Vehicle and energy storage technology

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Introduction

- Over the last 10 years, we have a long experience of dealing with advanced batteries for HEV/PHEV/EV applications
- Activities include:
  - Battery characterization
  - Battery models
  - Battery aging
  - Battery diagnostic and prognostics
  - Battery laboratory testing
  - Battery vehicle testing and evaluation
  - SoC in-vehicle estimation and control
  - Material characterization of aged cells

- All activities involve extensive experimental capabilities, vehicle prototypes, computer models and algorithms

Battery Modeling

- Used for large simulation and optimization problems

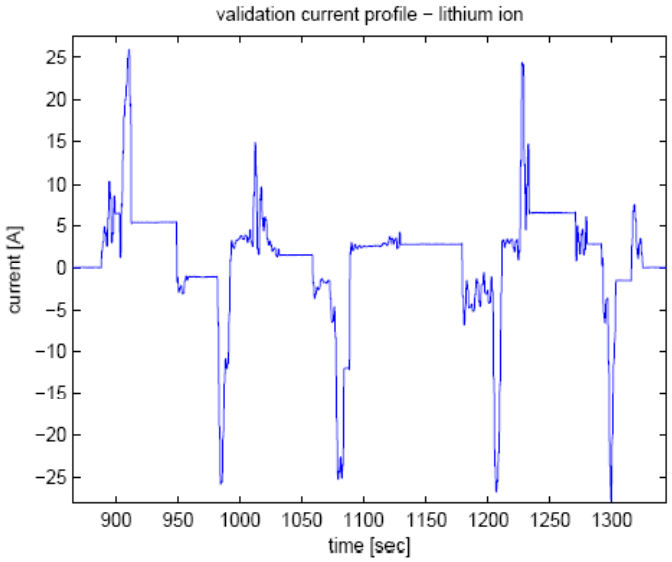
- Homogeneous, off-the-shelf hardware
  - 32 nodes
  - 80 Processors (2 or 4 Processors per node)
  - 2 GB Memory in each Node
  - RISC Intel based Architecture
  - Secured with multiple firewalls
  - Able to be commanded remotely
  - Multiple Operating Systems
  - 24 Port Gigabit Ethernet Switch

Genetic Algorithms adopted to identify battery parameters

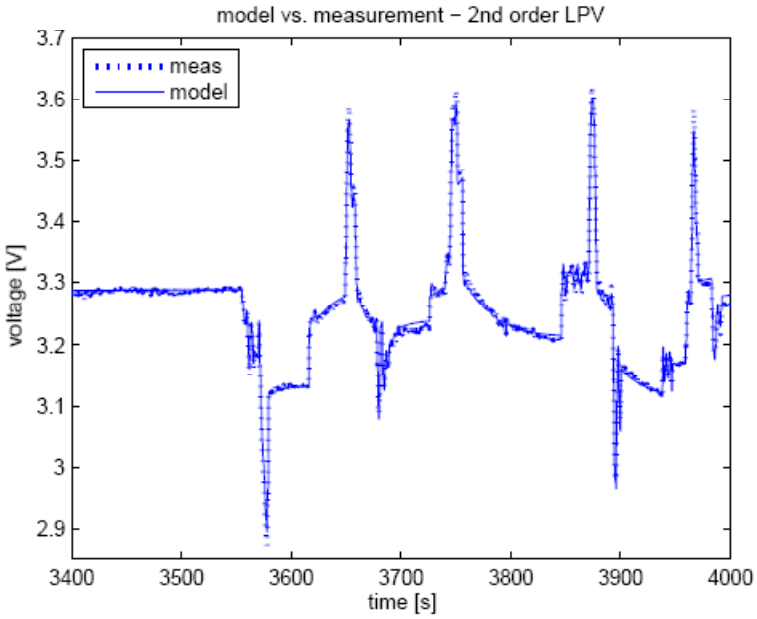
- It is computationally expensive, but…
- It is highly parallelizable – our version is capable of using multiple computers on our computing cluster to do one optimization

Preliminary Experimental Results

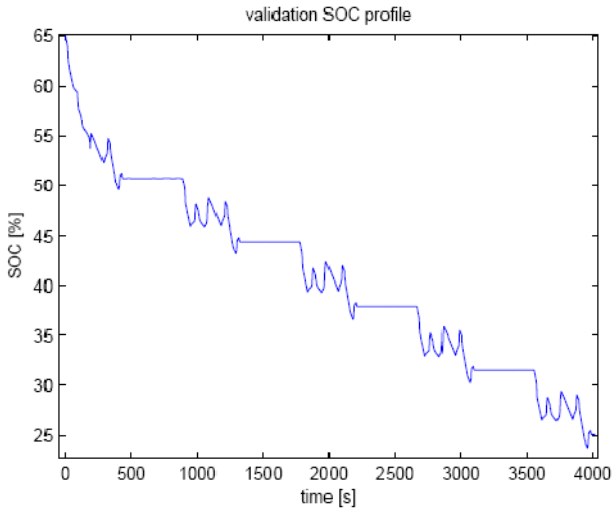
Model is validated using a driving profile generated from actual Toyota Prius driving data



One period of the current profile



Model output vs. voltage measurement – very good agreement



SOC profile of the overall test profile

Battery Aging Lab

- The aging facility has been fully operational since 1/08 with 6 stations + 2/3 more since August/September '08

- Laboratory has accumulated many aggressive HEV aging cycles (300,000 A.h approx) on multiple battery samples (A123 Li-ion cells and Panasonic NiMH modules) in last 8 months… and counting…

- Current testing and research programs with specific OEMs/government agencies have the existing facility fully committed for at least next 18 months (several chemistries, multiple samples, different SoC and DoD, aging cycles…). **Additional test set-ups to service additional needs are constantly being added to facility and will be built upon request**

- Aging is monitored at regular intervals with EIS and other electrical, non-intrusive diagnostics (in addition to capacity, power pulse and cold start tests)

Caveats ... and Needs

Aging data related to ‘cycles’ (defined by easily assessable profiles under well controlled conditions) are *not representative* of conditions actually encountered in real life vehicular applications.

- Need much more sophisticated aging assessment, experimentation, diagnostics and prognostics
- Need to understand at the system level (design, sizing, control…) damage mechanisms responsible for aging
- Need to translate cell information to pack behavior and failure modes
- Need to correlate macroscopic aging manifestations to internal material damage mechanisms

Assessment Tools

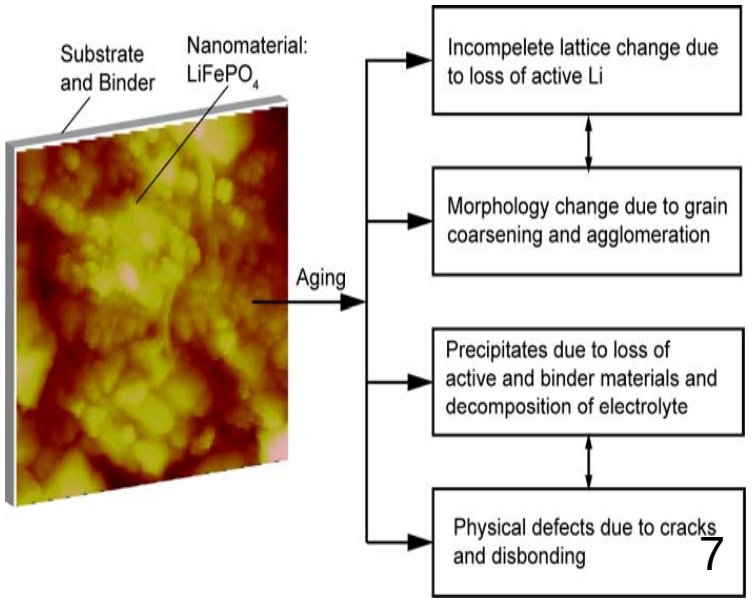
EIS Solartron

Non- or minimally intrusive electrical tests:

- ‘Conventional’ capacity, pulse/power tests at various temperatures, etc.
- Large signal battery characterization and identification
- EIS (small signal)
- *Ad-hoc* tests developed for specific applications

Destructive testing

Extensive material characterization on cells at various levels of aging under various conditions



Battery Life Estimation in PHEV Applications

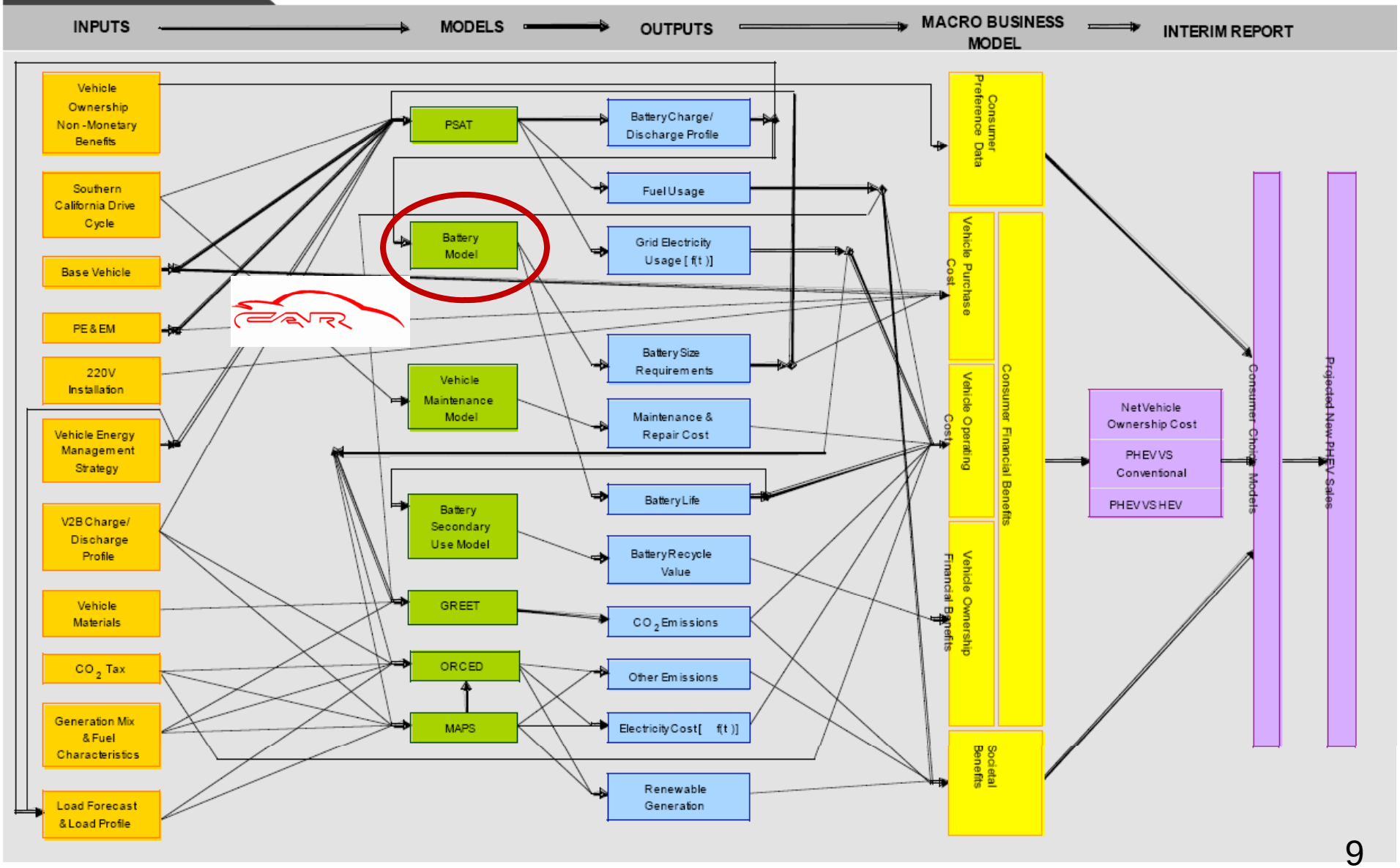
• **SENTECH, Inc.**, Oak Ridge National Laboratory (**ORNL**), General Electric (**GE**), Electric Power Research Institute (**EPRI**), and the **Center for Automotive Research** at Ohio State University are conducting a study of the benefits, barriers, opportunities, and challenges of grid-connected PHEVs in order to establish potential value propositions that will lead to commercially viable PHEVs.

• **Business scenarios** will be developed based on economic advantages that either increase the consumer value of PHEVs or reduce the consumer cost of PHEVs.

• The **technical and market barriers** will be identified along with the **infrastructure** and **technologies** needed to support value proposition.

• **Risks** associated with the scenarios will also be examined.

Data Flow


PHEV VPS Data Flow
INPUTS
MODELS
OUTPUTS
MACRO BUSINESS MODEL
INTERIM REPORT
Vehicle Ownership Non-Monetary Benefits
Southern California Drive Cycle
Base Vehicle
PE & EM
220V Installation
Vehicle Energy Management Strategy
V2B Charge/ Discharge Profile
Vehicle Materials
CO_2 Tax
Generation Mix & Fuel Characteristics
Load Forecast & Load Profile
PSAT
Battery Model
Vehicle Maintenance Model
Battery Secondary Use Model
GREET
ORCED
MAPS
Battery Charge/ Discharge Profile
Fuel Usage
Grid Electricity Usage [f(t)]
Battery Size Requirements
Maintenance & Repair Cost
Battery Life
Battery Recycle Value
CO_2 Emissions
Other Emissions
Electricity Cost [f(t)]
Renewable Generation
Consumer Preference Data
Vehicle Purchase Cost
Vehicle Operating Cost
Vehicle Ownership Financial Benefits
Consumer Financial Benefits
Societal Benefits
Net Vehicle Ownership Cost
PHEV VS Conventional
PHEV VS HEV
Consumer Choice Models
Projected New PHEV Sales

Overview

- A PHEV battery model was developed for this study through a collaborative effort between OSU-CAR and General Electric Global Research.
- The model is based on the concept of accumulated charge throughput.
- The objective is to determine the "damage" on the life related to each provided driving pattern / battery load profile; as a final output, the number of cycles is converted into equivalent miles / years that the battery pack could run within a capacity loss lower than 20%.
- Different “custom” driving cycles/typical days have been identified starting from average driving statistics and standard cycles (shown before)

Thank you!