

<b>Organization:</b>	<b>Rockwell Automation</b>
<b>Project Title:</b>	Development of Ultra-Efficient HTS Motor Systems
<b>Presenter:</b>	Rich Schiferl
<b>FY 2005 Funding:</b>	\$ 700 K

**Project Purpose 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. These research areas and FY05 objectives are listed below.

<b>Research Area</b>	<b>FY05 Objective</b>
1. Alternate HTS motor topologies	Investigate alternate methods to open circuit HTS coils or films. Issue report on studies and tests.
2. Alternate HTS wire technology applications	Build and test 2 <sup>nd</sup> Gen HTS coil for motor application studies.
3. Eddy current heating in air-core, rotating machinery	Complete report on tests and model verification
4. Adjustable speed drive integration / harmonic shielding for HTS motors	Verify simulation model with controlled test of HTS motor and drive system.
5. On-board refrigeration system development	Complete system model with CRADA work. Initiate design of test bed.
6. Coil quench protection system development	Quench model development and choose best prevention option. Demonstrate solution and perform exciter tests.
7. Composite torque tube advancement	Complete creep tests on multiple samples.
8. Cryogenic persistent switch investigation for HTS field windings	Complete test of persistent switch with HTS coil to prove performance.

**FY 2005 Performance, FY05 Results and FY 2006 Plans by research area:**

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

**FY05 Performance**

- Completed persistent current switch demonstration.

**FY05 Results**

- Demonstrated controllable persistent switch with HTS coil. Issued report.

**FY06 plans**

- Perform design study trade-off for PM vs HTS content and issue report.

2. Alternate HTS wire technology applications

**FY05 Performance**

- Demonstrate HTS rotating machines with 2G windings.

**FY05 Results**

- Demonstrated 2 hp motor in December 2004 (world's first) with 2G HTS field coils.

**FY06 plans**

- Develop specification for 2G motor coils for large hp motors.
- Continue 2G coil evaluations.

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

**FY05 Performance**

- Completed report on tests.

**FY05 Results**

- Report completed comparing tests to model results.

**FY06 plans**

- Perform motor design studies based on model.

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

##### **FY05 Performance**

- Computer model developed for air gap shield losses with variable speed drive powering motor.

##### **FY05 Results**

- Computer model results compared with FY05 test results on HTS motor hardware.
- Computer model of motor/drive system compared well with test results on 1000 hp motor.

##### **FY06 plans**

- Complete motor system design studies to reduce rotor heating.
- Issue report.

#### 5. On-board refrigeration system development

##### **FY05 Performance**

- Rotating cryocooler (pulse tube) purchased and model development initiated.

##### **FY05 Results**

- Signed agreement with NIST for rotating cryocooler modeling.
- Purchased cryocooler and initiated test rig design.

##### **FY06 plans**

- Complete design and test of rotating cryocooler and compare to model.

#### 6. Coil quench protection system development

##### **FY05 Performance**

- Quench models of 1G HTS coils developed.
- Quench testing of 1G coils performed.

##### **FY05 Results**

- Completed coil quench experiments on existing 1G HTS coils at liquid nitrogen temperatures and presented technical paper on results.
- Initiated CRADA with ORNL for HTS wire characterization and coil quench testing at 30 to 40 K.

##### **FY06 plans**

- Verify quench models and issue report.
- Complete field coil exciter design.
- Complete quench detection/prevention system design and demonstrate.

#### 7. Composite torque tube advancement

##### **FY05 Performance**

- Complete creep test fixture for adhesive tests.
- Initiated creep tests at elevated temperature.

##### **FY05 Results**

- Creep test fixture design and construction complete.
- Creep tests initiated.

##### **FY06 plans**

- Complete creep tests and issue report.

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

##### **FY05 Performance**

- Complete tests on persistent current switch with HTS coil.

##### **FY05 Results**

- MOSFET based switch performed adequately as controllable switch.
- Report issued on switch performance.

##### **FY06 plans**

- Task complete.

#### **Research Integration:**

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.

CRADA has been negotiated with ORNL for HTS wire characterization and 30 to 40 Kelvin HTS coil testing for quench studies. HTS coils will be mounted in an ORNL test cell where quench experiments will be conducted. Results of the test will be compared to model predictions.