Advanced Integrated Electric Traction System

Greg S. Smith
Email: gregory.3.smith@gm.com
Phone: (310) 257-3812
Organization: General Motors

Team members: Ames Laboratory
Arnold Magnetics
AVX
DuPont
Infineon
Oak Ridge National Laboratory

Project Duration: FY_'08_ to FY '11_

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Purpose of Work

- **Develop and demonstrate advanced technologies for an integrated ETS capable of 55kW peak power for 18 seconds and 30kW of continuous power.**
- **Meet DOE 2015 Targets**
  - **ETS that can accommodate a variety of automotive platforms and the design should be scalable to 120kW peak power for 18 seconds and 65kW of continuous power.**
  - **The ETS is to cost no more than $660 (55kW at $12/kW) to produce in quantities of 100,000 units per year, should have a total weight less than 46kg, and have a volume less than 16 liters.**
  - **The cost target for the optional Bi-Directional AC/DC Converter is $375.**
  - **The goal is to achieve these targets with the use of engine coolant at a nominal temperature of 105C.**
  - **The system efficiency should exceed 90% at 20% of rated torque over 10% to 100% of maximum speed.**

Barriers

- Accurate Requirements
  - Increase fidelity over the duty cycle
  - Flow down system requirements to components
- Technologies
  - Thermal management
    - Need to improve performance over existing pin fin cooling without increasing cost
  - Switch technology
    - Temperature – IGBT currently rated at 150°C usable, need >175°C
    - Module packaging will not meet cost or temperature requirements
  - Capacitor
    - Current high temperature dielectric materials too costly
    - Typical PP capacitor temperature ratings 85°C to 105°C, need to reduce exposure to temperature above 125°C for life
    - Capacitor with current high temperature materials is too large
  - Motor
    - Copper cost increasing
    - Laminations limit design flexibility to 2D
    - Housing mass too high
    - High rare earth magnet material cost
- Programmatic
  - Adoption of new technologies by suppliers
    - Sunk cost in other technologies/markets

Approach for FY'08

- **Phase I Concept Design/Integration Study (10/7 to 7/08)**
  - **Define component specifications**
  - **Research new technologies from Universities, Government Labs, suppliers, and internal GM R&D**
  - **Evaluate topologies for efficiency, cost, complexity, and ability to support various vehicle implementations (e.g. PHEV, HEV, FCV,EV)**
  - **Down select and confirm technologies**
  - **Design Concept that meets FreedomCAR ETS Goals**
- **Phase II Development/Demonstration (7/08 – 5/11)**

Approach - Description of Technology

- **Use technologies that are in various stages of development to produce an electric traction solution**
  - **Investigate a wide range of technologies**
    - **System integration**
    - **Advanced cooling technologies for motors and inverters**
    - **New alternative inverter topologies to minimize bus capacitance and inductors**
    - **Simplified interconnects**
    - **IGBT's and SiC Diodes**
    - **Gate drive and controllers**
    - **Capacitors**
    - **Bus structures**
    - **Housings**
    - **Magnets**
    - **Rotor and stator manufacturing processes**
  - **Confirm validity of emerging technologies**
  - **Integrate the valid technologies in a manner that supports a wide variety of applications (e.g. fuel cell, hybrids, electric, plug-ins)**

Approach - Uniqueness of Project and Impacts

- **Extensive systems analysis - determine appropriate topologies and their applications, component optimization, and packaging flexibility**

- **Transition power electronics from an industrial drive based application to an automotive based application**

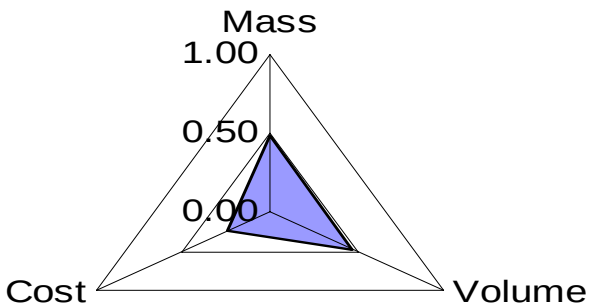
- **Apply systems solution based innovation, rethink how power electronics and electric motors are structured, and executed today**

Provide a systematic coordinated development of revolutionary technology for an ETS.

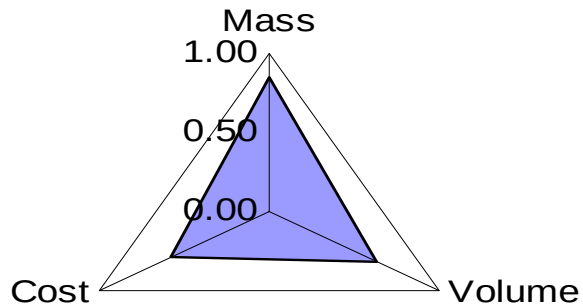
Performance Measures/Technical Accomplishments/Progress/Results

- **An Electric Traction Control System that meets all of the requirements and objectives in the EE/TT roadmap simultaneously @ a system cost of $660**

Current Production Inverter
(Prius data)



Current Production Electric Traction Motor
(Prius data)



- **Additionally improve commercial viability**
  - **Increase vehicle applications/adoption of technology**
  - **Increase supplier base**
  - **Increase competition – commodity based products**

Accomplishments/Progress/Results (cont.)

- **Systems Task 1.1**
  - Topology assessment – basic analysis for 4 topologies – complete
  - Requirements identified for HEV, PHEV, and FCV – first pass complete
  - Duty cycle analysis for each vehicle type – first pass complete
  - Component requirements – first pass complete
  - Packaging requirements for HEV, PHEV, and FCV – in process
- **Motor Task 1.2**
  - Torque speed requirements for HEV, PHEV, and FCV – first pass complete
  - Magnet evaluation and selection – in process
  - Stator configuration and manufacturing process evaluation and selection – in process
- **Gearbox Task 1.3**
  - Optimization of motor speed versus gear reduction – first pass (from motor perspective) complete
- **Inverter Task 1.4**
  - IGBT and diode evaluation and selection – in process
  - Capacitor evaluation and selection – in process
- **Charger Task 1.5**
  - Breadboard build – complete
  - Software debug – in process
  - Demonstration of bi-directional operation – planned

Technology Transfer

- **Alignment of technology development with future vehicle needs**
- **Work with suppliers to develop technical and component base for automotive industry**

Activities for Next Fiscal Year

- Phase II **Development/Demonstration**
  - Design Advanced Integrated ETS
    - Electrical, thermal and structural analyses, mechanical packaging, and engineering drawings
    - Work closely with suppliers to refine and optimize component designs
    - FMEA
    - Manufacturing assessment
    - Cost analysis
    - Applying learning from GM's electrification experience
      - Manufacturing
      - Component deficiencies for design and manufacturing processes
  - Build POC hardware
    - Purchase parts, develop build processes and test procedures
    - Design test equipment for characterization

Summary

- **Achieving the cost, volume, and mass objectives of this project will increase the use of electric traction in the automotive fleet**
- **The systems approach of this project allows for an overall assessment of requirements and technology selection to optimize the complete traction drive**
- **Topology selection, accurate requirements definition and advanced technologies/materials provide the greatest opportunity for success**
- **Alignment of future vehicle needs with technology development and the development of suppliers will increase technology transfer**
- **FY09 Plan**
  - **Design ETS and procure parts**

Questions