Silicon Carbide Drive for High-Speed Motor Applications

Medium voltage electric machine provides increased efficiency and smaller system footprint

In many heavy industrial applications, gas turbine powered drive systems are the standard. However, an increasing number of end users are showing greater interest in electric drive systems due to more stringent emission standards and demand for increased reliability, better availability, and more operational flexibility. Despite this interest, deployment of variable speed drive (VSD) medium and high voltage motors is lagging. Market barriers include high capital cost, large footprint, low switching frequency, and high losses at high voltage ratings for VSDs based on today's silicon power electronics. One way to address these barriers is to incorporate next-generation power conversion technologies based on high voltage silicon carbide semiconductor switching technology.

To address this market need, a research team will develop a medium voltage drive that is to be integrated with a high-speed motor for use in direct drive equipment. The major research and development focus of the project is on the silicon carbide based high frequency switching devices that can work directly with high voltages, switch at high frequencies, and do so very efficiently. To minimize project risk, the project team will primarily utilize previously developed technologies for the balance of the integrated system. Based on the project team's assessment of the most likely applications to first adopt the new technology, the developed electric machine will be rated at 1.6 megawatts (MW).

The electric machine being developed will incorporate a rotor with a composite sleeve and total harmonic distortion barrier to minimize rotor heating. Utilizing previously developed technology innovations will minimize project risk. *Photo courtesy of Calnetix Technologies*

Benefits for Our Industry and Our Nation

This project will help the U.S. gain a competitive technical advantage in the design and manufacture of next generation medium and high voltage electric drive systems and spur the necessary investment to commercialize the technologies. The medium voltage, high-speed electric machine provides many benefits over existing comparable systems, including:

- Total system efficiency—including the variable speed drive, motor, and isolation transformer—of approximately 94%, which is an improvement of 3%-4% over current technologies
- Estimated total system footprint of approximately 3.1 m^2/MW, which is significantly smaller than current technologies
- Reduction in electric grid loads and infrastructure costs

Applications in Our Nation's Industry

This project will develop a medium voltage, high rotor velocity electric machine that is well suited for high-speed direct drive equipment in many industry sectors. The developed drive system is suitable for gas compression applications in natural gas pipelines and offshore platforms, air compression for air separation, flywheel-based energy storage, and various power generation and turbo expansion applications.

Project Description

The objective of this project is to design and develop a medium voltage (4,160 Volt) high-speed electric machine that is well suited for use in direct drive equipment, utilizing silicon carbide (SiC) switching devices which enable higher voltage operating conditions and improved efficiency. The motor and variable speed drive will be rated at 1.6 MW operating at 15,000 RPM. The major innovation and focus of research efforts will be the medium voltage application of SiC-based high frequency switching devices. For the motor, the project team will utilize an existing high-speed permanent magnet motor design and modify it for medium voltage operations; this minimizes the risk and development effort for the motor. The integrated system is expected to achieve a total system efficiency of approximately 94% and greatly reduced footprint compared to current alternative technologies.

Barriers

- Silicon carbide based circuits and control systems have not yet been fully investigated in medium voltage motor drives
- Targeted end use industries tend to be reluctant to try new technologies and approaches

Pathways

This project consists of three main phases. In the first phase, the main focus will be on the development of a two-level inverter architecture that builds upon a new 10 kV silicon carbide device being developed by Wolfspeed, Inc. Once the inverter architecture is developed, the actual inverter and its control system will be built. In the third and final phase of the project, the developed power electronics as well as the integrated drive and motor system will be tested at Florida State University.

Milestones

This three year project began in May 2016.

- Evaluate two-level 1.2 kV inverter architecture utilizing 1.2 kV silicon carbide technology (2017).
- Evaluate two-level half bridge version of inverter architecture utilizing 10 kV silicon carbide technology (2017).
- Develop a detailed VSD design based on 10 kV silicon carbide technology (2018).
- Develop a detailed motor design (2017).
- Conduct functional testing of the motor and VSD (2018).
- Test integrated drive and motor at full speed and full power (2019).

Commercialization

Due to more stringent emission requirements as well as a desire for lower operating costs, greater efficiency and more operational flexibility, there is market interest in electric drive systems to replace the current gas turbine powered drives in heavy duty industrial applications. This project is expected to develop a new medium voltage high-speed electric machine that is well suited for this market segment—megawatt class direct drive applications in industry. Calnetix has identified several specific applications where the potential for market entry is greatest, including natural gas compression, air compression for air separation, flywheel-based energy storage, and various power generation and turbo expansion applications. Because Calnetix is a recognized leader in such high-speed electric drive systems, it will be in a good position to promote commercial adoption of the technology through its existing customer and sales network.

Project Partners

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