DC Fast Charge Impacts on Battery Life and Vehicle Performance

P.I. - James Francfort
Presenter - Matthew Shirk
Idaho National Laboratory
15 May 2013

VSS113

INL/MIS-13-28644

Overview

Timeline

Field Study
- October 2012-October 2013

Laboratory Study
- April 2013-April 2014

Barriers

- Cost
- Infrastructure
- Risk Aversion
- Constant Advances in Technology

Budget

- DOE Funding: $1.1M
- Spent to date: $0.7M

Partners

- Idaho National Laboratory – Lead Lab
- ECOtality™ – Testing Partner

Objectives

- Remove barriers to EV adoption by quantifying the impacts of DC-Fast Charging an EV on battery pack capacity (vehicle range) and power capability (performance)
  - Barriers addressed: *Cost, Risk Aversion*, and *Infrastructure*
    - providing information to model cost-benefit trade-offs of fast charging
    - benefits PEV consumers and infrastructure providers
- Support modeling and study efforts by collecting complete driving, charging, and battery test data to be shared with VSST labs
  - Barriers addressed: *Constant Advances in Technology*
    - utilizing state-of-the-art test procedures
    - proving timely resultant data to support modeling/simulation

Timeline

On-Road Mileage Accumulation & Testing (4 vehicles/packs)
10/2012-10/2013

- Baseline lab and track testing
- 30k miles on-road – data logging and monitoring
- Battery pack testing at 10k mile intervals
- End-of-test lab and track testing at 30k miles

Laboratory Cycling & Testing (2 vehicles/packs)
10/2012-4/2014

- Baseline lab and track testing
- 30k miles equivalent cycling
- Battery pack testing at 10k mile equivalent intervals
- End-of-test lab and track testing at 30k miles

On-Road Vehicle Cycling/Testing Approach

Four identical, dedicated 2012 Nissan Leafs

Track Testing

- Baseline and End-of-Test
- 0-60 Acceleration Performance
- Constant Speed Range Test

Lab Testing

- Constant Current Discharge Test
- Electric Vehicle Power Characterization Test (EVPC)
- Low Peak Power Test
- Pack removed and tested at 10k road mile intervals

Mileage Accumulation

- Vehicles run in pairs in AM/PM shifts
  - DCFC and L2
- Vehicles at the same
  - Ambient Temp
  - Drive Route (Simultaneous)
- Dedicated Drivers and route
- 1Hz data logging
- Energy throughput & power magnitude distribution comparable between all cars

Charging

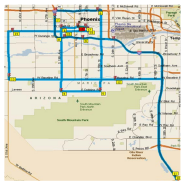
- 2 Cars DC-Fast Charge Only
- 2 Cars AC-Level 2 Charge Only
- 1Hz data logging
- Charging immediately follows drive

Laboratory Pack Cycling/Testing Approach

Two identical, dedicated 2012 Nissan Leafs

Lab Testing

- Constant Current Discharge Test
- Electric Vehicle Power Characterization Test (EVPC)
- Low Peak Power Test
- Tested at 0 and 10k road mile equivalent intervals



Cycle Accumulation

- Both packs cycled identically
- Constant Ambient Temp 30 C
- Cycle profiles based on road vehicle testing

Charging

- 1 Pack DC-Fast Charge Only
- 1 Pack AC-Level 2 Charge Only
- Charging profiles reflect field charging data and pack charge power limits
- Charging immediately follows discharge

Technical Accomplishments – Baseline Track Testing

Baseline track testing - ✓ Complete

Minimal variation between test vehicles at BOT

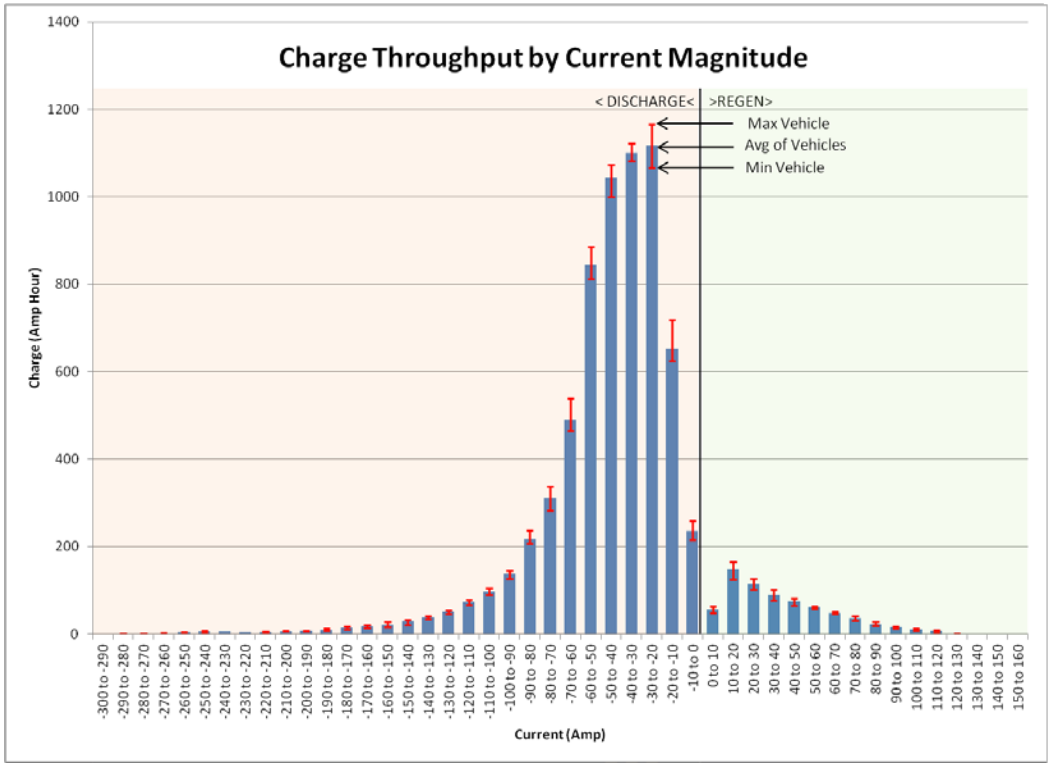
Description	VIN 1011 0-60 mph [1,2,3]	VIN 2078 0-60 mph [1,2,3]	VIN 2183 0-60 mph [1,2,3]	VIN 4582 0-60 mph [1,2,3]
Acceleration Duration:	10.8 s	10.9 s	10.8 s	10.8 s
Peak Power (DC) from Battery:	89.7 kW	87.7 kW	88.7 kW	89.2 kW
Top Speed at ¼ Mile:	77.0 mph	76.6 mph	76.9 mph	76.8 mph
Top Speed at 1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

NOTES:

1. Vehicle track testing at delivered curb weight plus 332 ± 10 lbs (including driver and test equipment), distributed in a manner similar to the original curb loading of the vehicle.
2. Performance numbers based on "Normal" vehicle mode.
3. The acceleration and maximum speed testing results were averaged from 12 runs in which the vehicle state of charge (SOC) at the beginning of the acceleration run was at 90.9%, 86.3%,81.4%,77.8%,73.7%,70.3%,66.3%,62.20%,57.7%,52.7%,48.3%, and 44.4%, respectively.
4. The maximum speed was reached before the one-mile mark.

Technical Accomplishments – On-Road Operation and Data Logging

20k miles/car and lab testing scheduled mid-March



Two-Month Sample of Driving Charge Throughput by Current Magnitude

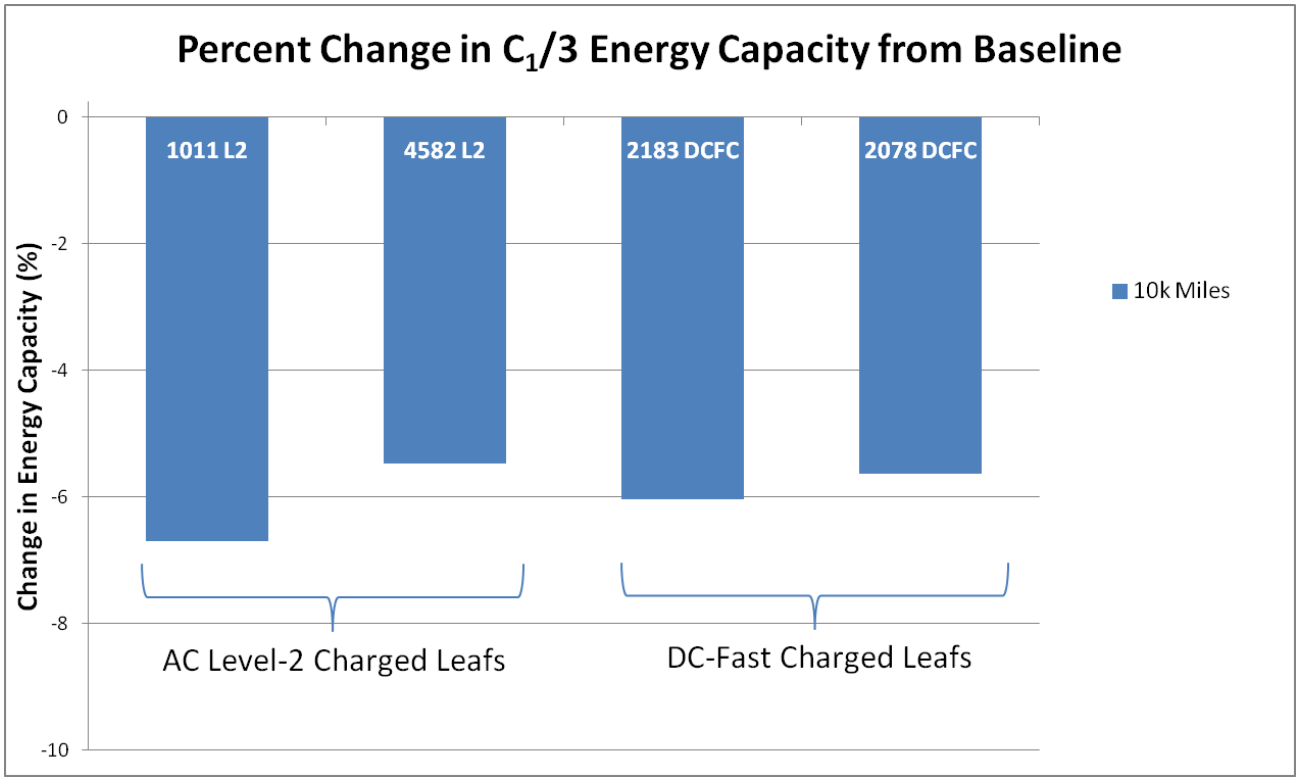
- Monitoring to ensure comparable energy and power use between cars

VIN	Charge Type	Miles	Charges	Avg Miles per Day
1011	AC L2	17858	255	140
4582	AC L2	17929	254	144
2183	DCFC	17699	258	139
2078	DCFC	17640	255	137

March 8, 2013 On-Road Mileage Accumulation

Technical Accomplishments – Baseline & 10k pack tests

Baseline and 10k laboratory pack testing (on-road packs) ✓ Complete

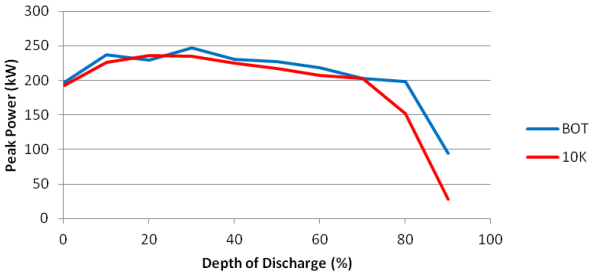


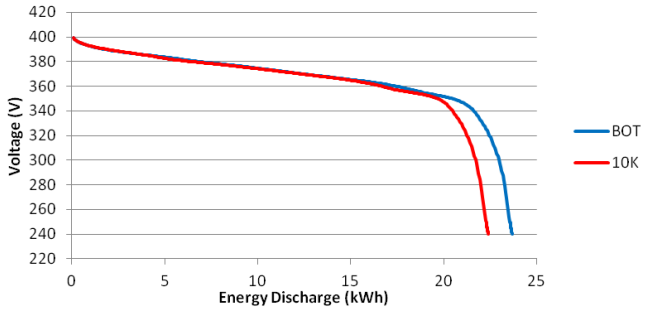
At 10k miles, no significant differences in Energy Capacity between L2 and DCFC groups

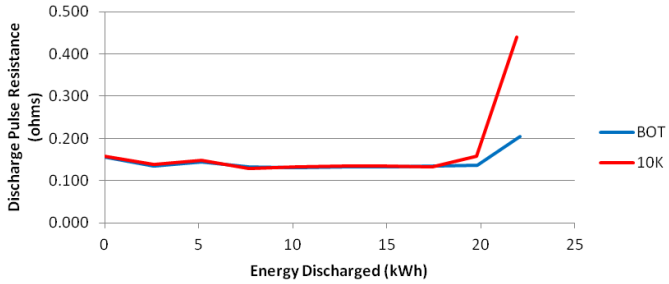
Full results of pack testing published in progressive reports (AVTA web)

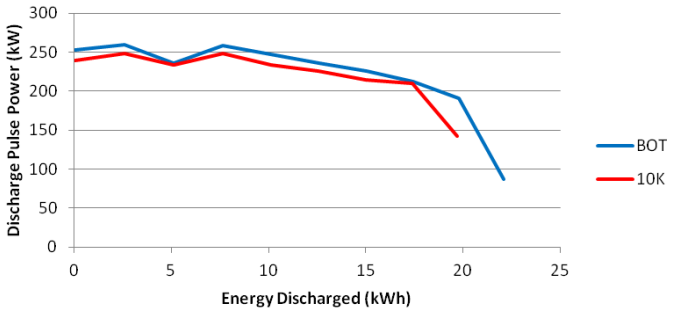
Technical Accomplishments – Baseline & 10k pack tests (Continued)

- **Static Capacity** (C1/3 Constant Current Discharge Test)
  - Ah and kWh capacity
- **Electric Vehicle Power Characterization Test**
  - Charge and Discharge Internal resistance vs. SOC
  - Charge and Discharge Power Capability vs. SOC
- **Low Peak Power Test**
  - Discharge Power Capability vs. SOC









Collaboration

- Idaho National Laboratory is the prime, with ECOtality serving as the sole sub-contractor
  - ECOtality cycling/testing 4 on-road vehicles
  - INL cycling/testing 2 lab vehicle packs
  - Round-Robin testing of 2 packs at each facility at BOT, EOT
- Collaboration with USABC to utilize the state-of-the-art EV pack testing protocols for benchmark testing

Future Work

FY13

- Complete 30k on-road testing, with laboratory pack testing at 20k and 30k
- Continue INL laboratory cycling and testing towards 30k on-road testing pack-cycling equivalent

FY14

- Complete laboratory pack testing
- Report on full results of on-road and lab testing
- Propose continuation of project and study to link cell or module testing to full-pack testing
- Planned peer-reviewed paper on key findings of study

Summary

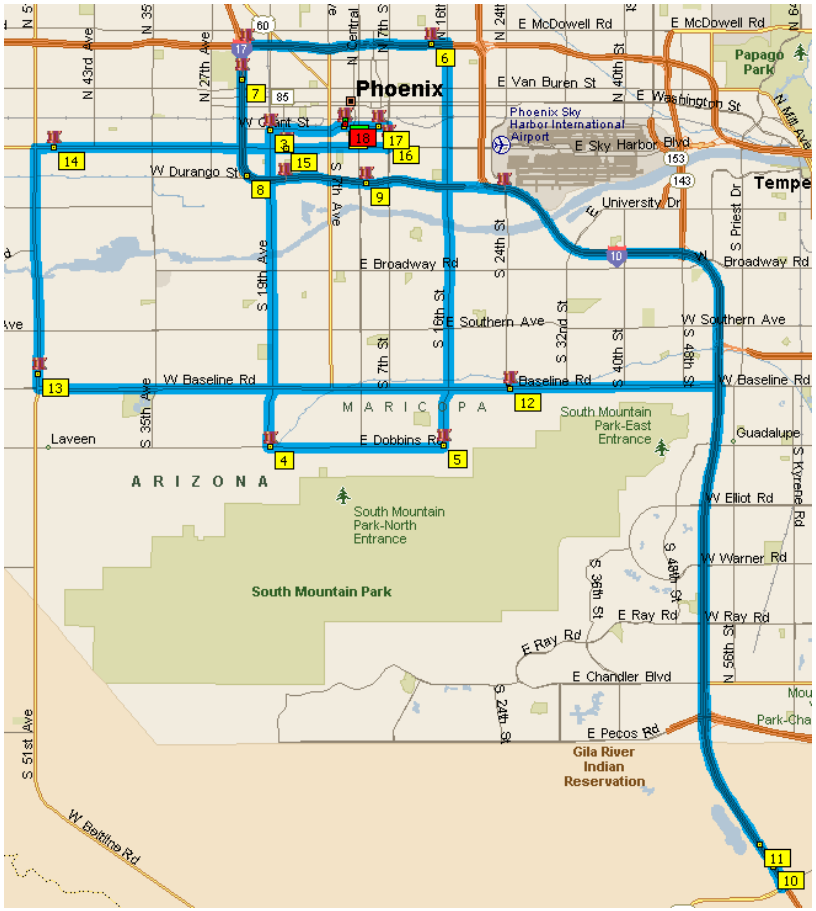
- On-Road operation of 4 identical EVs, dedicated to DC-Fast or AC Level-2 Charged
- Laboratory cycling and testing of 2 identical EV packs: DC-Fast or AC Level-2 Charged
- Comparison of battery performance between types of charging at 10, 20, and 30 thousand miles
- Lab testing at constant, moderate temps to remove temperature variability – compare trends back to on-road tested packs as secondary study
- Complete data logging on-board to understand ambient conditions and usage
- Additional EV and charging data available to AVTA partners

Technical Back-Up Slides

Technical Backup Slide 1

Description		VIN 4420	VIN 3143	VIN 1011		VIN 4582		VIN 2183		VIN 2078	
		Shipped to INL after Battery Test		AC Level 2 Charged				DC Fast Charged			
Test	**Measureable**	**BOT**	**BOT**	**BOT**	**10K**	**BOT**	**10K**	**BOT**	**10K**	**BOT**	**10K**
Static Capacity	Ah Discharged (Ah)	64.30	64.59	63.95	59.73	64.81	61.19	64.28	60.32	63.86	60.24
	kWh Discharged (kWh)	23.40	23.47	23.31	21.75	23.59	22.30	23.38	21.97	23.24	21.93
EVPC	Charge Resistance (Ohm) @ 20% DOD (kW)	0.1132	0.1112	0.1144	0.1136	0.1144	0.1152	0.1144	0.1136	0.1132	0.1124
	Discharge Resistance (Ohm) @ 80% DOD (kW)	0.1360	0.1335	0.1420	0.1770	0.1360	0.1586	0.1361	0.1707	0.1390	0.1689
	Charge Power Capability @ 20% DOD (kW)	73.88	74.85	73.73	78.30	73.17	77.49	74.08	79.72	75.30	78.35
	Discharge Power Capability @ 80% DOD (kW)	198.46	202.52	190.39	141.96	198.25	164.93	197.71	150.13	193.13	152.94
LPP	Power Capability @ 80% DOD (kW)	198.44	201.77	182.35	134.73	198.38	151.89	195.55	135.69	186.43	145.25

Technical Backup Slide 2



Controls to minimize variation

- *Fixed route*
- *L2, DCFC vehicle pairs run simultaneously*
- *Dedicated drivers*
- *Same climate control settings – auto/72 F*
- *Electronic data logging and manual logs*
- *Power levels and energy throughput monitored by vehicle*