APEEM Components Analysis and Evaluation

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Overview

Timeline

- Start – FY13
- Finish – FY13
- 20% complete

Barriers

- VTP 2011-2015 Multi-year Program plan goal:
  - “Validate, in a systems context, performance targets for deliverables from the Power Electronics and Energy Storage Technology R&D activities”

Budget

- Total project funding
  - DOE share – 100%
- Funding for FY12: $ 200K (DOE APEEM)
- Funding for FY13: $ 300K (DOE VSST)

Partners

- ORNL’s Power Electronics and Electric Machinery group

Project Objective

- **Overall Objective**
  – Validate, in a systems context, performance targets for deliverables from the Advanced Power Electronics and Electrical Motors R&D activities
- **FY13 Objective**
  – Evaluate current and proposed electric machine and power electronics technology in the context of a vehicle to understand the applicability of a particular technology to a given powertrain and to determine areas/regions for component design improvement based upon system usage patterns
  – Enhance the current benchmarking and prototype evaluation capabilities of the DOE APEEM with the addition of transient based testing through use of the ORNL Vehicle Systems Integration Laboratory.

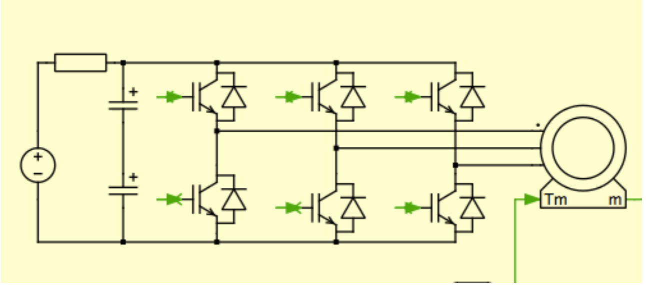
Milestones

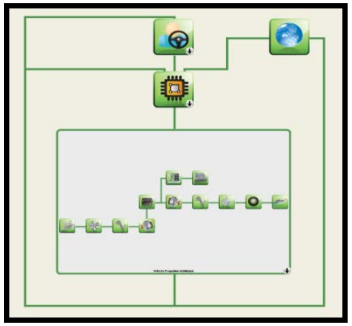
Date	Milestones and Go/No-Go Decisions	Status
Sept-2013	Milestone: Evaluate current DOE APEEM motor technology at a vehicle system level to understand powertrain applicability and identify regions for potential electric machine design improvement	**In Progress**
Sept-2013	Milestone: Enhance DOE APEEM benchmarking capability to include transient based component-in-the-loop testing through the ORNL VSI laboratory	**In Progress**

Approach/Strategy

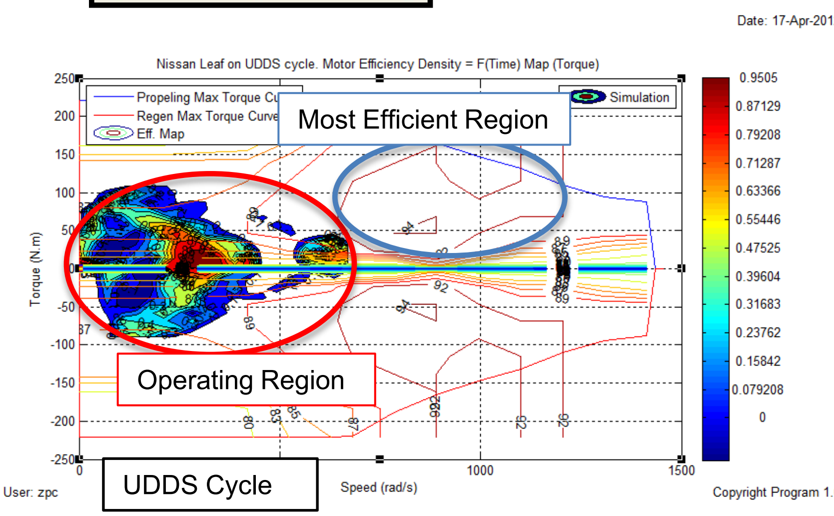
- Support DOE APEEM modeling activities with:
  - Autonomie simulations to evaluate electric powertrain technologies at the vehicle system level
  - Co-simulation of circuit level simulation software (PLECS and pSPICE) to model the traction drive system independent of the vehicle system
  - Systems approach evaluation of APEEM technologies in simulation environment
    - Variety of powertrain configurations
    - Different drive cycles: UDDS, US06, HWFET, and LA92.
  - Identification of frequent operating regions for potential design improvement or driveline optimization.

PLECS
Circuit Simulation



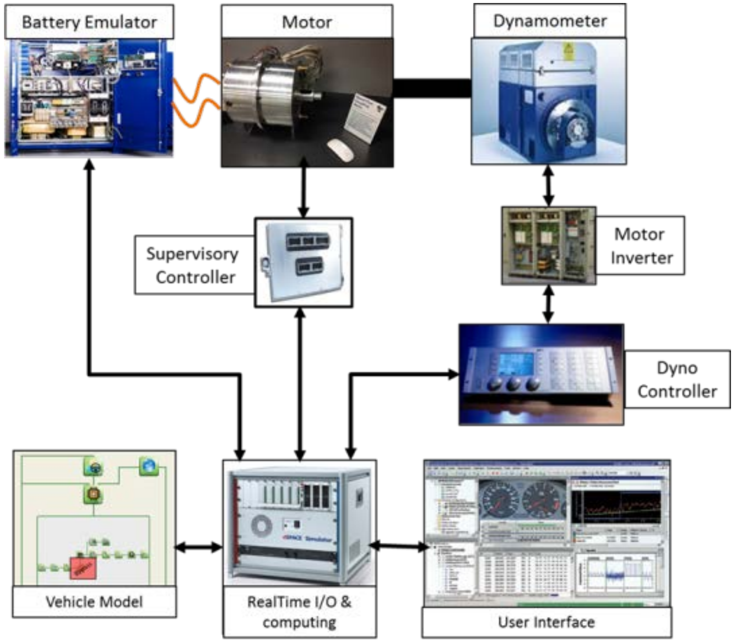


Autonomie
Vehicle Simulation



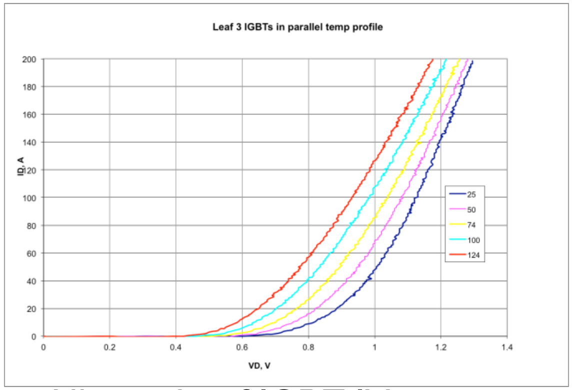
Approach/Strategy

- Support DOE APEEM benchmarking activities:
  - Develop transient-based testing hardware-in-the-loop system featuring:
    - 400kW, 800V battery emulator
    - 220kW, 12000rpm, low inertia dynamometer
    - Real time computer and interface modules
  - Characterize new technologies and investigate transient behavior and integration issues in various powertrain architectures through hardware-in-the-loop practices.
    - Real power electronics under test
    - Virtual vehicle emulation

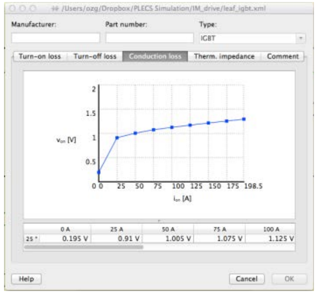


Technical Accomplishments
Simulation Study

- Baseline Nissan Leaf TDS modeling - Inverter

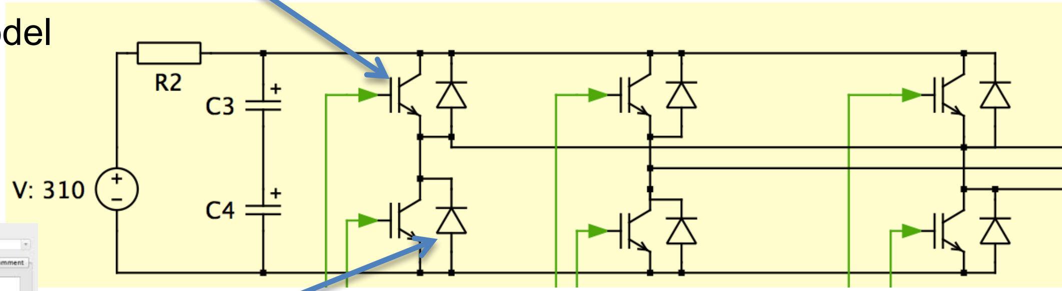


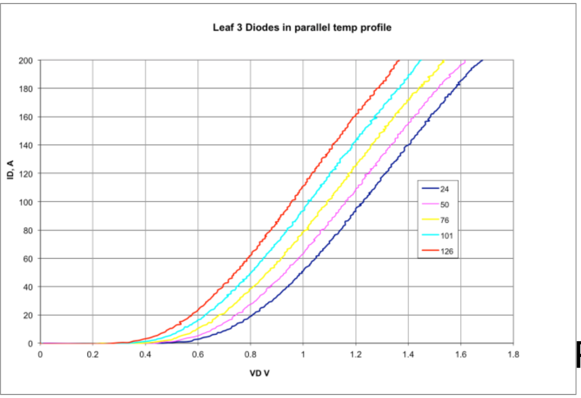
Nissan Leaf IGBT IV curve

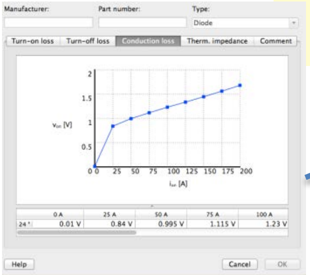


PLECS IGBT model

- Tested and characterized the Nissan Leaf IGBTs and Diodes for conduction and switching losses.
- Inserted the loss data into the PLECS models





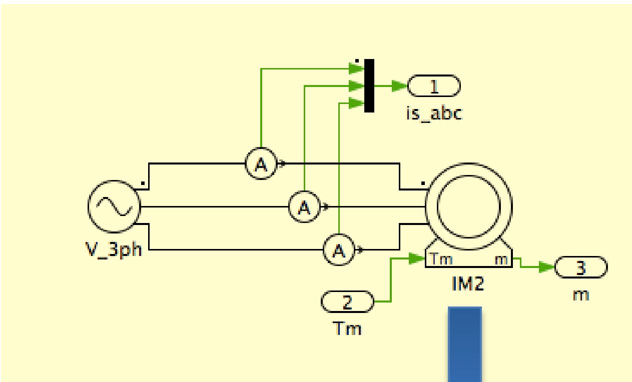


PLECS diode model

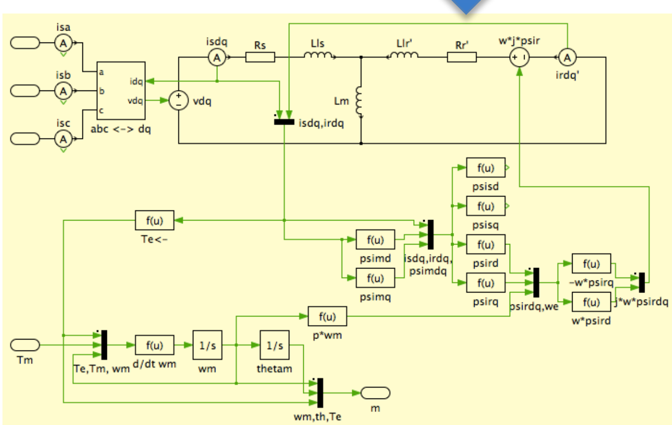
Nissan Leaf diode IV curve

Technical Accomplishments
Simulation Study

- High Speed Induction Machine Modeling



PLECS Induction Machine Model



Induction machine parameters

Induction Machine (Squirrel-Cage) (mask) (link)

Three phase squirrel-cage induction machine. The input signal Tm represents the mechanical torque, in Nm. The vectorized output signal of width 3 contains
- the rotational speed wm, in rad/s
- the mechanical rotor position th, in rad
- the electrical torque Te, in Nm.

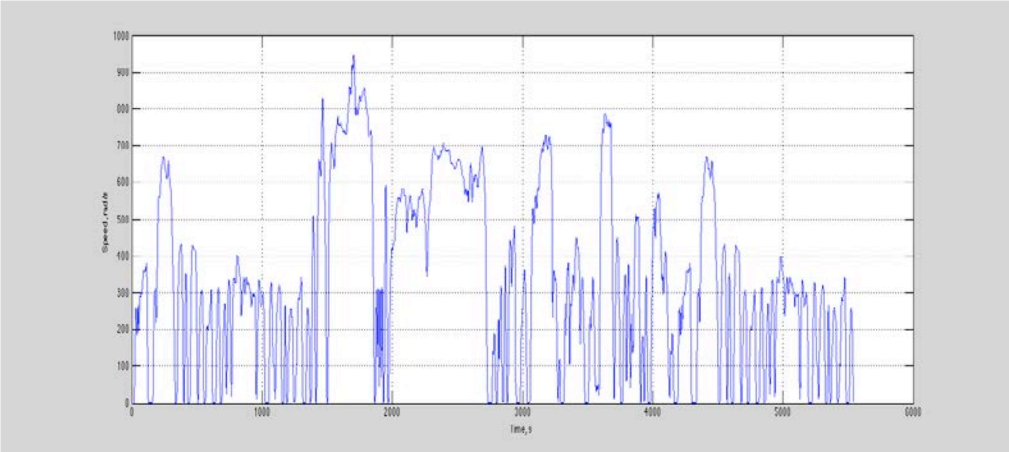
All parameters and electrical quantities are referred to the stator side.

Parameters

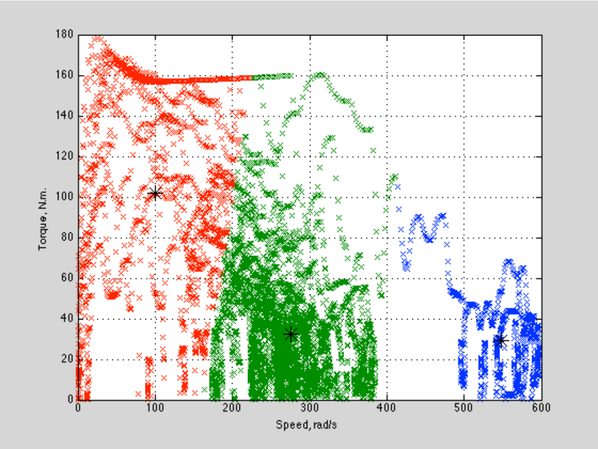
Parameter	Value	Parameter	Value
Stator resistance Rs:	87.6e-3	Friction coefficient F:	0
Stator leakage inductance Lls:	150.6e-6	Number of pole pairs p:	2
Rotor resistance Rr':	36.14e-3	Initial rotor speed wm0:	0
Rotor leakage inductance Llr':	114.86e-6	Initial rotor position thm0:	0
Magnetizing inductance Lm:	2.367e-3	Initial stator currents [isa0 isb0]:	[0 0]
Inertia J:	0.005956	Initial stator flux [psisd0 psisq0]:	[0 0]

Technical Accomplishments
Simulation Study

- Nissan LEAF model was simulated in Autonomie over all of the four driving schedules and the combined driving schedule (CDS).
- The torque vs. speed plot shows three different regions in the motoring mode with most of the activity.



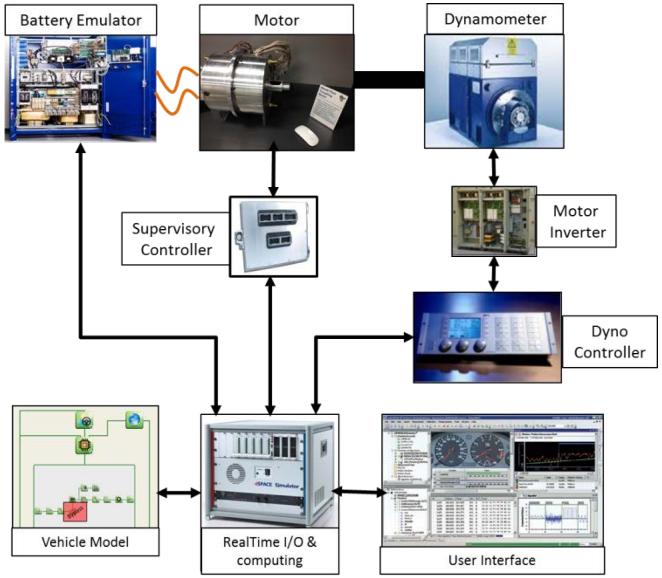
Motor Speed

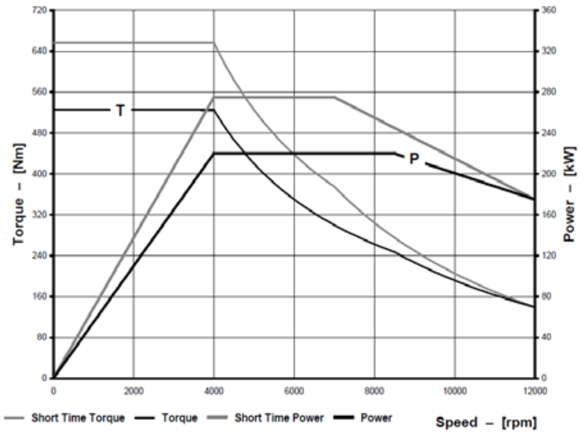


Traction Motor Torque Speed Plot

Technical Accomplishments
Hardware-In-the-Loop Test Capability

- ORNL Vehicle System Integration (VSI) Laboratory Component test cell
  - Component already in place:
    - Battery emulator
      - 400kW
      - 800V , 600A
  - Components to be procured:
    - Low inertia dynamometer
      - 220kW
      - 500Nm, 12000rpm max speed
    - Hardware in the loop real time computer
      - dSPACE
      - Autonomie vehicle model





Collaboration and Coordination

Organization	Type of Collaboration/Coordination
ORNL Power Electronics and Electric Machinery group	Simulation, Motor characterization
DOE APEEM	Enhanced benchmarking support

Proposed Future Work

- **Remainder of FY13**
  - Procure high speed, transient dynamometer and commission it in VSI Lab
  - Support ORNL PEEMRC modeling activities
- **FY14**
  - Support DOE APEEM programs
    - Benchmark electric machines and power electronics in virtual vehicle with new testing facility
    - Provide modeling and simulation support at the vehicle level to evaluate candidate APEEM component technologies

Summary

- Relevance
  - Validate, in a systems context, performance targets for deliverables from the Advanced Power Electronics and Electrical Motors R&D activities
- Approach
  - Systems approach evaluation of APEEM technologies in a simulation environment
  - Characterize new technologies and investigate transient behavior and integration issues in various powertrain architectures through hardware-in-the-loop practices.
- Technical accomplishments and Progress
  - Specified and initiated procurement activities for low inertia dynamometer and HIL platform
  - Supported DOE APEEM program vehicle level simulation study for characterization of component technologies in various powertrain architectures subjected to multiple drive cycles.
- Collaborations:
  - ORNL PEEMRC
  - DOE APEEM
- Proposed Future Work
  - Procure and commission high speed, transient dynamometer
  - Support DOE APEEM programs with new test facilities and vehicle simulations.