

Idaho National Laboratory

Testing Results: *PLUGLESS*[™]**Wireless Charging System by Evatran Group Inc.**



www.inl.gov

Richard "Barney" Carlson October 2013

INL/CON-13-29978



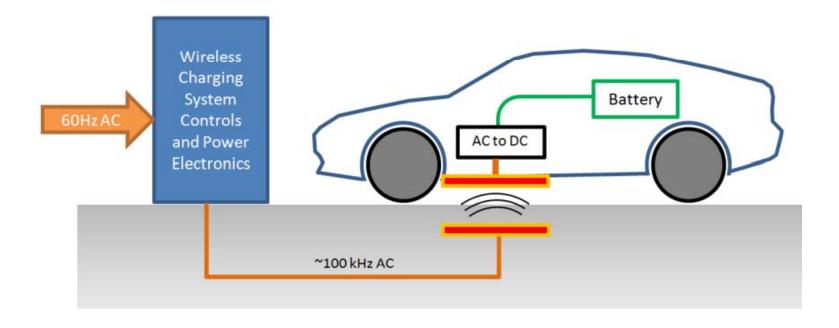


What is Wireless Charging for Plug-In Vehicles?

- Wireless Power Transfer (WPT) across an air gap
 - Power Electronics convert grid power (60Hz) to higher frequency power

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- Typical operating frequency: 20 kHz to 200 kHz
- Coil to Coil coupling via magnetic resonance enables high efficiency power transfer across the air gap
- Higher frequency power rectified is into DC power to charge the battery



INL Wireless Charging Testing

- <u>Scope</u>: Provide Results from Testing
 - System Efficiency
 - Electric and Magnetic (EM) Field Strength
 - Impact on Grid (power quality, harmonics, etc.)

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- Support SAE J2954 committee
- Factors that impact System Efficiency and EM Field
 - Coil to Coil Position
 - Alignment (X, Y, θ , Tilt)
 - Gap between coils
 - Output Power
 - Temperature (warm-up effects)

INL Wireless Charging Test Equipment

- **Programmable Loads**
 - AC Loads (9.0 kW) Chroma 63804
 - DC loads (58 kW) Chroma 63210
- Hioki 3390 Power Meter
 - 4 channel AC and DC current and voltage
 - Real-time integration for power & energy
- NARDA EHP-200a
 - Electric Field
 - Magnetic Field
- FLIR SC640 Thermal Camera T/2
- Fiberglass channel strut frame with multi-axis positioning table
- CAN communications (as required)
- Custom LabVIEW test control program for data acquisition and test host function to synchronize all test operations



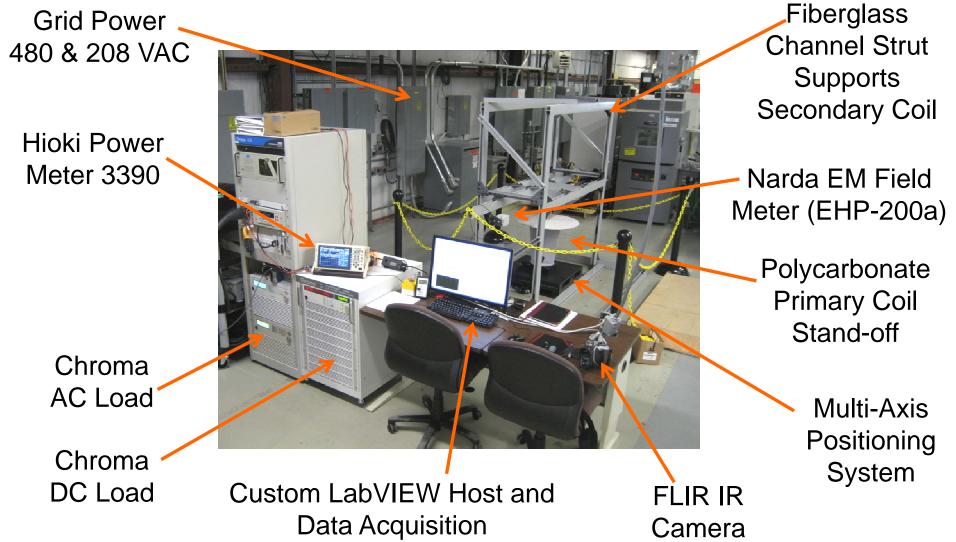






INL Wireless Charging Laboratory Testing

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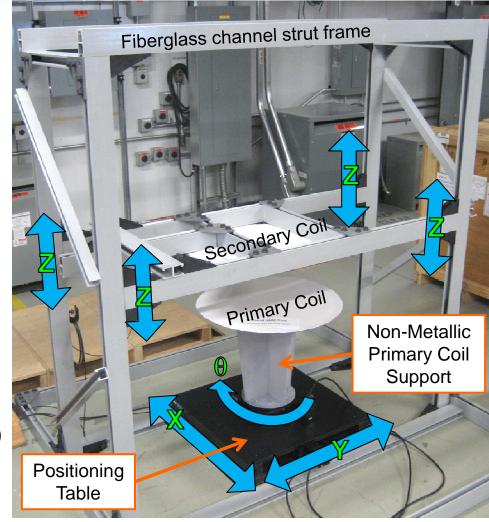


INL Wireless Charger Coil Positioning

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- Primary Coil
 - Software position control
 - Ball-screw positioning table with servo motors
 - X, Y, θ
 - Supported by polycarbonate stand-off
 - Increase distance to the metallic positioning table
- Secondary Coil
 - Suspended from fiberglass channel strut frame
 - Manually adjusted
 - Z position (coil to coil Gap)
 - Tilt by differential Z



PLUGLESS[™] Wireless Charging System from Evatran Group Inc.

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- Rated power: 3.3 kW output (208 VAC input as tested)
- 30 A circuit breaker
- Nominal Gap between coils: 100mm (4.0")
- Vehicle application: Chevrolet Volt (as tested)
- Dimensions:
 - Primary Coil (circular) above ground installation
 - Approx. Circular: 559mm dia. x 470mm long
 - Secondary Coil (oval) attaches under rear of vehicle
 - Rectangular: 464mm long x 525mm wide



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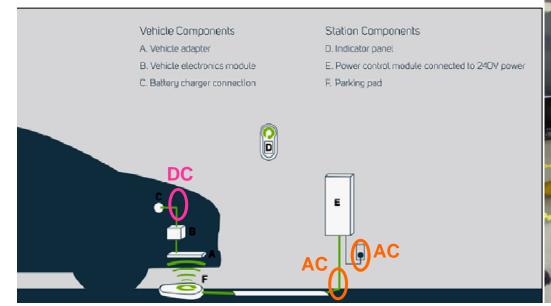


http://www.pluglesspower.com/ wp-content/uploads/2013/06/ PluglessL2_Specs.pdf

INL Laboratory Test Setup: PLUGLESS[™] by Evatran

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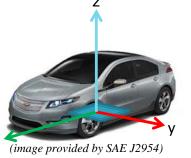
- Three Measurement Nodes
 - AC Grid Input (60 Hz)
 - Control Panel output to Primary Coil (parking pad)
 - DC Vehicle Adaptor output to On-Board Charge Module (OBCM)
 - Secondary coil output was unable to be measured due to sealed vehicle-side enclosure





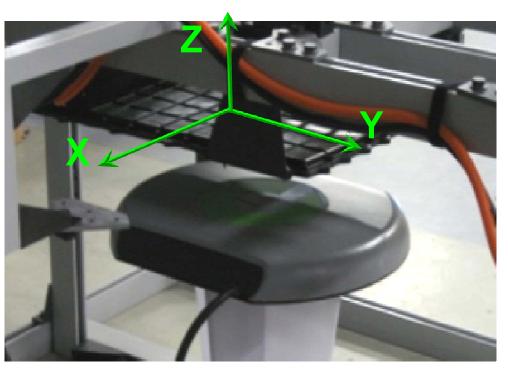
INL Laboratory Test Setup

- Measurement orientation
 - Origin:
 - Bottom face the Vehicle Adapter enclosure
 - Center of the Secondary Coil (inside Vehicle Adapter)
 - X: towards front of vehicle
 - Y: towards drivers side
 - Z: up through roof



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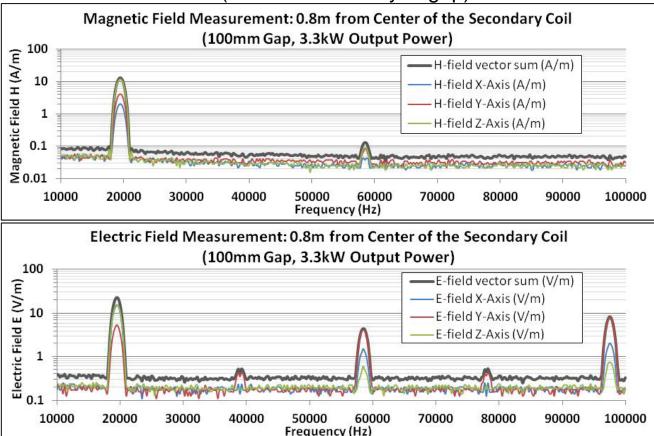
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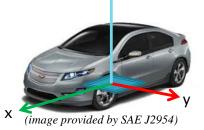
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EM Field Frequency Scan 10kHz – 100kHz

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- 100mm coil to coil gap, 3.3kW output power (nominal case)
- EM field measurement position (baseline test position)
 - X=0mm
 - Y=800mm (from the center of Secondary coil)
 - Z=-50mm (centered vertically in gap)





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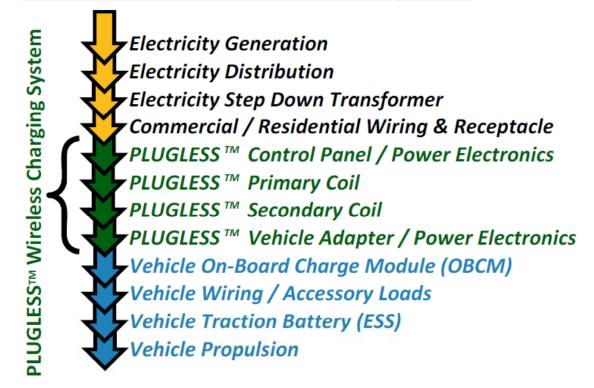
- Operating frequency
 - 19.5 kHz
- Peak Magnetic Field (H-field)
 - 12.9 A/m
 - (16.2 μT)
- Peak Electric Field (E-field)
 - 22.1 V/m

Definition: System Efficiency

System Efficiency = Energy into PLUGLESS[™] Vehicle Adapter Energy into PLUGLESS[™] Control Panel

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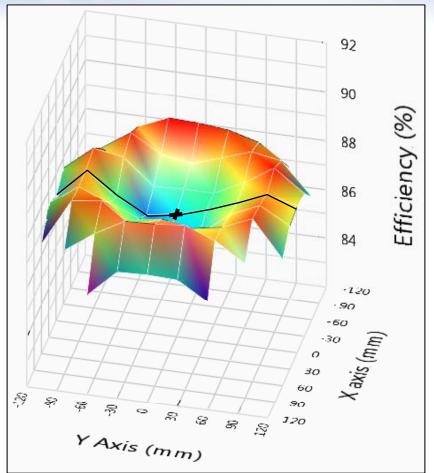
Power Flow from Generation to Vehicle Operation



System Efficiency Variation with Coil Position

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- 3.3 kW output power
- 100mm gap between coils
- X-axis and Y-axis show Primary Coil position relative to Secondary Coil



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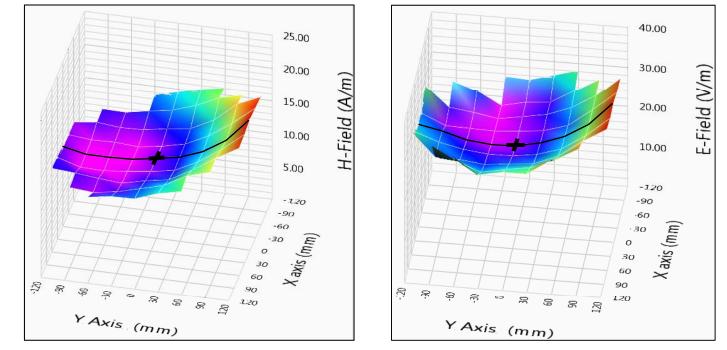
Efficiency Results (at 3.3 kW output with 100mm gap)

Maximum Efficiency (%)	88.8%
Nominal Efficiency (%)	87.0%
Minimum Efficiency (%)	86.1%

Primary Coil position relative to Secondary Coil (mm) (-90,-30) (0,0) (120,-60)

EM Field Variation with Coil Position

- 3.3 kW output power
- 100mm gap between coils
- X-axis and Y-axis show Primary Coil position relative to Secondary Coil



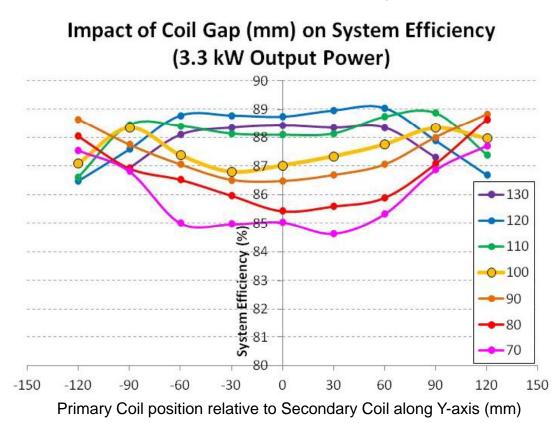
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EM Field Results (at 3.3 kW output wit	h 100mm gap)	Prima
Maximum H-field (A/m)	21.9	(0,12
Nominal H-field (A/m)	12.9	(0,0)
Maximum E-field (V/m)	35.2	(60,1
Nominal E-field (V/m)	22.1	(0,0)

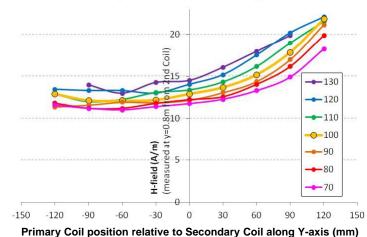
Primary Coil position relative to Secondary Coil (mm) (0,120) (0,0) (60,120) (0,0)

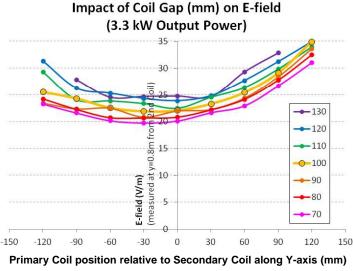
Coil to Coil Gap Impact on System Efficiency and EM Field

- 3.3 kW output
- EM field measured at
 - X = 0.0 m Y = 0.8 m
 - Centered vertically in gap (Z=-50mm)



Impact of Coil Gap (mm) on H-field (3.3 kW Output Power)



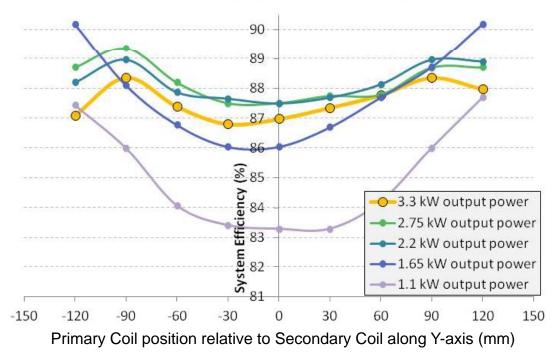


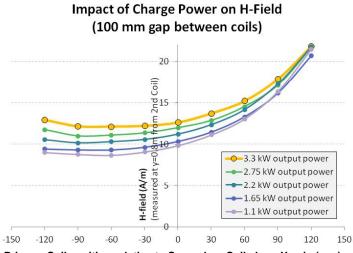
Output Power Impact on System Efficiency and EM Field

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- 100mm coil to coil gap
- EM field measured at
 - X=0.0m Y=0.8m
 - Centered vertically in gap (Z=-50mm)

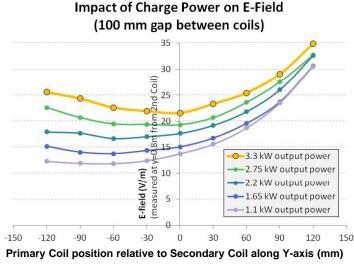
Impact of Charge Power on System Efficiency (100 mm gap between coils)

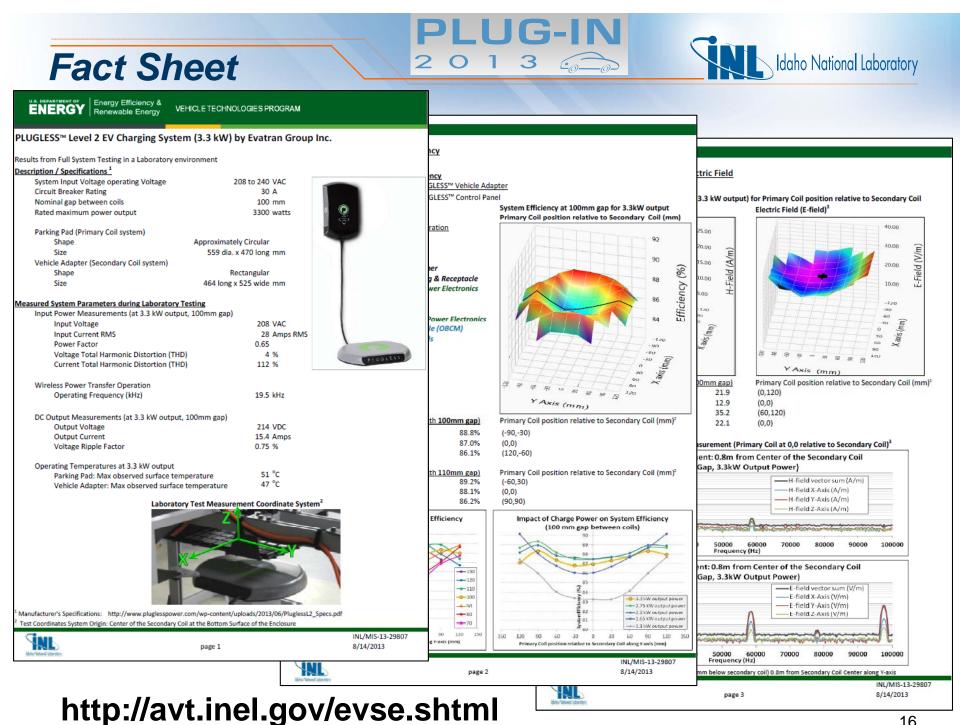




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Primary Coil position relative to Secondary Coil along Y-axis (mm)







- INL's laboratory testing of the PLUGLESS[™] Wireless Charging system by Evatran Group Inc. is complete
 - System Efficiency and EM field measurement impact from

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- Coil to Coil Position
 - Gap
 - Alignment Offset
- Output Power
- EM field meter measurement location
- Fact Sheet has been published

- http://avt.inel.gov/evse.shtml



Acknowledgement

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More Information

http://avt.inl.gov