



Electric Motor R&D

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FY 2005 AOP Task No.: 3.2

**Advanced Power Electronics and Electrical Machines
Quarterly Review
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**OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY**

Project Summary

- **Background**

ORNL has extensive experience in motor technologies. Many researchers in the PEEM group have years of working experience in motors and inverters.

- The world's first axial-gap permanent-magnet (PM) motor, the first axial-gap field-weakening motor, the first hybrid-secondary-uncluttered induction motor, and the first high-strength-undiffused brushless motor were invented and produced by this group.
- In the past 10 years, 12 patents on advanced motor technologies were granted by the U.S. Patent Office to this group.

This group is fully committed to producing world-class research results for the FreedomCAR Program under the DOE's leadership.

Project Summary (cont'd)

- **Expected Outcome**

Reduce motor size, weight, and cost without negatively impacting power density, cost, life expectancy, and performance of the entire drive system.

- **Approach**

- To build a reluctance interior- PM machine with brushless-field-excitation with a core length that is reduced approximately 30% compared to the Toyota Prius motor (with the same diameter and same speed).
- A hybrid-secondary-uncluttered-PM (HSUPM) machine will also be designed to reduce costs by combining the generator and the motor into one machine so that only one set of permanent magnets and one frame will be needed. The torque capability will be doubled with this design.
- A corona/voltage study will be performed to see how high we can push the voltage before corona occurs, damaging the insulation.

Project Summary (cont'd)

- **Timeframe**

- Mid to long term

- **Relation to Other Projects or Industry Interactions**

- Flux weakening, flux enhancement, and CPSR enhancement techniques
- Advanced traction motor RFP
- Starpower navy transportation technology for collaborative R&D
- Integrated inverter for HEVs and fuel cell powered vehicles
- John Deere

- **Funding**

- FY 2005 – \$580K

Project Summary (cont'd)

- **Objectives**

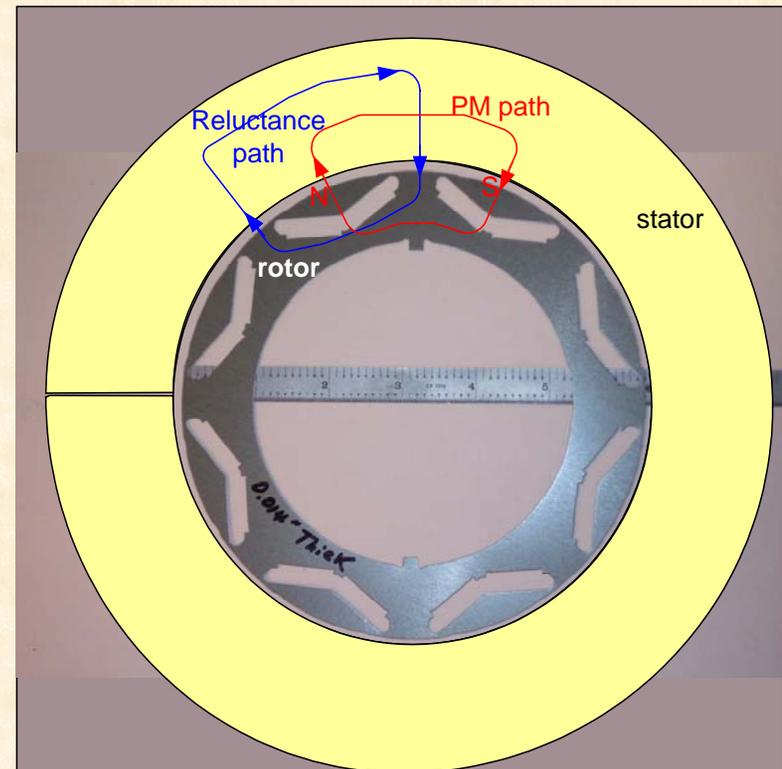
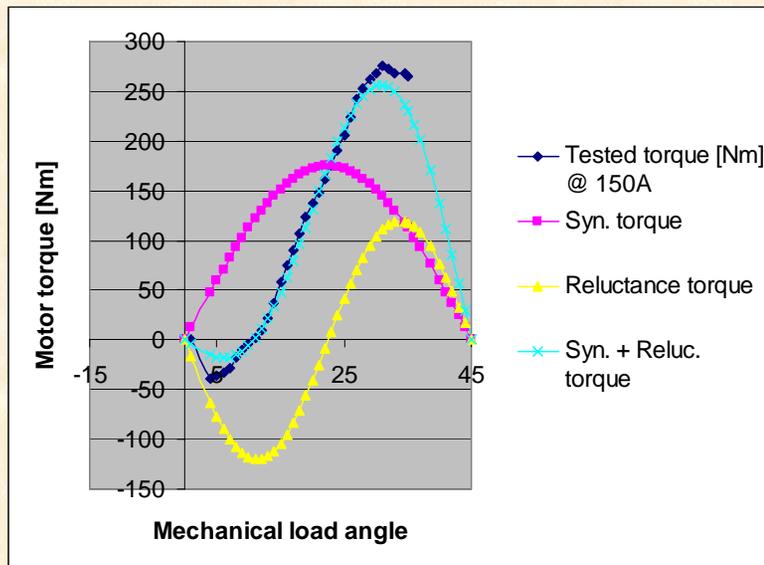
To develop new motor technologies for meeting the FreedomCAR targets

- **FreedomCAR Targets Addressed**

- Size
- Cost
- Weight of drive system

Project Summary (cont'd)

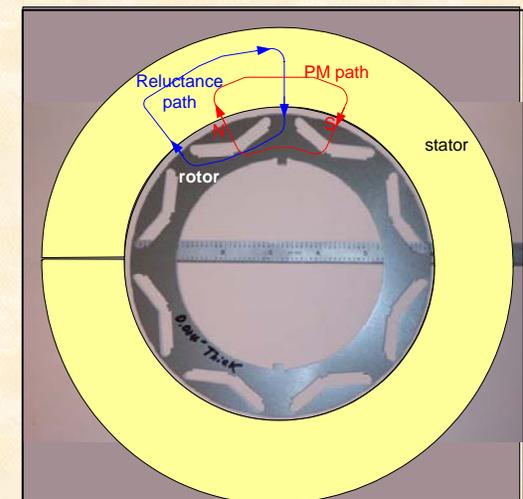
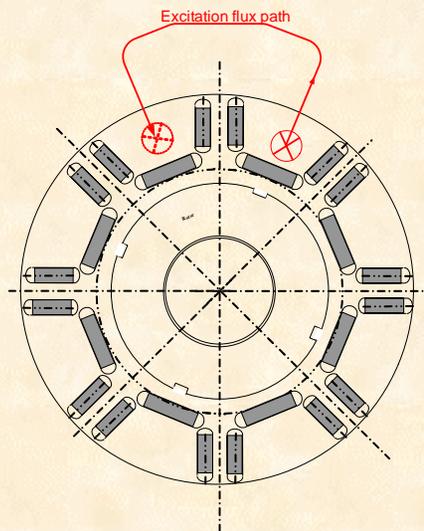
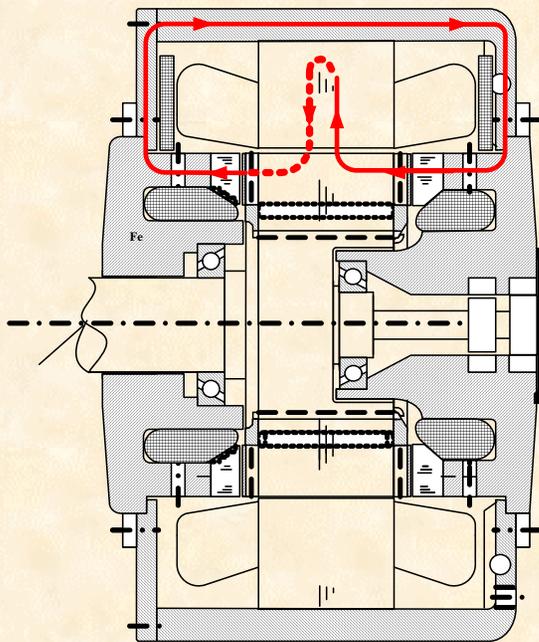
Two torque production components of Prius motor: PM path and reluctance path



Project Summary (cont'd)

Three torque production components for interior PM reluctance with brushless excitation motor

PM path • Reluctance path • Excitation path



Project Summary (cont'd)

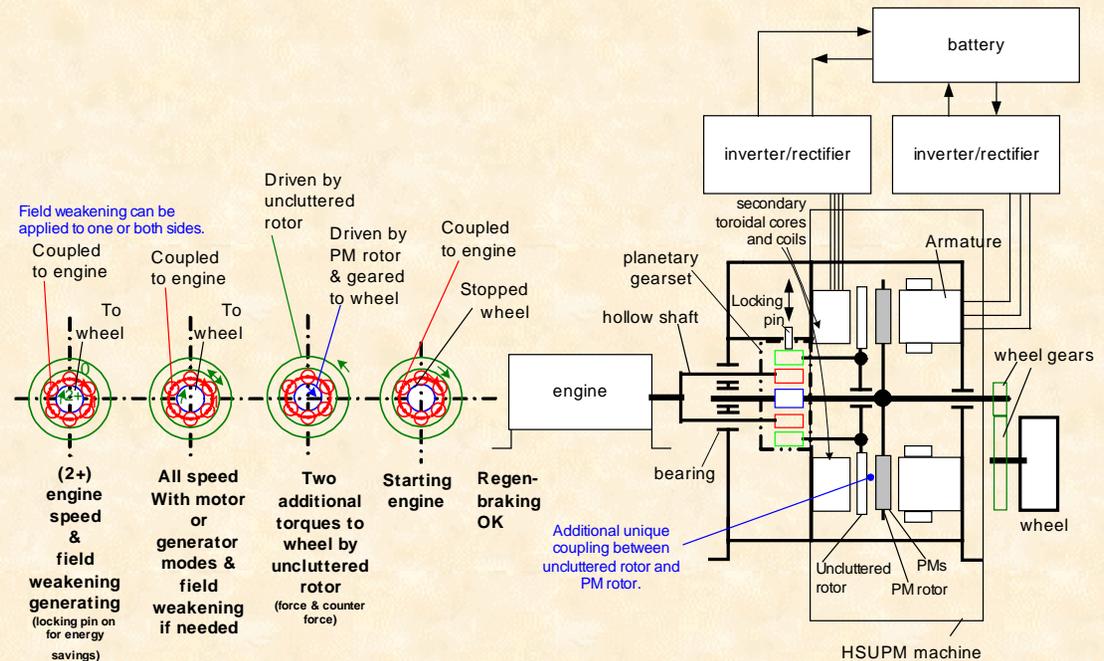
HSUPM machine

The Technology

The machine contains an uncluttered rotor and a PM rotor. The two rotors and the engine are coupled to a planetary gear set.

The PM rotor and the armature form one machine while the uncluttered rotor with the PM rotor forms a second machine.

As the armature drives the PM rotor to produce torque to drive the wheel, the uncluttered rotor can also drive the PM rotor for a higher wheel torque. The uncluttered rotor sees a reaction torque that further increases the wheel torque via the gears.



FY 2004 Progress/Results

- **June 2004 Status**

- Double torque was obtained from a GE induction motor by replacing the rotor with a radial-gap HSUB rotor.

- **June – September 2004 Status**

- Established computation tools for predicting motor performance.
- Simulation results on Prius-motor torque and HSUB motor torque.
- Published reports on Toyota/Prius motor manufacturing designs and torque capabilities.

Progress was completed on schedule.

FY 2005 Plan

- Design, model, simulate, complete drawings, fabricate, and test the reluctance interior-PM-with-brushless-field-excitation machine
- Complete partial preliminary design of a hybrid-secondary-uncluttered-PM (HSUPM) machine
- Investigate corona/motor voltage

Milestones/Deliverables

03/30/05 – Report on findings from corona/motor voltage study

05/30/05 – Final report on simulation results of the IPM-reluctance motor with the brushless field excitation control

09/30/05 – Report on Interior-PM-Reluctance-with-brushless-field-excitation motor performance tradeoffs and benefits regarding FreedomCAR goals (to be incorporated into the annual report)

FY 2005 Progress to Date

- **Interior PM reluctance machine with brushless excitation motor design tasks**
 - Modeling
 - Simulation
 - Validation of model
- **Acquired test equipment and assembled test platform for corona test – waiting on safety approvals for test.**

Future Plans

- Provide technical support to advanced traction motor RFP awardees.
- Integrate the IPM-reluctance motor and inverter in the floating-loop cooling system.
- Simplify design, simulate, and build the prototype of uncluttered rotor for use in HSUPM motor.
- Assess world-wide advanced motors.
- Continue innovative development of motors.