

## Superconductivity for Electric Systems 2006 Project Summary

<b>PROJECT TITLE:</b>	Development of Ultra-Efficient HTS Motor Systems
<b>ORGANIZATION:</b>	<b>Rockwell Automation</b>
<b>PRESENTERS:</b>	Rich Schiferl, Chris Rey
<b>FY 2006 FUNDING:</b>	\$ 650 K – Rockwell Automation, \$ 225 K – ORNL

**Project Purpose, Benefits, and Objectives:** The purpose of the project is to perform research in eight areas related to commercial viability of industrial motors with high temperature superconducting (HTS) windings. The eight areas were identified based upon Rockwell Automation design and testing of HTS based motors up to and including the laboratory test of a 1600 hp motor. HTS motors will have half the losses of conventional motors of the same rating. Applications will be for motors above 1000 horsepower for utility and industrial customers. A 5000 hp HTS motor could save a single customer \$50,000 in energy costs per year. About 1/3 of U. S. electrical energy generated is used to power motors of this size. Potential energy savings for the U. S. alone, if HTS motors fully penetrate the marketplace, could be \$1 Billion per year. The eight research areas and FY06 objectives are listed below.

Research Area	FY06 Objectives
1. Alternate HTS motor topologies	Perform trade-off studies of permanent magnet vs. HTS motor designs and issue report.
2. Alternate HTS wire technology applications	Develop specification for 2G motor coils for large hp motors and continue 2G coil evaluations.
3. Eddy current heating in air-core, rotating machinery	Perform motor design studies based on modeling results.
4. Adjustable speed drive integration / harmonic shielding for HTS motors	Complete studies to reduce rotor heating.
5. On-board refrigeration system development	Complete design and test of rotating cryocooler and compare to model.
6. Coil quench protection system development	Verify quench models, quench detection/protection system demonstration, complete exciter design.
7. Composite torque tube advancement	Complete creep tests and issue report.
8. Cryogenic persistent switch investigation for HTS field windings	Complete final report.

**FY 2006 Performance and FY 2007 Plans:** Progress has been made in each of the research areas identified above. Below is a summary of the results and next year's plans.

### 1. Alternate HTS motor topologies

#### **FY06 Performance**

- Completed permanent magnet (PM) motor vs HTS motor design comparison.

#### **FY06 Results**

- PM motor performance lies between conventional induction and HTS.

#### **FY07 plans**

- Continue trade-off studies of PM vs HTS with various HTS/PM rotor content.

### 2. Alternate HTS wire technology applications

#### **FY06 Performance**

- 2G coil / conductor requirements established for HTS industrial motors

#### **FY06 Results**

- Cost and performance targets provided to DoE and wire supplier.
- Published technical paper on HTS motor benefits / economics.

#### **FY07 plans**

- 2G wire and joint characterization with ORNL and coil quench modeling to assist with conductor design.

### 3. Eddy current heating in air-core, rotating machinery

#### **FY06 Performance**

- Stator design concepts developed for large motors

#### **FY06 Results**

- Test rig development plan for demonstration of stator designs

#### **FY07 plans**

- Build and test stator for HTS motor.

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### 4. Adjustable speed drive integration / harmonic shielding for HTS motors

#### FY06 Performance

- Rotor heating reduction options characterized

#### FY06 Results

- Report issued on design studies and models

#### FY07 plans

- Complete system models on best option.

### 5. On-board refrigeration system development

#### FY06 Performance

- Rotating cryocooler demonstration.

#### FY06 Results

- Test rig design, fabrication, and testing completed.

#### FY07 plans

- Issue final report on tests vs model expectations.

### 6. Coil quench protection system development

#### FY06 Performance

- 1G coils quench testing at 30 K completed at ORNL.
- Quench models developed.

#### FY06 Results

- Quench models verified with test on 1G coils.
- Quench detection and prevention system defined.
- Four technical papers published.

#### FY07 plans

- Complete task.

### 7. Composite torque tube advancement

#### FY06 Performance

- Creep tests initiated on torque tube adhesives.

#### FY06 Results

- First set of tests completed.

#### FY07 plans

- Complete task.

### 8. Cryogenic persistent switch investigation for HTS field windings

#### FY06 Performance

- Final report issued.

#### FY06 Results

- Method defined for next HTS motor.

#### FY07 plans

- Task complete.

**Significant FY 2006 Results:** Four technical papers published on quench testing and modeling. One technical paper published on HTS motor benefits and economics. The quench phenomenon in HTS coils has been fully characterized through testing of multiple 1G HTS coils at 30 Kelvin and results have been used to establish a reliable quench detection and protection system for large HTS coils.

**Research Integration:** A CRADA was established with ORNL for 30 Kelvin quench testing and modeling of large HTS coils. Test results were very instrumental in developing an understanding of the quench phenomenon in HTS coils. Based on these test results, quench in HTS coils is expected to be a very detectable event that can be avoided with a reliable detection and prevention system.

Modeling of the performance of a pulse tube refrigerator in a high-g environment will be conducted through an agreement between Rockwell Automation and NIST. Modeling results will be compared to test data.

A technical paper on HTS motor benefits and economic considerations will be presented at the IEEE Petroleum Chemical Industry Conference in September. This conference is attended by engineers from companies who use large electric motors for pump, fan, and industrial processes.