance



Optimal WPT positions



Conclusion/Opportunities

- ✓ Extra effort is required for demonstrating the WPT technology in real world scenarios starting with closed campus scenarios.
- ✓ Collecting data from real-world projects, including NREL's shuttle one, to be utilized for better understanding the technology, control design and validating design tools.
- ✓ Updating and utilizing WPTsim tool for analyzing more complex charge design scenarios (e.g. interstate, urban and rural roads).
- ✓ Working to have an EasyMile autonomous shuttle operating at NREL campus with the possibility to install a wireless charger to it.

Thank you

www.nrel.gov

NREL/PR-5400-72805

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