Scalable, Low-Cost, High Performance IPM Motor for Hybrid Vehicles

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DOE Peer Review Presentation

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imagination at work

This presentation does not contain any proprietary information

Purpose of work FY'08

Design 55kWpk IPM motor to meet DOE specification

Table 2. Motor Specifications

Requirement	Target
Minimum top speed (rpm)	14,000
Peak power output at 20% of maximum speed for 18 seconds and nominal voltage (kW)	55
Continuous power output at 20 to 100% of maximum speed and nominal voltage (kW)	30
Weight (kg)	≤35
Volume (l)	≤9.7
Unit cost in quantities of 100,000 ($)	≤275
Operating voltage (Vdc)	200 to 450; nominal 325
Maximum per phase current at motor (Arms)	400
Characteristic current (ψmag/Ld)	< Maximum current
Efficiency at 10 to 100% of maximum speed for 20% of rated torque (%)	> 95
Back EMF at 100% of maximum speed, peak line-to-line voltage (V)	< 600
Torque pulsations-not to exceed at any speed, percent of peak torque (%)	< 5

Barriers

The specifications for hybrid vehicle motors are challenging in terms of power density, efficiency and cost. This requires a comprehensive approach to advance the state of the art, including novel concepts to push past barriers.

- High stator core and rotor/magnet losses, due to
  - high electrical frequency
  - simplified winding structures with high harmonic content
- Complexity in motor stator and rotor drives up cost
- High PM content drives up cost

Approach

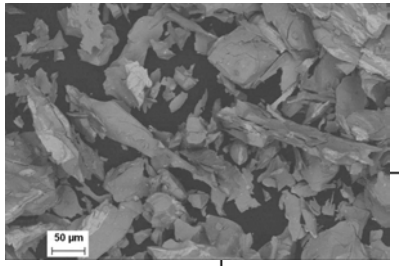
- To reduce losses & meet high efficiency requirements, GE will engineer high-resistivity nanostructured magnetic materials while maintaining balance of properties and low cost
- Heroic motor efficiency requirements – must address every significant loss component
- Simplified stator windings will reduce end-turn length (impact losses and cost) together with motor mass and volume
- Minimization of high-cost materials in the motor design - get maximum performance value from rare-earth PM materials

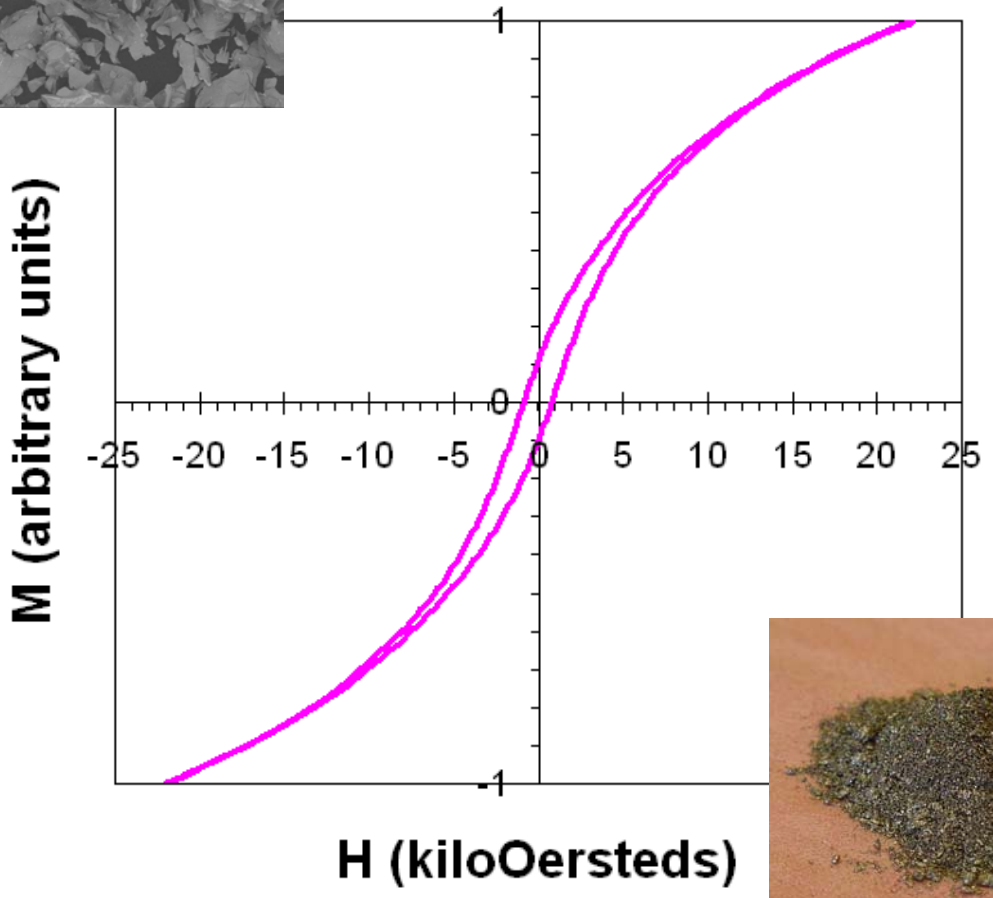
Progress: 10/07-1/08

New start 10/2007

- Slot & pole configuration selected
- Rotor mechanical design rules established
- Benchmarking of existing IPM motors initiated
- 6 candidate high-resistivity soft magnetic alloys cast
  - Melt-spinning trials underway
- Selected 3 rare-earth PM compositions
  - Pulverization and sintering trials underway

Rare Earth Permanent Magnet Powder



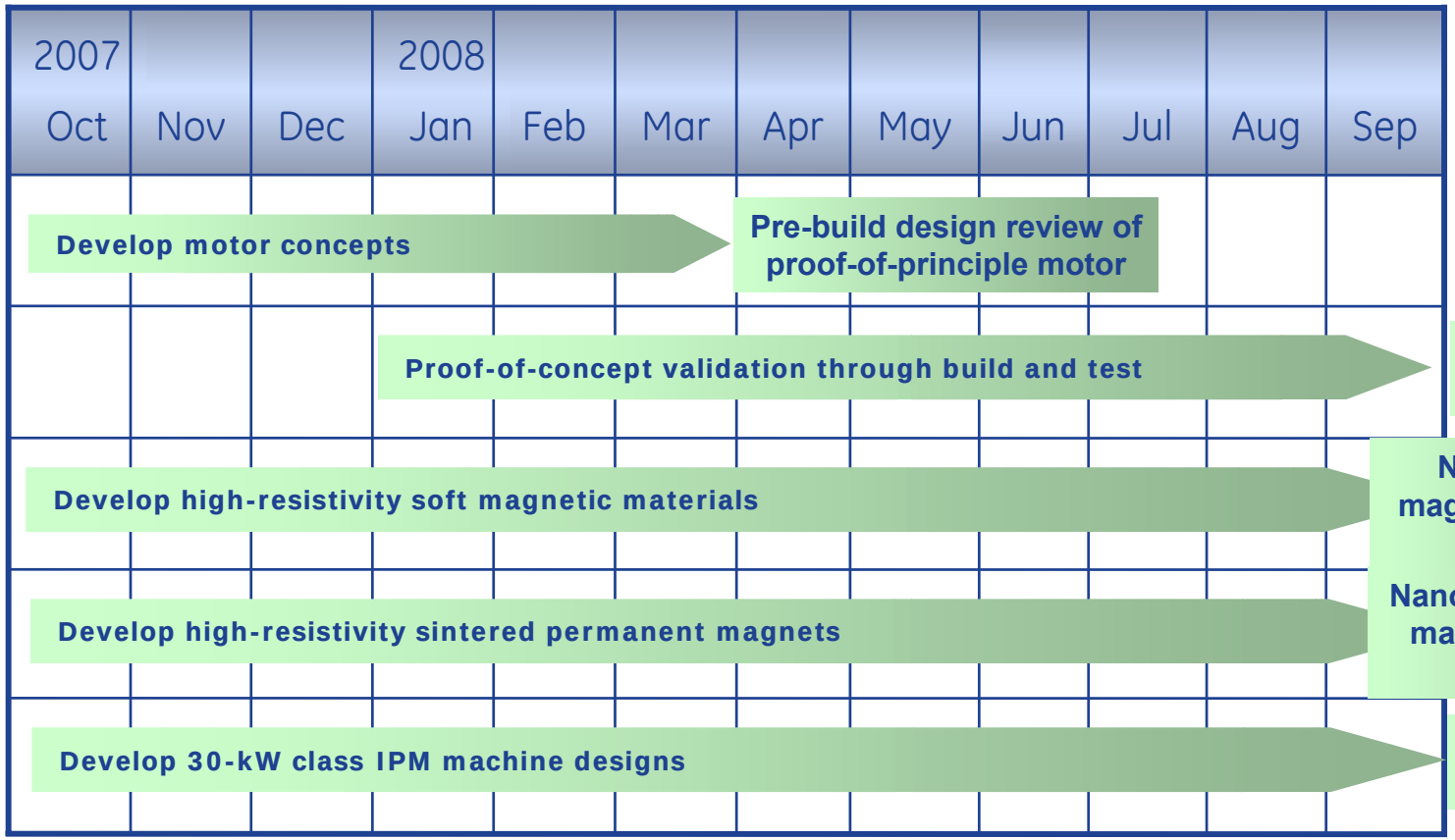


- Precursor powder of rare earth permanent magnet composition
- Properties and structure verified for use in high-resistivity composite permanent magnet

Technology Transfer

- GE Consumer and Industrial's motor business is providing technical oversight and review
- Successful build and test of 3 designs in project years 1, 2 & 3 will drive business plans

Plans for FY'2008



High-performance, low-cost IPM FY08 decision point

- 55kW IPM design effort utilizes all the FY08 learnings
  - Proof-of-concept IPM motor manufacturing
  - Performance of advanced motor design features in proof-of-concept IPM motor
  - High-resistivity magnetic material properties
- Predicted performance gives insight into feasibility of meeting DOE design targets
- Is predicted IPM performance appropriate?

High-performance, low-cost IPM beyond FY08

FY09

- Build and test 55kW IPM motor
- Deliver 55kW IPM to DOE for test
- Design scaled-up IPM > 120kW
- Design of high-resistivity magnetic material process scaleup

FY10

- Build and test scaled-up IPM
- Trial scaled-up production runs of high-resistivity magnetic materials

Summary

Fast-paced program utilizing GE's depth and breadth…

✓Advanced material development

✓Advanced electric machine design

…to develop world-beating high power density, high efficiency and low cost IPM for US hybrid OEMs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