U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Integration of Novel Flux Coupling Motor and Current Source Inverter

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Project ID: APE034

2011 U.S. DOE Hydrogen and Fuel Cells Program and Vehicle Technologies Program Annual Merit Review and Peer Evaluation Meeting

Overview

Timeline

- Start: October 2010
- End: September 2013
- 11% complete

Budget

- Total project funding
  - DOE share – 100%
- Funding received in FY11
  - $465K

Barriers

- **Barriers addressed**
  - **High permanent magnet (PM) cost for motor**
  - **Bulky and costly DC link capacitors for VSI**
  - **Bulky and costly DC link inductor for CSI**

VT Program Targets addressed

- **DOE 2020 Drive System Power Density Targets**
  - 1.4 kW/kg
  - 4 kW/l
- **DOE 2015 Drive System Cost Target**
  - -- $12/kW

Partners

- Work with SMC vendor on optional core material
- ORNL Team Members: Randy Wiles, Gui-Jia Su, Lixin Tang

Objectives

To integrate a non permanent magnet (PM) electric machine and a current source inverter (CSI)

- **minimizing capacitors**
- **eliminating rare earth materials used in traditional traction motors**
- **eliminating the DC link inductor in the CSI through utilization of the leakage flux linkage in the motor**

Meet the DOE 2020 drive system targets of 1.4 kW/kg, 4.0 kW/L, and the DOE 2015 cost target of $12/kW

Milestones

FY11

•Perform electromagnetic computation and finite element analysis (FEA) toward a design suitable for a proof-of-concept prototype and conduct tests.

•Go/No Go decision: The feasibility for integration will be judged by sufficient leakage inductance for the CSI and the blocking of the AC flux going into the rotor of the motor.

FY12

•Optimize design for prototype motor and prototype inverter. Also start fabrication if FY12 Go/No Go decision is favorable.

•Go/No Go decision: Determine if the optimized motor and inverter designs can meet the objectives.

FY13

•Complete fabrication of prototype motor and prototype inverter.

•Complete integration of the motor and inverter.

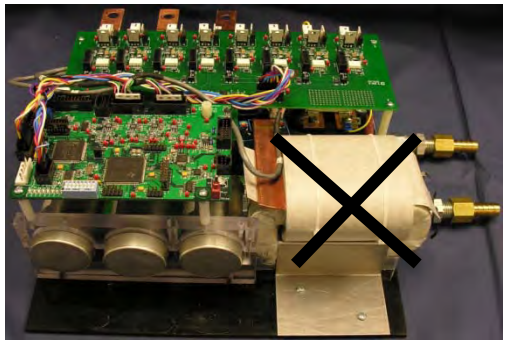
•Test the integrated system.

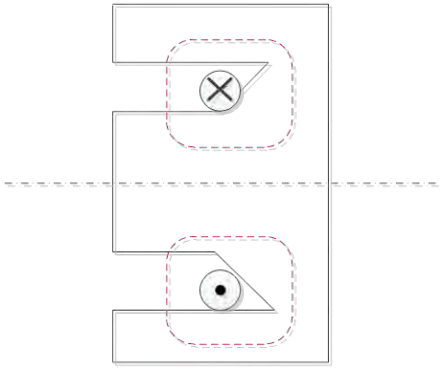
Approach/Strategy (cont'd)

- **This new project builds upon previous R&D accomplishments**
  - **ORNL CSI research has demonstrated capacitance reductions of 90%**
  - **ORNL Novel Flux Coupling Machine Without Permanent Magnets provides IPM like performance using no PMs**
- **Approach integrates the two technologies and uses inductance from the motor to replace the CSI inductor**
  - **Reduces weight and volume (inductor largest and heaviest component in CSI)**
  - **Reduces cost**
- **This totally new concept involves technical challenges in ability to manipulate and successfully separate the motor coil flux components**

Approach/Strategy (cont'd)

Technical Strategy:



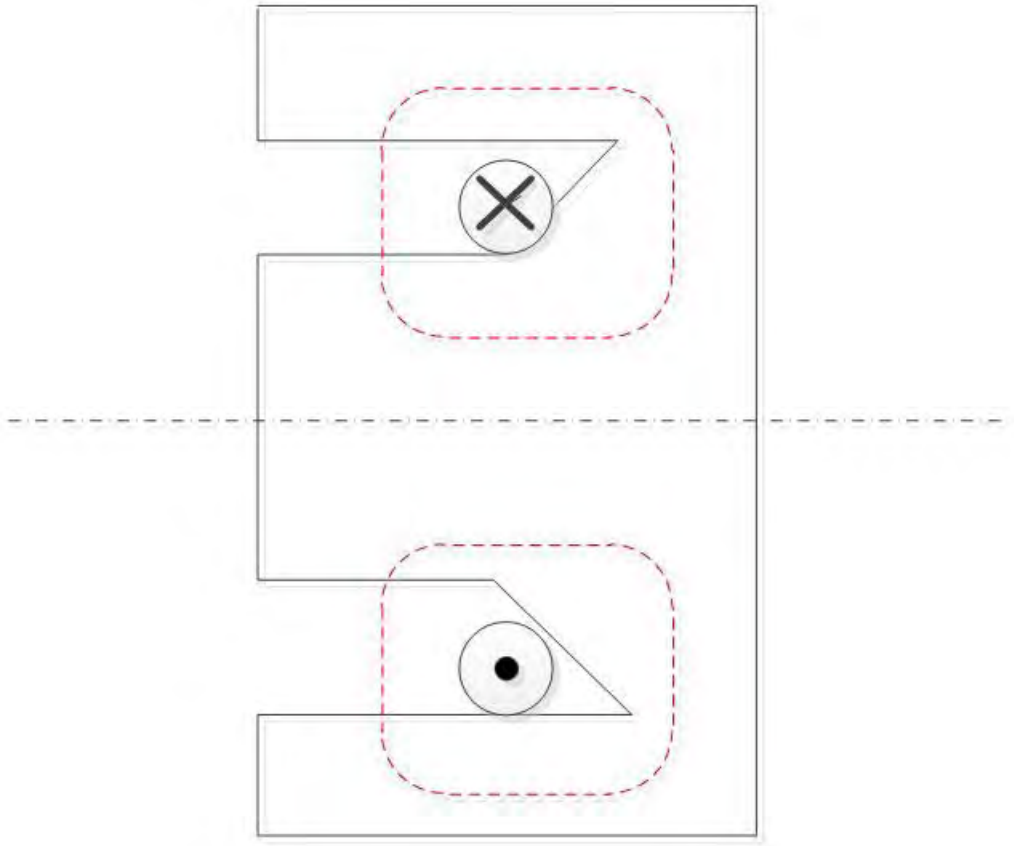


Cross sectional view of motor excitation core

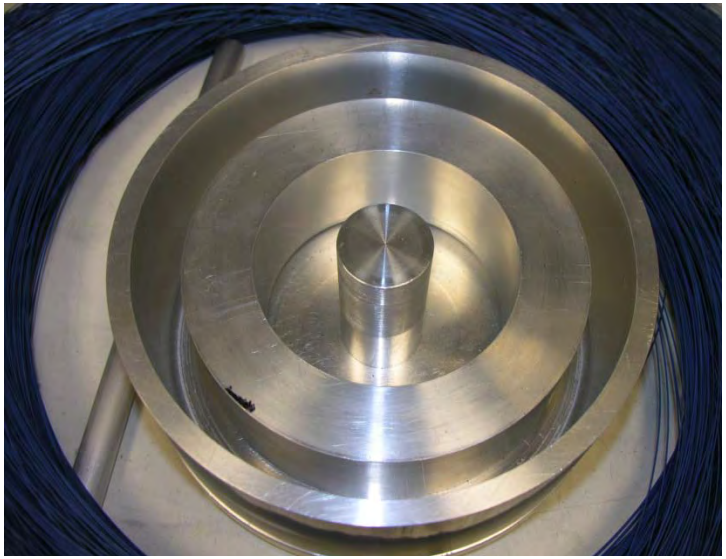
- **To use the leakage inductance of the excitation core of the novel flux coupling machine to eliminate the bulky, heavy inductor in the current source inverter.**
- **The DC current component of the inverter produces excitation flux for the electric machine. This flux goes through the excitation core and the axial air gaps to reach the rotor.**
- **The AC component in the DC link current produces AC flux that is not allowed to go through the axial air gaps to the rotor. It is blocked by a short-circuited coil that serves as a gate keeper.**
- **There is also a shunt-wound coil for additional flux production when the load current is too low for producing sufficient excitation flux.**

FY11 Technical Accomplishments

Calculation indicates that the motor excitation wound core can produce sufficient leakage inductance for the current source inverter (CSI)



FY11 Technical Accomplishments



Designed and fabricated fixture for building a DC+(high frequency) excitation core

Fabricating an experimental excitation core

Collaborations

Working with soft magnetic composite manufacturers for excitation core materials.

Depending on success in FY 11 discussions will be held with stakeholders.

Future Work

FY11

•Continue designing and fabricating simple stationary magnetic flux path tests to prove concept

•Conduct tests to prove feasibility of separating DC flux and AC flux

•Incorporate into a CSI for PWM and function tests for design revisions.

•Establish design parameters for the integration of the CSI and novel flux path motor.

FY12

•Optimize design.

•Fabricate prototype motor.

•Fabricate prototype inverter.

FY13

•Complete fabrication of prototype motor and prototype inverter

•Complete integration of the motor and inverter

•Test the integrated system.

Summary

- **Previous R&D has demonstrated;**
  - **CSI reduces bulk capacitance requirement by 90%; inductor in CSI is heaviest, largest single component.**
  - **Novel flux coupling motor yields IPM-like performance using no PMs**
- **This project integrates the two technologies and uses the motor coil to replace the CSI inductor.**
- **Concept expects to meet DOE 2020 system weight and volume targets and 2015 system cost target.**
- **Initial calculations indicate that the excitation core of the novel flux coupling motor can produce sufficiently high inductance to meet the inverter's PWM and boosting needs.**
- **Experimental test setup has been completed and experimental validation of concept is ongoing.**