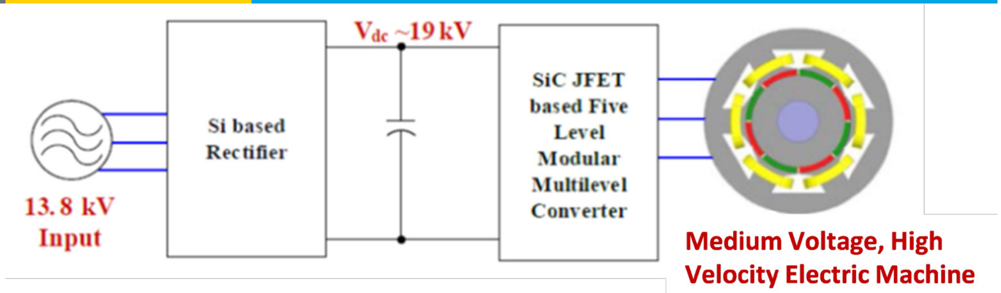
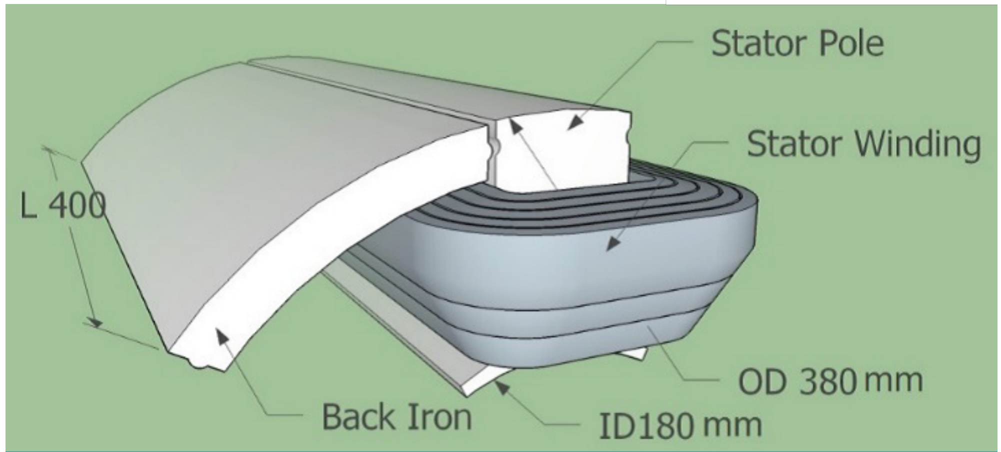
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Innovative Medium Voltage, High Rotor Velocity Electric Machine

Next Generation High Power Density Drive with Silicon Carbide Based Converter

Novel design provides a highly efficient option for medium voltage, high power density applications in industry





Above: A schematic of the medium voltage, high rotor velocity electric machine. Below: The proposed modular stator with concentrated winding structure will simplify the insulation system design and increase reliability. *Images courtesy of Ohio State University*

Deploying variable speed drive (VSD) in medium voltage motors would provide large electricity savings, but the adoption rate of medium voltage VSDs is still very low. Market barriers include high capital cost, large footprint, low switching frequency, and high losses at medium 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 medium voltage silicon carbide semiconductor switching technology. Yet underinvestment in commercial products with silicon carbide semiconductor technology continues to be an issue due to low technology and manufacturing readiness levels and lack of manufacturer and end-use customer acceptance.

To improve drive efficiency and power density of large industrial motors, a research team will develop an integrated medium voltage, high velocity electric machine and silicon carbide based power converter. The developed drive system—a forced-air cooled, 1 Megavolt Ampere (MVA) unit—can be connected directly to a 13.8 kiloVolt (kV) electric grid, eliminating the need for a large step-down transformer. This will result in substantially smaller system footprint and reduced cost, as well as greater power density. It is projected that the new electric machine will achieve a total system efficiency of more than 97%—a marked improvement over medium voltage drives in the market today.

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 voltage electric drive systems and spur the necessary investment to commercialize the technology. The medium voltage, high rotor velocity electric machine provides many benefits over existing comparable systems, including:

- Total system efficiency of more than 97%.
- Inversed power density of approximately 1.2 m^3/Megawatt (MW), which is significantly better than the performance goal set by DOE for medium voltage drive systems.
- Estimated footprint of approximately 1.1 m^2/MW, which is significantly smaller than existing medium voltage drives in the market today.

Applications in Our Nation's Industry

This project will develop a medium voltage, high rotor velocity drive system in the megawatt size range that is suitable for numerous industry sectors, such as oil and gas, chemical, and mining industries. Drive systems of this kind are used for pumping, fans, compressors, and other similar industry applications.

Project Description

The objectives of this project are to design, fabricate and test an innovative high performance, high-speed drive capable of integrating into 13.8 kV electric grids while avoiding energy losses associated with power transformers. The project team, led by Ohio State University (OSU), will utilize a unique and unprecedented system design incorporating a silicon carbide based five-level modular multilevel converter (MCC). The drive combined with the electric machine is expected to achieve a total system efficiency of 97.2%, inversed power density of 1.2 m^3/MW, and physical system footprint of 1.1 m^2/MW.

Barriers

- Silicon carbide based circuits and control systems have not yet been fully investigated with high voltage devices; in particular, electromagnetic interference in medium voltage power converters is a challenge.
- Use of silicon carbide devices imposes challenges for the insulation systems of the power cables and machine windings.

Pathways

This project builds upon previous research and advances in silicon carbide technologies. In order to validate the novel system design, the first phase of the project will focus on analysis, simulation, and design efforts. In the second phase, the work will center on the development of a down-scaled 100 kVA machine prototype and silicon carbide power converter. In the third and final stage a full-scale 1 MVA integrated prototype will be built and tested.

Milestones

This three year project began in February 2016.

- Component characterization, module development, and preliminary design (2017).
- Control hardware and software development, including validation of control algorithm (2017).
- Design, build and test a down-scaled MMC (2018).
- Build and test a full-scale MMC, including verification of voltage, current, and frequency capability (2018).
- Integrate and test full-scale variable frequency drive and motor (2019).

Commercialization

The project is expected to demonstrate on a pilot scale a new transformer-less medium voltage electric drive system, building on recent advances in silicon carbide technology and market gains these new technologies have made. A successful demonstration of the new medium voltage drive will be a significant step toward its commercial readiness. As the final step in the project, the team will prepare a detailed market transformation and commercialization plan. The team will develop documentation about the technology and disseminate that information through OSU's established Center for High Performance Power Electronics industry consortium. The team will actively reach out to the OSU industry consortium to find potential commercialization partners in order to form a complete chain from technology to product to market for the various applications. Among the first targeted markets for the technology will be large fan, pump, and compressor applications in oil, gas, and mining industries.

Project Partners

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DOE/EE-1429 • March 2017