Power Electronics and Electric Machines

“Plug-In Hybrid Electric Vehicle Power Electronics and Electric Machines Research and Development Activities”

Presented to
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Susan Rogers
Office of FreedomCAR & Vehicle Technologies
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Power Electronics and Electric Machines for PHEVs

- Along with batteries, power electronics and electrical machines constitute the propulsion system for PHEVs

- All elements must meet targets to produce cost-effective solutions
## Scope of PEEM Activities

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PEEM Program Structured to Meet PHEV R&D Plan Schedule

• Current R&D Portfolio is Appropriate for Broad Range of Vehicle Electrification

• Vehicle Assessments to be Performed in FY08
  – PHEV designs will emerge
  – PHEV requirements will be more fully developed
  – PHEV R&D efforts can be more sharply focused as targets emerge

• Advanced Technology from R&D Activities will Support PHEV Plan Technology Milestones
PHEV Challenges

• Electric Traction Drive
  – Current 100 kW system cost is about $3,500
  – Cost is critical issue
  – Volume is also important issue

• Power Management
  – PHEV charge depleting mode will require dc/dc converter to provide stiff voltage source
  – Accommodate widely varying battery output
    • load regulation
    • line regulation

• Charging
  – On-board charging system
PEEM Traction Drive R&D Responsive to Full Spectrum of Electric Vehicles

Blended ICE/Electric
- Power Requirement $\geq 55$ kW
- Parallel architecture
- Intermittent short operation

Sized for Electric Only
- Power required increases (up to 200 kW)
- Series architecture
- Always “on”

PHEV Position in Spectrum Depends on Design
Electric Propulsion System PEEM Targets are Aggressive

Cost ($)

Volume (l)

Weight (kg)

% Reduction Needed
Power Management DC-DC Targets are Similarly Aggressive

Cost ($)

Volume (l)

Weight (kg)

% Reduction Needed
Anticipating FY08 Assessment Results

• Traction Drive
  – Greater reduction in cost, volume, and weight required for PHEV (compared to HEV or FCV)
  – Tradeoffs between PEEM and batteries likely to require PEEM cost target < $8 kW and power density > 4 kW/l

• Vehicle Power Management
  – Bidirectional dc-dc converter will be required to provide stiff vehicle voltage
  – Likely targets
    • cost < $25/kW
    • power density > 3 kW/l

• Vehicle Charging
  – On-board charging system using traction drive PEEM may be most cost-effective solution
PEEM R&D Program Structure

• **Addresses Complete Application Spectrum**
  – Power levels from 55 to 200 kw

• **Technology Demonstrated at 55 kW Level**
  – Better performance parameters (e.g. $/kW, kW/kg, kW/l) at higher power since overheads spread over higher power
  – Ensures targets are met across entire spectrum of possible PHEV designs

• **Maintain Scalability to Meet Higher Power**
PEEM R&D Thrusts Directed at Achieving Targets
(example – cost target)

Long-term Cost Target for 55 kW System is $440

- **Elimination of Dedicated Coolant System**
  - Savings of ~$175
  - Use of on-board coolants

- **Elimination of Boost Converters**
  - Savings of ~$250
  - Motor design innovation to extend CPSR
  - For PHEV CD mode; converter still needed for voltage regulation so savings mitigated.
Research Pathways

• **Traction Drive EM**
  – Higher motor speed: increase power and performance parameters
  – Field weakening/strengthening: increase low-end torque, extend CPSR, and possibly eliminate boost converter

• **Charging PE**
  – Using PEEM system for battery charging to minimize cost

16,000 rpm with brushless field excitation
Research Pathways

• **Traction Drive PE**
  – Innovative topologies: decrease losses, decrease capacitor requirements, and high temperature operation
  – Utilize functional integration (e.g. converter and inverter): reduce part count and increase reliability
  – Novel heat management solution: allow reduction in size using high temperature components and enhanced heat transfer
  – Increase capacitor performance and decrease bus ripple current to decrease capacitor size

• **DC-DC Converter**
  – Innovative topologies: ensure efficiency, decrease cost, weight, and volume and allow high temperature operation
PHEV PEEM Solicitation Addressed Four Areas of Interest

- **High-Temperature Inverter**
  - Requirements: 55kW peak; 15 year lifetime; coolant 105°C liquid or air
  - Targets: ≤4.6 L; ≤4.6 kg; ≤$275

- **High-Speed Motor**
  - Requirements: 55kW peak for 18 sec.; 30 kW continuous; 15-year life
  - Targets: ≤9.7 L; ≤ 35 kg; ≤ $275
  - Scaleable to 120 kW peak for 18 sec. and 65 kW continuous

- **Traction Drive System**
  - Requirements: 55 kW peak; 30 kW continuous; 15-year life
  - Targets: ≤16 L; ≤46 kg; ≤$660; coolant 105°C liquid

- **Bi-directional DC/DC Converter**
  - Phase I Study to establish optimal voltage for drive system
  - Phase II Hardware design and fabrication
Industrial Efforts Have Been Initiated

PEEM PHEV Solicitation Awards Announced
Projects total $33.8 million
Contract Negotiations On-going

- **Team Lead: Delphi Automotive Systems**
  - Award: ≤ $4.9 million
  - Description: High temperature inverter (105°C coolant)
- **Team Lead: Virginia Polytechnic Institute**
  - Award: ≤ $1.7 million
  - Description: Advanced soft switching inverter for reducing switching and power losses
- **Team Lead: General Electric Global Research**
  - Award: ≤ $3.4 million
  - Description: Increasing traction motor power density and efficiency
- **Team Lead: General Motors Corporation**
  - Award: ≤ $7.9 million
  - Description: Integrated traction drive system
- **Team Lead: U.S. Hybrid Corporation**
  - Award: ≤ $1.3 million
  - Description: Bi-directional dc-dc converter including vehicle system study to determine optimum battery and dc link voltages
PEEM Activity

- PEEM integral part of PHEV drive system
- Very challenging targets
- Targets likely to be further squeezed for PHEV application as PHEV designs more fully assessed
- PHEV R&D pathways identified (refined as PHEV targets emerge)
- Mix of national lab and industrial work will meet PHEV Plan milestone schedule