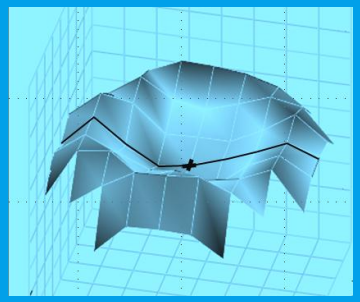
DC FAST, WIRELESS, AND CONDUCTIVE CHARGING EVALUATION PROJECTS

Matt Shirk, Idaho National Laboratory


SAE Hybrid and Electric Vehicle Technologies Symposium
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SAE INTERNATIONAL

Idaho National Laboratory

INL/CON-13-30492

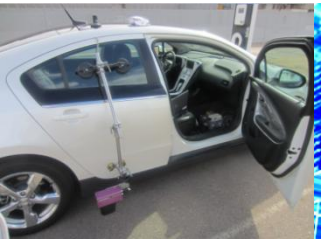
Overview

Idaho National Laboratory – Advanced Vehicle Testing Activity

- US Department of Energy Vehicle Technology Office
- INL lead lab for light-duty, on-road advanced vehicle and infrastructure testing
- Testing partner Intertek Testing Services Arizona - on-road and track vehicle testing, battery lab testing

Grid Connected Electric Vehicles and Infrastructure Research and Testing Projects

- ‘Effects of Electric Vehicle Fast Charging on Battery Life and Vehicle Performance’ study
  - On Road
  - Lab Cycling
- Wireless charging system testing
- Conductive EVSE testing



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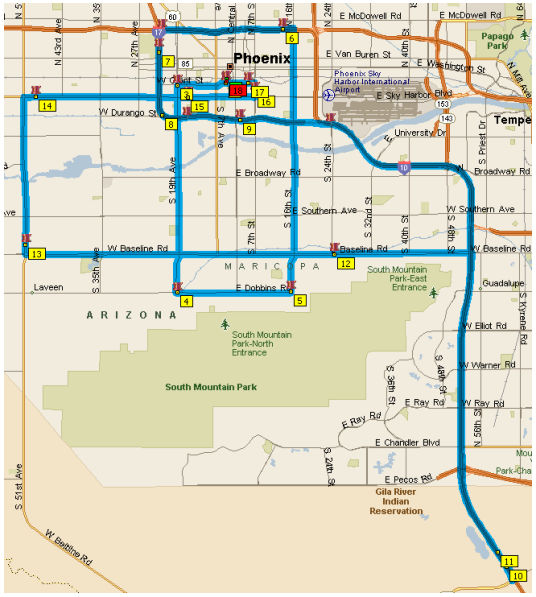
Effects of Electric Vehicle Fast Charging on Battery Life and Vehicle Performance Study – On Road Cycling Design

Evaluate changes in batteries between vehicles charged exclusively AC L2 or DCFC

- Two 2012 Nissan Leafs – DC Fast Charged Only (50 kW)
- Two 2012 Nissan Leafs – AC Level 2 Charged Only (3.3 kW)

Other variation in use minimal among the four EVs

- Fixed public road route in Phoenix, AZ
- Vehicles driven in pairs – 1 DCFC with 1 ACL2
- Dedicated drivers rotated through cars
- Auto climate control set at 72ºF



Vehicles driven/charged twice per day

- Each vehicle driven one morning shift, one evening shift
- Morning Shift 1, followed by Morning Shift 2
- Evening Shift 1, followed by Evening Shift 2
- Vehicles switch pairing, and shift number daily
- Vehicles return to base from local urban loop when 5 mi estimated range remains

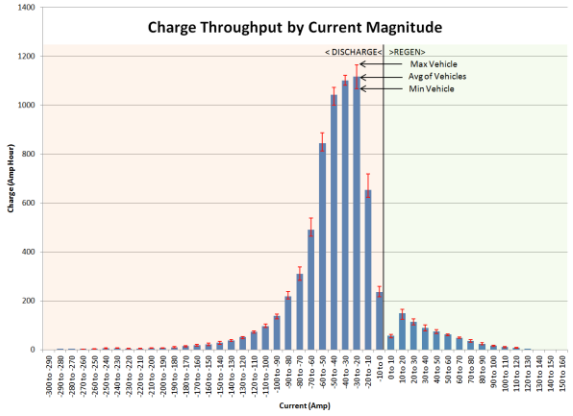
Effects of Electric Vehicle Fast Charging on Battery Life and Vehicle Performance Study – On Road Cycling Data Collection

Continuous 1 Hz data collected from each car during driving, charging

- Battery Voltage, Current, Temperature, State-of-Charge
- Vehicle Speed
- Ambient Air Temperature

The driving data is used

- Understand demands on battery, differences between vehicles
- Validate minimal differences in operation outside of charging
- Observe changes in range over time



Effects of Electric Vehicle Fast Charging on Battery Life and Vehicle Performance Study – Vehicle Performance Testing

Track Testing for Vehicle Performance

- Performed at Beginning of Study (~70 miles on Odometer) and at 50,000 Miles (Pending)

Beginning of Study Acceleration testing results

Description	VIN 1011 0-60 mph [1,2,3]	VIN 2078 0-60 mph [1,2,3]	VIN 2183 0-60 mph [1,2,3]	VIN 4582 0-60 mph [1,2,3]
Acceleration Duration:	10.8 s	10.9 s	10.8 s	10.8 s
Peak Power (DC) from Battery:	89.7 kW	87.7 kW	88.7 kW	89.2 kW
Top Speed at ¼ Mile:	77.0 mph	76.6 mph	76.9 mph	76.8 mph
Top Speed at 1 Mile[4]:	92.4 mph	92.7 mph	92.7 mph	92.6 mph

Beginning of Study 45 mph constant-speed range testing results

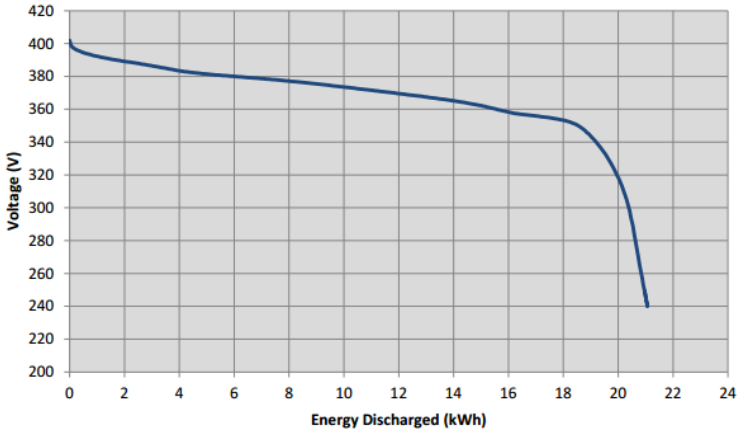
Description	VIN 1011 45 mph Test[2,3]	VIN 2078 45 mph Test[2,3]	VIN 2183 45 mph Test[2,3]	VIN 4582 45 mph Test[2,3]
Average DC power out of battery (kW):	9.2	9.3	9.6	9.2
DC energy out of battery (kWh):	21.0	21.4	20.8	20.8
Battery discharge capacity (Ah):	57.1	59.0	57.5	57.0
Total distance traveled (mi)[4]:	105.8	104.3	99.9	102.6

- Characterize vehicle performance changes over 50,000 miles
- Differences among vehicle charging type groups after 50,000 miles of driving and charging

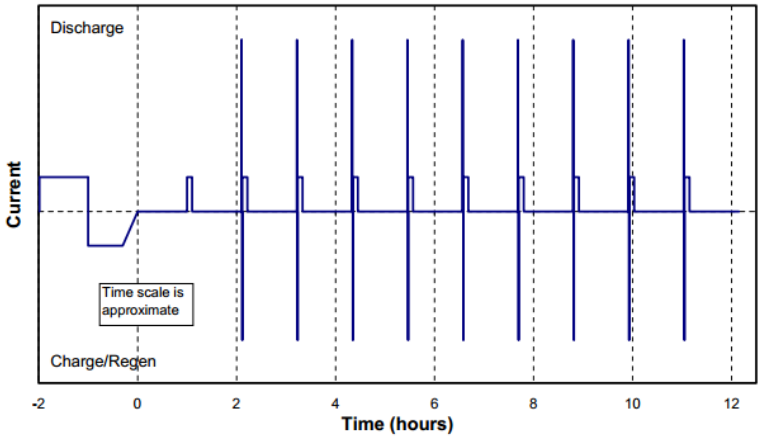
Effects of Electric Vehicle Fast Charging on Battery Life and Vehicle Performance Study – Battery Performance Testing

Batteries tested when vehicle new, 10,000 mile intervals

- **Capacity – C_3/3 constant current discharge test (22.07 A)**



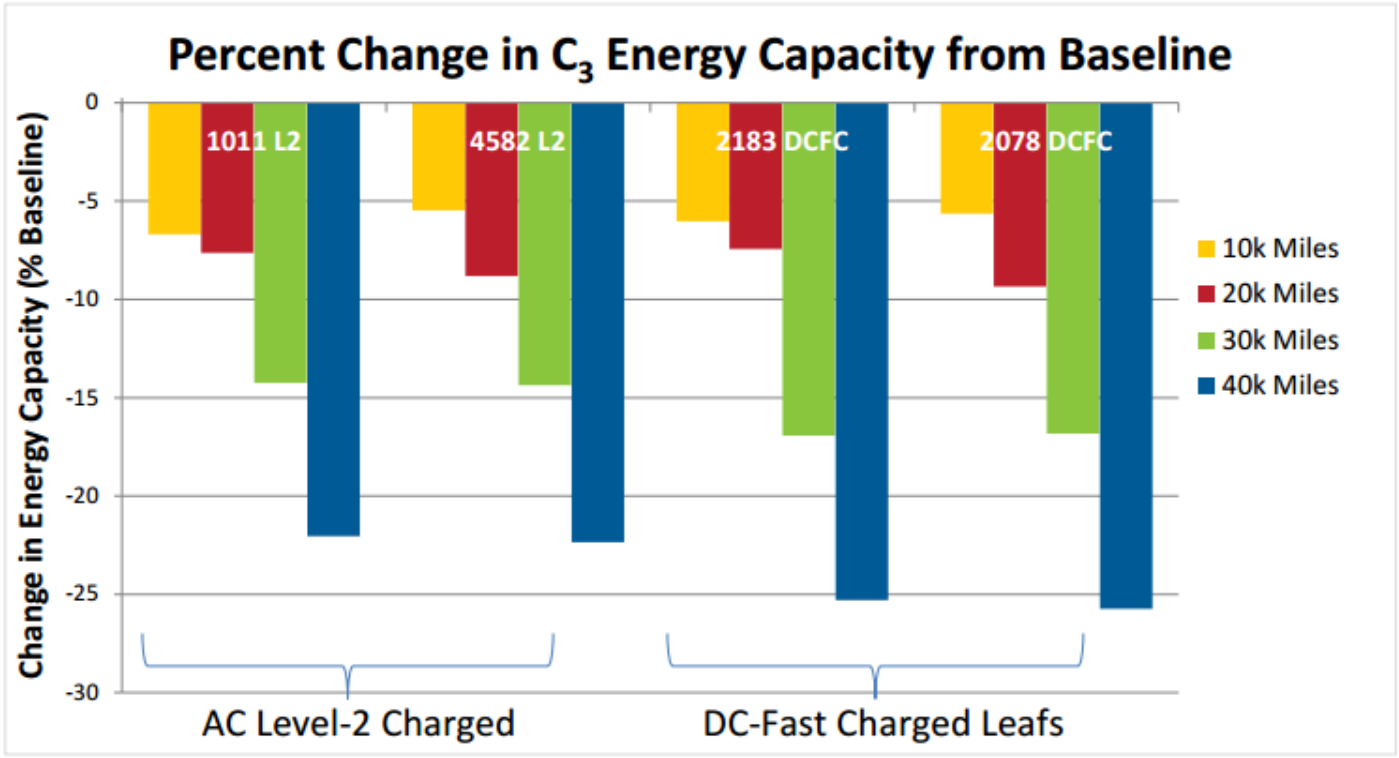
- **Power Capability and Internal Resistance – Electric Vehicle Pulse Power Test and Low Peak Power tests**



Effects of Electric Vehicle Fast Charging on Battery Life and Vehicle Performance Study – Results to Date

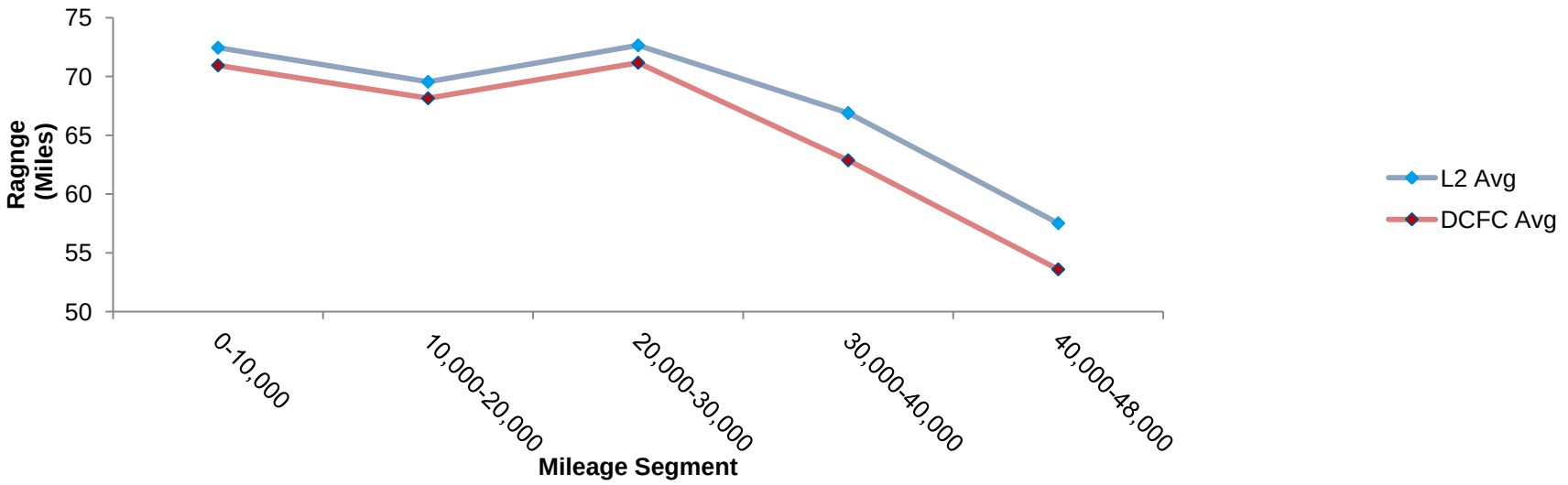
C_3 Energy Capacity[2] (kWh)

	1011 L2	4582 L2	2183 DCFC	2078 DCFC
Baseline (New)	23.31	23.59	23.38	23.24
10,000 Miles	21.75	22.3	21.97	21.93
20,000 Miles	21.53	21.51	21.64	21.07
30,000 Miles	19.99	20.2	19.42	19.33
40,000 Miles	18.10	18.34	17.53	17.37



Effects of Electric Vehicle Fast Charging on Battery Life and Vehicle Performance Study – Results to Date

Average Range per Charge Grouped by Charge Type

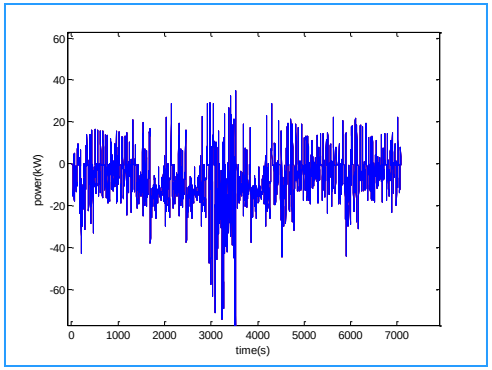


Average Miles per Day					
Mileage Interval	Timeframe	L2-1011	L2-4582	DC-2183	DC-2078
0-10,000	Oct-Dec	144.9	144.9	139.2	144.6
10,000-20,000	Jan-Mar	137.0	141.2	136.1	136.5
20,000-30,000	Apr-Jun	146.0	144.6	142.2	142.5
30,000-40,000	July-Sep	134.3	133.3	125.7	125.8
40,000-48,000	Oct-Feb	115.9	114.2	106.5	107.9

Effects of Electric Vehicle Fast Charging on Battery Life and Vehicle Performance Study – Laboratory Cycling and Performance Testing

Two additional 2012 Leaf Packs are cycling at 30˚ C in the laboratory

- Identical drive/regen power profile for discharge cycle
- One charge power limited at 3.3kW, other at 50kW
- Two cycles per day – Bitrode FTF power processing machines
- Fixed temperature (30ºC), removes temperature variable – Cincinatti Sub Zero walk-in chambers
- Primary – compare AC L2 lab results to DCFC lab results
- Secondary – compare on-road to lab, compare constant temperature to seasonal variation and extremes



Wireless Charging Testing Overview

Systems are tested to characterized

- System efficiency
- Electric/Magnetic field strength
- Impact on grid – power quality, harmonics, etc

Investigate impact of variation in

- Coil-to-coil alignment
- Gap between coils
- Charge power level
- Presence of debris

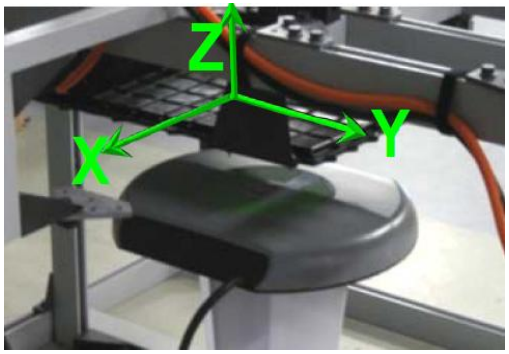
Testing in ‘open air’ in lab vs on-vehicle operation

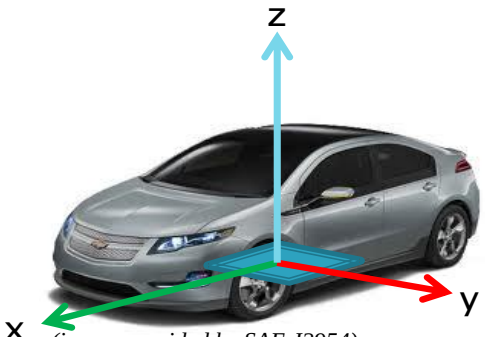
Testing conducted in accordance to SAE J2954 TIR guidelines

Wireless Charging Testing - Results from PLUGLESS™ Wireless Charger from Evatran Group Inc.

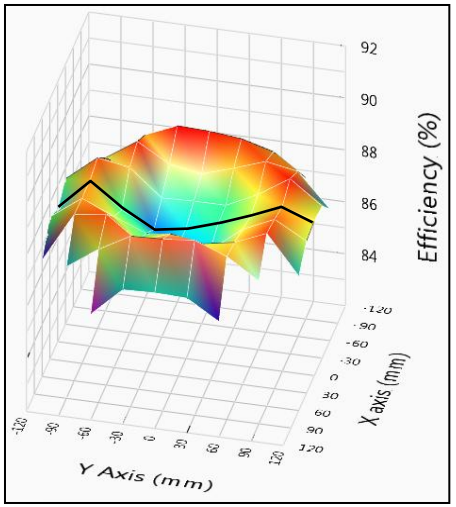
Summary of test results at various coil offsets

Efficiency Results (at 3.3 kW output with **100mm gap**)		Primary Coil position relative to Secondary Coil (mm)
Maximum Efficiency (%)	88.8%	(-90,-30)
Nominal Efficiency (%)	87.0%	(0,0)
Minimum Efficiency (%)	86.1%	(120,-60)





(image provided by SAE J2954)



Full results available as fact sheet on INL AVTA website

http://avt.inl.gov/evse.shtml

Conductive Charger Testing

Benchmark Testing of Conductive Charging Systems

High Feature L2 EVSE

- Smart grid capable
- Integral energy meter
- Backlit display

High Value L2 EVSE

- Basic features/low cost

DC Fast Chargers

Measure Power Consumption

- During charging
- Standby

Cyber Security Testing

EVSE Response to

- Error conditions
- Grid power interruption

http://avt.inl.gov/evse.shtml

Future Work & Acknowledgements

- **DC Fast Charge Study**
  - 50k mile battery lab tests and track vehicle testing scheduled to occur in March, 2014
  - Full paper will include all of the track, on-road, and laboratory data analysis.
  - Laboratory cycling at 30ºC will continue for one year
  - Analysis of the lab cycled packs – comparison with on-road
- **Wireless Charging**
  - Continue testing systems
  - Support SAE J2954 standards committee with testing results
  - Radiated Emissions testing
- **Conductive Charger Testing**
  - Storage assisted fast charger and grid impacts characterization
  - Cyber security testing
  - Metering and feature testing for L2 chargers

- **Summary**
  - All of the information resources referenced here and more: ***http://avt.inl.gov***
- **Acknowledgements**
  - The work presented has been funded by Department of Energy Vehicle Technologies Office