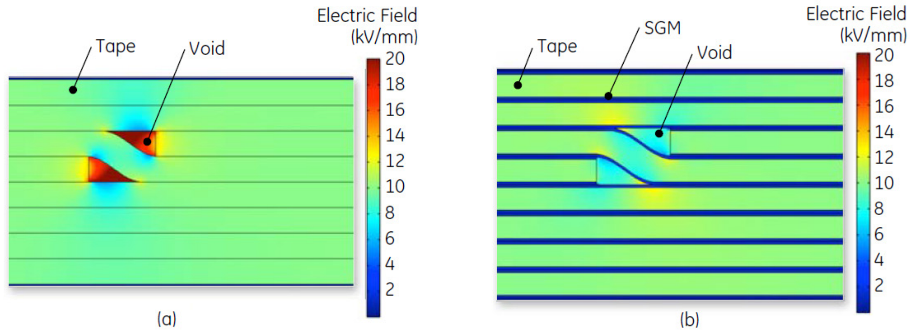
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Resistively Graded Insulation System for Next-Generation Converter-Fed Motors



Illustrations of the electric field distributions in a lapped-tape insulation structure with a defect: (a) An insulation structure without a stress grading network and (b) an insulation structure with stress grading materials (SGM) between tape layers. The SGM layer provides resistive grading to the insulation, reducing partial discharge which reduces the effectiveness of the insulation over time.

Graphic image courtesy of GE

Enabling a high-voltage insulation system for thinner insulation and improved reliability

Next-generation converter-fed motors use frequency converters with wide-bandgap semiconductors to enable operation at high voltages, frequencies, and temperatures. These operating conditions contribute to higher failure rates in electric field insulation systems. High switching frequencies and voltage ramp rates cause partial discharge in the insulation system, which can accelerate device failure. The development of a resistively-graded insulation system can reduce the incidence of partial discharge, enabling thinner insulation builds of electric machines with improved reliability.

The insulation system under development in this project seeks to reduce the effect of defects in current insulation systems that contribute to partial discharge. The technical approach combines two features of insulation system design: 1) polymer tapes are produced using high-pressure processing methods that reduce the incidence of defects, and 2) resistive coatings are applied to both sides of the polymer tape, shielding defects from the fields that lead to partial discharge. The project will begin with the development of a thermo-electric model to identify the key parameters to guide the experimental design for developing the material. Development of the polymer film resistive coating will involve materials procurement and testing to identify the insulation properties of different material combinations. This process will determine the formulation of the resistive coating to be used in testing with polymer films and binders to make up the insulation system. The selected insulation systems will undergo voltage endurance testing as a final validation for the proof of concept.

Benefits for Our Industry and Our Nation

Developing resistively-graded insulation systems for next-generation motors has many benefits, including the following:

- Energy savings in industrial motors by enabling SiC converter-fed motor systems, potentially as high as 5-10%.
- Improvements in the efficiency and power density of electrical machines.
- Enabling thinner insulation builds of electrical machines with improved reliability compared to the state-of-the-art.

Applications in Our Nation's Industry

The insulation system proposed by this project is broadly applicable to medium and high voltage industrial motors, enabling greater energy savings, reliability, and performance. Additionally, advancing a robust U.S.-based supply chain of wide bandgap devices can serve product applications ranging from industrial equipment to renewable power generation to engines for the transportation sector.

Project Description

The project objective is to design, test, and validate an insulation system applicable to next-generation converter-fed motors. Key features of the end product insulation design will be its reliability under high electrical stresses and temperatures, as well as thinner insulation requirements for high voltage electrical machines. The technology will involve the integration of a resistive coating between layers of polymer tape in a lapped-tape insulation structure to minimize the partial discharge caused by defects in the structure. This project will focus on the development of a resistive coating, including material selection, distribution, and geometric structure within the insulation system.

Barriers

- Developing an accurate analytical model to estimate electrical and thermal stresses under a range of operating conditions (e.g. variations in temperature, system voltage, current, and voltage rise time).
- The analytical model must obtain reliable outputs within manageable computation times for the time constraints of the project. This may require simplification of the computational complexity of the model.
- Identifying the design parameters of the insulation structure and resistive coating that can achieve the key performance parameters identified for the end-product insulation material.

Pathways

The first stage of the project will be development of the analytical model to estimate electrical and thermal stress distributions on material samples under a variety of conditions. The results of this model will inform the experimental design of the material development stage of the project, guiding materials selection, geometric structure, and processing methods for the insulation system. Material development will involve selection among several commercially available thermoplastic and thermoset films, as well as binders for the resistive coating. Prior to tape and binder selection, researchers will begin formulation of the resistive coating using inputs from the model. To accelerate learning in the early stages of the project, easily-available and representative materials will be selected for the preliminary resistive coating formulation. The completed insulation materials that are ready for endurance testing will move on to the proof of concept stage, where the voltage endurance of the proposed systems will be measured against the key performance parameters defined for the project.

Milestones

This 1 year project began in 2017.

- Develop thermo-electric model to calculate thermal and electrical stress distributions under complex operating conditions (Completed).
- Determine resistive coating formulation and validate a resistive coating material that meets electrical and manufacturing requirements (2018).
- Complete mechanical and electrical design of the insulation system and complete voltage endurance curves validating the proof of concept (2018).

Technology Transition

Resistively graded insulation systems are a key technology for the commercialization of next-generation converter-fed motors. The operating conditions of high-voltage electrical machines make them particularly susceptible to failure due to partial discharge. Solving this issue would overcome one of the major barriers to market adoption of next-generation converter-fed motors, bringing them closer to commercialization.

Project Partners

GE Global Research
Niskayuna, NY
Principal Investigator: Qin Chen
Email: *ChenQ@ge.com*

For additional information, please contact

Isaac Chan and John Winkel
U.S. Department of Energy
Advanced Manufacturing Office
Phone: (720) 356-1630
Email: *John.Winkel@ee.doe.gov* ■

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