Commercially and Technically Viable Motor System with Increased Energy Efficiency

Fully Integrated High Speed Megawatt Class Motor and High Frequency Variable Speed Drive System

Providing a Smaller Footprint, Cost Effective Integrated Motor Drive for Industrial Applications

Left: The project partners will consider the use of hot isostatic pressing to join metals together in the production of the metal rotor. Shown here are examples of products produced with this method. Right: Litz coil, which has challenges related to cooling, connections, and other properties (but it conducts better high frequency currents and is extremely flexible allowing for many design shapes) will be used for windings in the high speed motor. Shown here is a Litz wire joint test conducted by one of the project partners.
Images courtesy of Clemson University

Many prototype high speed motors have been reported in literature and some commercial products are even operating in the field, but there is no single integrated motor and drive system commercially available for multi-megawatt ratings in the chemical and petroleum refining industries, natural gas infrastructure, and general industrial applications. Also, traditional materials and design standards are not able to achieve the performance targets of a high speed motor and high frequency variable speed drive for these applications.

Development of a motor and drive system requires a fully integrated approach in which design tradeoffs can be consolidated and considered against the system as a whole. Researchers are developing a technology to evaluate motor design criteria for specific applications in order to design, construct and validate a fully integrated high speed megawatt class motor drive system. There are numerous factors that must be considered in the successful development of an integrated motor drive system. For high speed motor design, researchers will consider the electromagnetic and rotor dynamic performances, thermal management, rotor stress, motor insulation and coil design, and bearing design. For design of the high frequency variable drive, researchers will consider medium voltage output, high frequency operation, power quality, thermal management, and high speed performance optimization. Balancing all these factors in an integrated design is necessary to ensure the system is cost effective and meets all specified technical targets.

Benefits for Our Industry and Our Nation

This project will develop a fully integrated, high speed megawatt class motor drive system with a clear path for commercialization. Research partners will help further scientific understanding and contribute to literature in the field while designing, constructing, and testing the integrated system. The innovative technology has many benefits, including:

- Enhancing manufacturing capabilities within the United States by developing innovative processes and systems.
- Providing a cost effective motor drive with greater power density and a smaller footprint than present industry systems.
- Reducing size and weight of the systems in offshore applications.
- Demonstrating performance and applicabiity of commercially available silicon carbide semiconductor devices.

Applications in Our Nation's Industry

The proposed fully integrated system would serve as a commercially viable and technically sound methodology for high speed industrial system applications, especially for the oil and gas sector. A sizeable market exists for high speed, high horsepower applications in the compressor industry, both onshore

and offshore, utilizing conventional variable frequency drive and synchronous and asynchronous motors. This industrial application is also expected to grow with the increased domestic shale gas market.

Project Description

The project objective is to develop a fully integrated, high speed megawatt class motor and high frequency variable speed drive system. During the project, researchers will utilize advanced manufacturing methods and consider special non-traditional materials. A preliminary base design, which uses a "squirrel cage" induction motor topology, will be improved during the project's initial stage using non-traditional materials and design methodologies. The proposed variable frequency high speed drive will utilize an advanced series connected H-bridge inverter topology, using commercially available silicon carbide wideband gap (WBG) semiconductors suitable for both medium voltage and high frequency output.

Barriers

- Integrating WBG semiconductors into the drive system while managing electromagnetic compatibility concerns.
- Quantifying pass/fail criteria for testing will be difficult because the scope of the full system test depends on the operating boundaries of the motor drive system and the dynamic interaction between the system components.
- Managing thermal challenges due to the high frequency currents, medium voltage insulation and friction in a small volume machine.

Pathways

Over the course of the project, the technology will be transitioned to pilot scale. The project will be completed over the course of five phases: preliminary design and analysis; system component testing and design validation; detailed design and creation of manufacturing drawings; integrated prototype-system manufacturing; and motor and drive testing. The project team will use seven main tasks in order to complete the phases; many of these tasks will be overlapped and Go/No-Go decision points will be addressed along the way.

Milestones

This three year project began in May 2016.

- Complete detailed motor design, including manufacturing drawings, specifications, and work instructions (2017).
- Complete detailed high frequency variable speed drive design (2017).
- Complete construction of fully integrated system (variable frequency drive and motor) (2018).
- Complete testing of the prototype fully integrated system (2019).

Commercialization

The project is expected to deliver a high speed, integrated motor and drive system that surpasses the performance metrics of current commercially available options.

The project partners will develop a commercialization plan focusing on reducing the installed cost of the system and aiding in tailoring the system for specific industries and applications. Stakeholders will be engaged in the design, construction and testing phases of the project with respect to the performance, operation, and cost of the system. While the target market is already utilizing conventional variable frequency drive and synchronous/ asynchronous motors, the compressors developed in this project offer the added benefits of reduced size and weight as well as decreased operating costs. In addition, TECO Westinghouse Motor Company will work to engage potential customers for a three year beta testing of the fully integrated system that would transition it from pilot scale to commercial scale.

Project Partners

Clemson University
Clemson, SC
Principal Investigator: J. Curtiss Fox, PhD
Email: jfox@clemson.edu

Rensselaer Polytechnic Institute
Troy, NY

TECO Westinghouse Motor Company
Round Rock, TX

For additional information, please contact

Sridhar Seetharaman and Allen Hefner
U.S. Department of Energy
Advanced Manufacturing Office
Email: Sridhar.Seetharaman@ee.doe.gov ■