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Electric Drive and Advanced Battery and Components Testbed (EDAB)

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Energy Storage & Transportation Systems

Idaho National Laboratory

Advanced Vehicle Testing Activity (AVTA)

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Overview

Timeline

- FY10 - Project planning, vehicle design, and test plan development
- FY11 - Vehicle conversion, acquire ESS for testing
- FY12 – Calibrate vehicle control system to battery requirements, ESS testing, conduct on road testing

Budget

- FY10 – $ 356,000
- FY11 – $ 660,000
- FY12 – $ 300,000

Barriers

- Test advanced technology ESS's in on-road conditions
- Test a wide range of ESS's sizes and capabilities (BEV, EREV, PHEV)
- Test power electronics and components in on-road conditions

Partners

- Idaho National Lab - lead
- ECOtality North America - testing
- Oak Ridge National Lab - control system
- AVL North America - vehicle integration

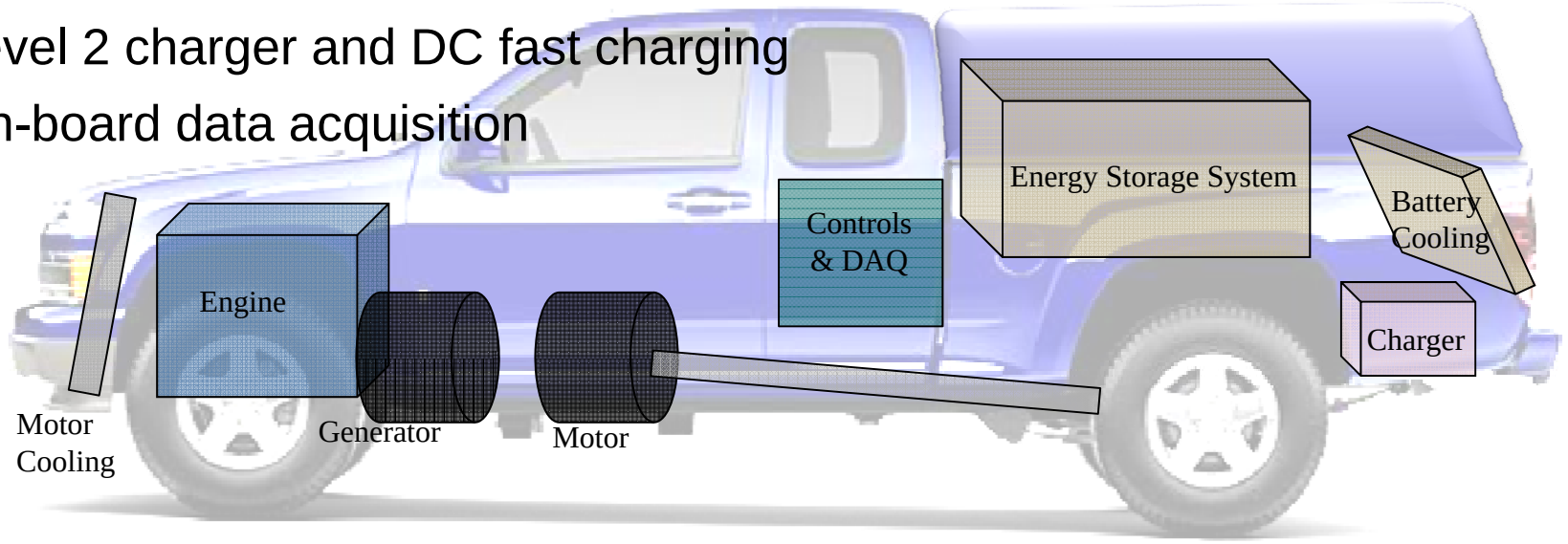
Objective / Relevance

- Provide an on-road and dynamometer capable platform for testing Energy Storage Systems (ESS) developed via DOE ESS supported funding projects
  - Battery Electric Vehicles (BEV)
  - All-Electric Capable Plug-in Hybrid Electric Vehicles (EREV)
  - Blended Plug-in Hybrid Electric Vehicles (PHEV)
- Capture data from ESS performance, capacity fade, and operating condition data during on-road operation
- Capture data from motor and power electronic during on-road operation

Phase 1	**Project Planning (Vehicle specifications, and test plan)**
Phase 2	**Convert vehicle into Series PHEV to enable on-road testing** Safety and Flexibility to accept a wide range of ESS to be tested Controls to enable proper operation of each type of ESS
Phase 3	**Test the Energy Storage System** Dynamometer (Finalize calibrations and Baseline tests) Battery laboratory testing (beginning of life, during, and end of life) On-road testing until ESS “end of life” (or 3 yrs max or 100k miles)

Approach - Vehicle Testbed

- Mid sized Pickup truck
  - ESS mounted in truck bed
  - Truck cap will cover / protect ESS
- Series powertrain configuration
- Controls system has three control configurations with a weight / road load emulation algorithm to test ESS for intended operation
  - BEV compact 4 door electric sedan (3000 lbs)
  - EREV mid sized 4 door sedan (3500 lbs)
  - Blended PHEV mid sized SUV (4000 lbs)
- Level 2 charger and DC fast charging
- On-board data acquisition



Approach - Overall Test Plan

- Chassis Dynamometer testing (ORNL)
  - Finalize control system calibrations specific to ESS
  - Vehicle baseline testing for each ESS
- ESS Reference Performance Testing (RPT)
  - Beginning of life (BOL)
  - Periodically during on-road testing
    - every 1,500 miles or 30 days of driving(40 to 60 cycles)
  - End of life (EOL)
- On-Road Testing
  - In Phoenix area
  - Approx. 50% city, 50% highway driving
  - Approx. 100 to 150 miles per day
  - Varying range of driving and charging patterns

Milestones

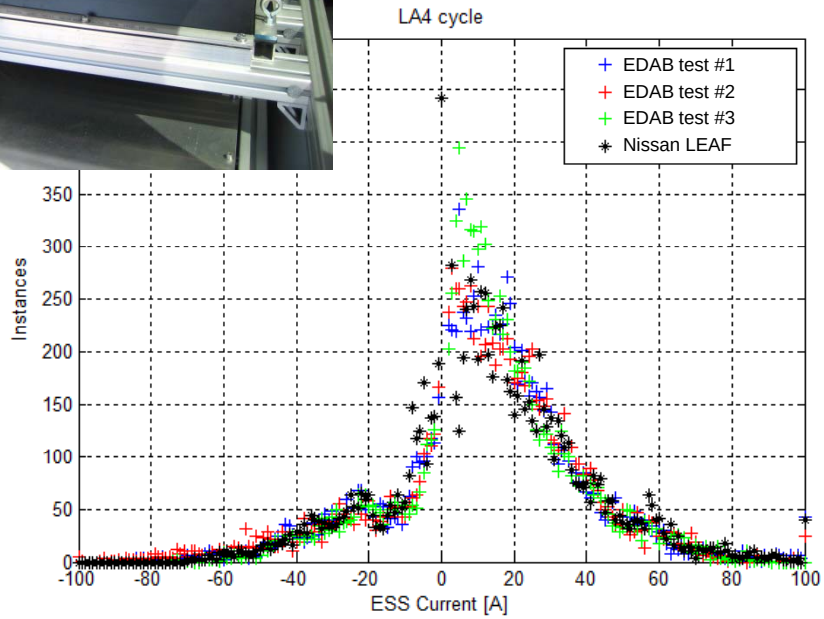
- April 2011 – received 1st ESS (EnerDel Li-ion pack 70 Ah rated)
- June 2011 – vehicle conversion complete
- Nov 2011 – fully functional ESS integrated into vehicle
- Feb 2012 – control system calibration complete
- Feb 2012 – BOL ESS testing complete
- March 2012 – on-road testing initiated

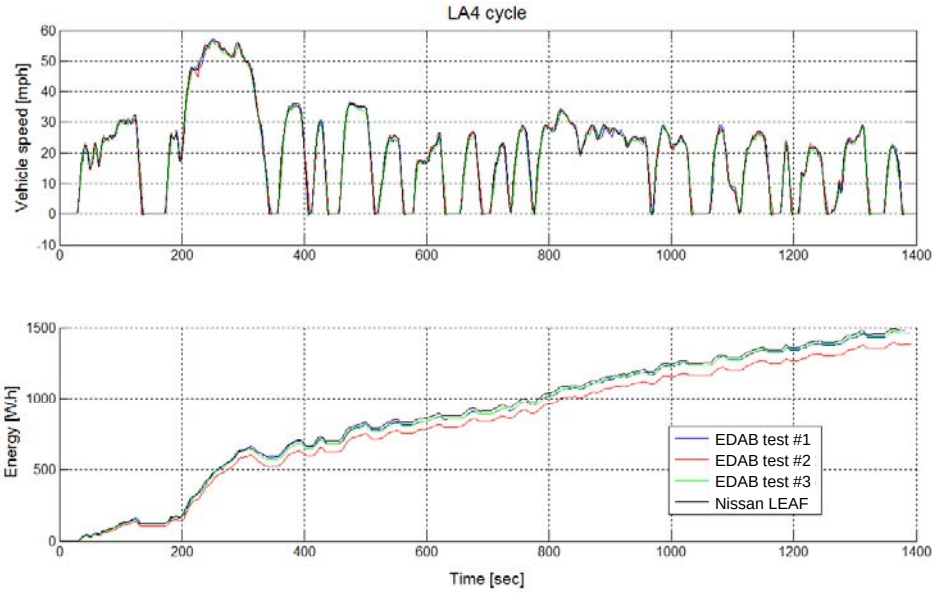
Technical Accomplishments

- Vehicle conversion into Series PHEV complete
- ESS successfully integrated into vehicle after two ESS issues are corrected by ESS manufacturer
- Control system calibration complete (ORNL)
  - ESS power and energy within 6% of baseline BEV (Nissan Leaf)
- Baseline dynamometer testing completed (ORNL)
- On-road testing initiated
  - On-road driving daily of 2 cycles (drive, charge, drive, charge)
  - initial results show ESS operating as in a BEV

Technical Accomplishments (continued)

- Control system is calibrated to utilize the ESS within the operating range of a Nissan Leaf
- Energy throughput over standard drive cycles differs less than 6% from Nissan Leaf
- Current profiles are very similar

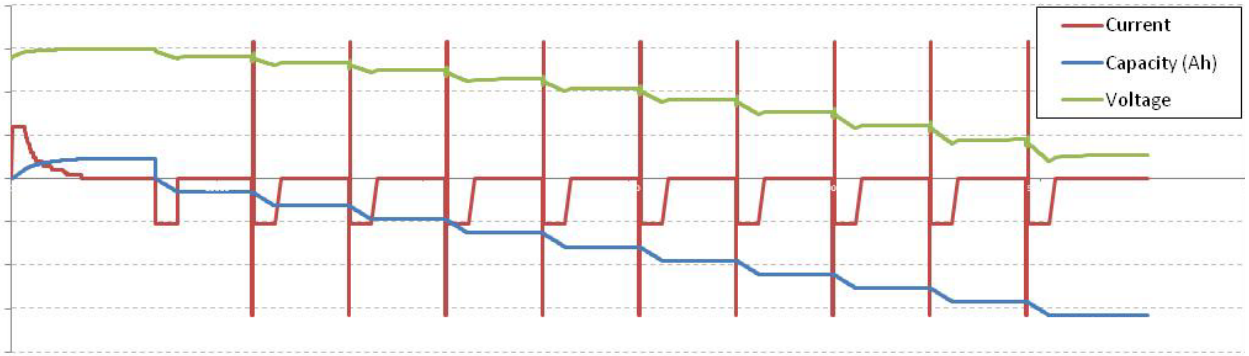




Technical Accomplishments (continued)

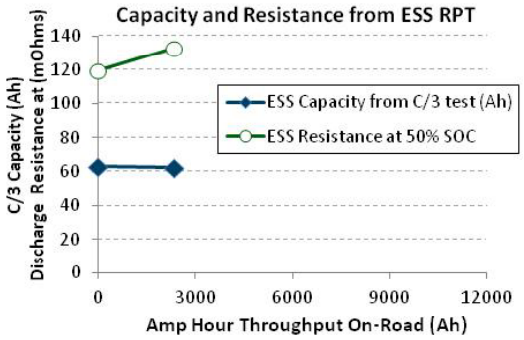
- Beginning of Life ESS testing is complete
  - C/3 capacity testing
  - EVPC power pulse testing

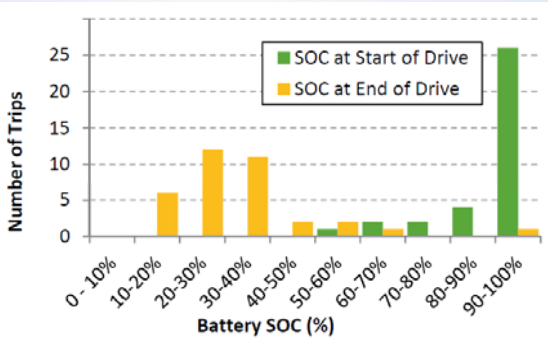
- Beginning of Life testing results
  - Capacity (C/3)
    - 63.1 Ah
  - EVPC Discharge Resistance (@ 50% DOD)
    - 120 mOhms
  - EVPC Charge Resistance (@ 50% DOD)
    - 96 mOhms



Technical Accomplishments (continued)

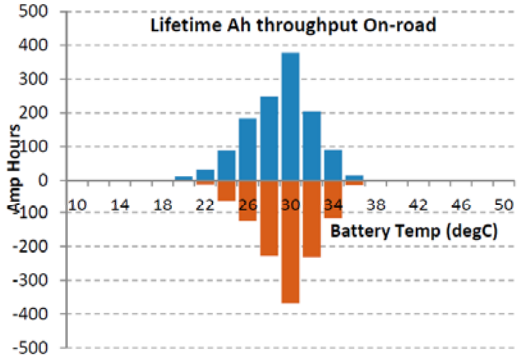
- On-road testing commenced March 2
  - EnerDel 70Ah pack

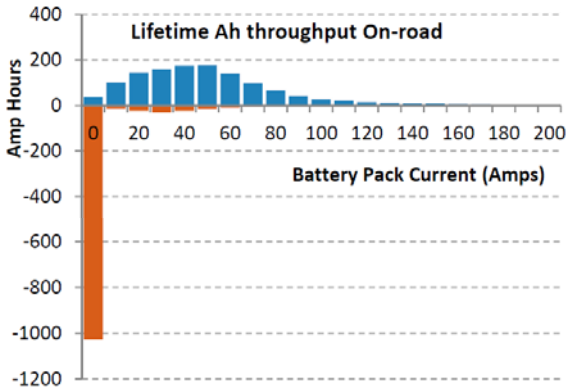




On-road results to date

- 2,500 Ah total throughput
- 0.7% ESS capacity fade
- 11% increase in discharge resistance
- 1,600 miles driven
- 243 DC Wh/mi
  - Very similar to Nissan Leaf operation
- 54% City / 46% Hwy
- On-road ESS temperature operating between 20 degC and 35 degC
- Most on-road ESS operation below 70 A (i.e. below C_1 rate)





Collaboration

- Results from ESS testing will be provide to U.S. DOE, Tech Teams, and other National Labs for use with modeling tools, energy storage development, and improved understanding of operating conditions of ESS's during driving and charging
- After ESS has reached End of Life (EOL), the ESS will be transferred to 2nd Use ESS projects

Future Work

- Test several ESS's
  - Designed for BEV, or EREV, or PHEV
  - Various ESS chemistries or configurations
- Two to Four additional test platforms to be built after successfully demonstrating on-road testing capabilities and flexibility
- Utilize and test various motor and power electronics technologies

Summary

- The project is in Phase 3 (ESS testing)
  - Baseline dynamometer testing and controls calibration is complete
  - Beginning of Life ESS testing is complete
  - On-road ESS testing has been initiated

- Provide data/results from on-road operation of advanced technology ESS
  - Power and Capacity Fade results
  - Impact of driving / charging patterns on ESS
  - Temperature operation effects
  - Cell balancing impact and interaction by on-road operation
  - Power and energy utilization impact
- Provide data / results from on-road operation of motor and power electronics
- Provide EOL ESS to "2nd Use ESS" Experiments

Reviewer-Only Slides

EDAB Synergies with other DOE Activities (PHEV R&D plan)

- Energy Storage
  - Testing mechanism for testing battery pack deliverables from ARRA program
  - Preparation of "end of life" battery packs for use in "2nd use" battery experiments
  - Ability for fast charging (demonstration, communication, impact on battery life)
  - Ability for testing and demonstration of advanced battery system combinations
    - Batteries and ultra capacitors combinations
    - Energy battery and Power battery combinations
- Electric Drive Systems
  - Provide on-road benchmark data to Power Electronics community from one advanced traction drive DC Brushless motor system (others in future with additional vehicle test platforms)
  - System interactions during on-road driving
    - Noise on high voltage bus; temperature limitations / cooling requirements validation; communications challenges (traction drive, battery system, APU)
- Vehicle Efficiency Technologies
  - Provide battery in-use data to modeling community
  - Provide motor and power electronics operation data to modeling community
  - EREV and PHEV controls systems and calibrations utilized