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

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GE Global Research
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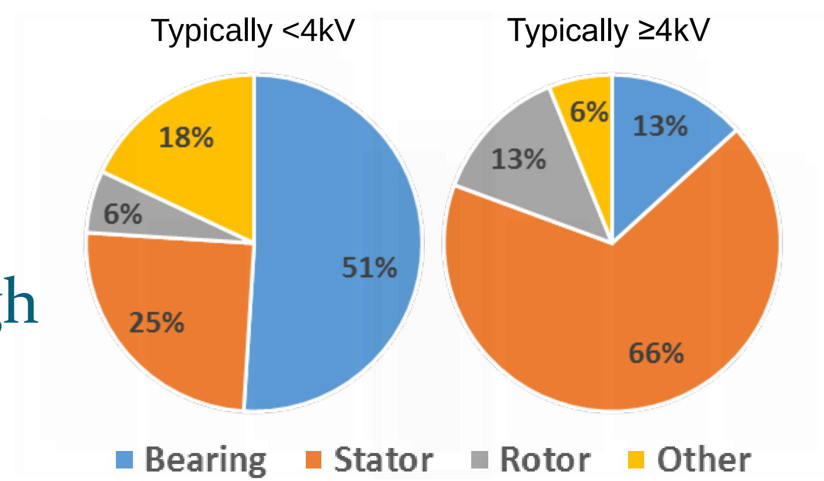
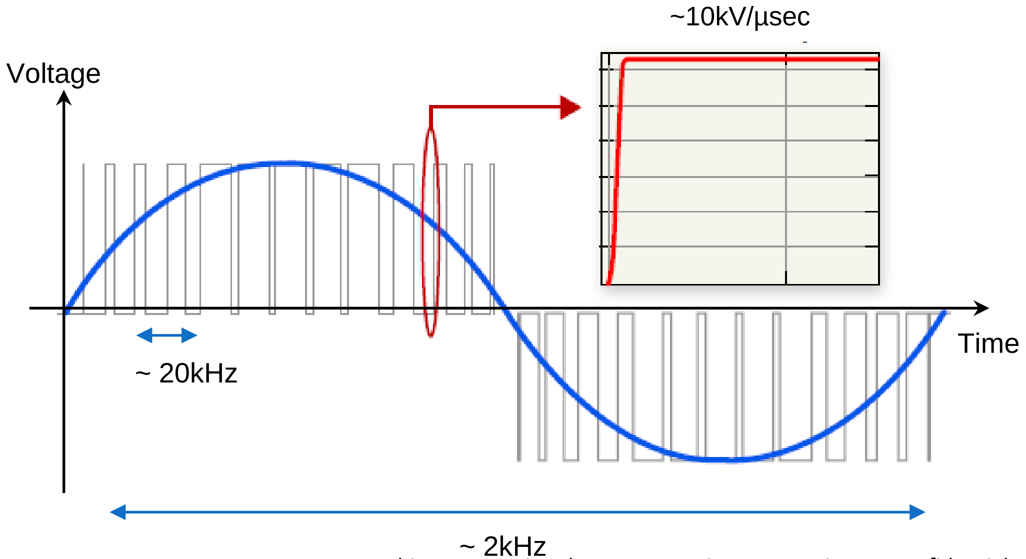
Project Objective

- Achieve 2x operating electric field compared to the state-of-the-art insulation for converter-fed machines
- Key challenges: high frequency, high temperature, cost

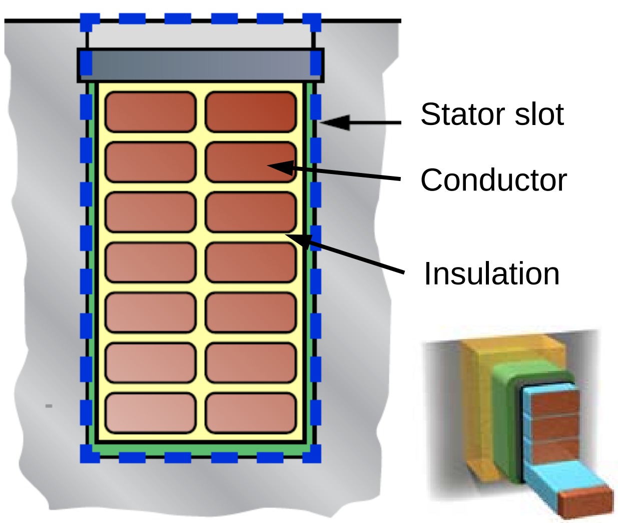
Motor failure modes



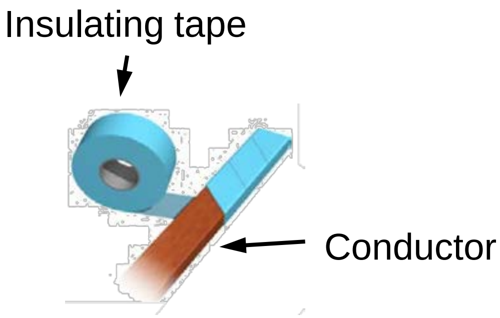
Waveform (drives with silicon carbide devices)

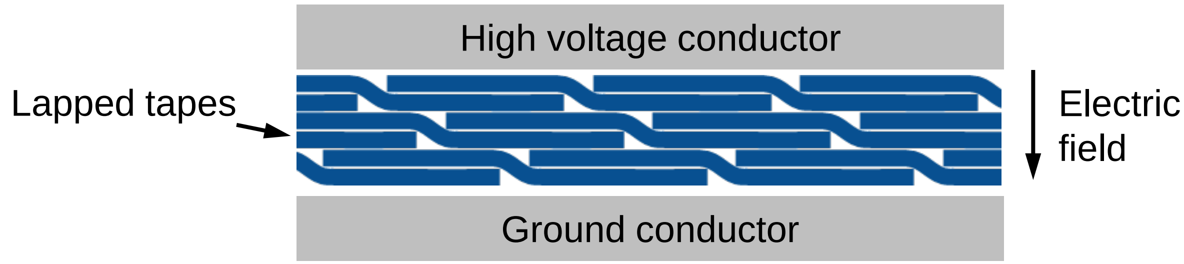


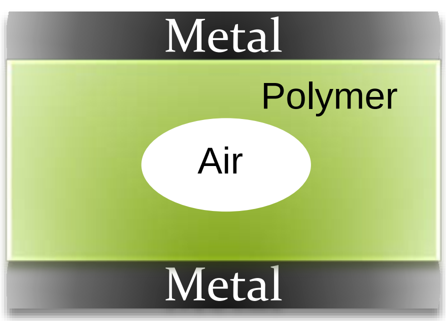
Stator slot structure

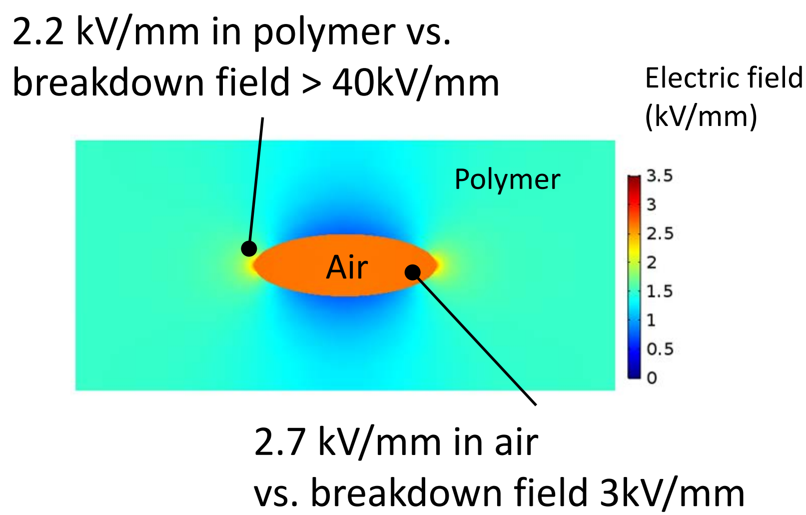


Technical Innovation



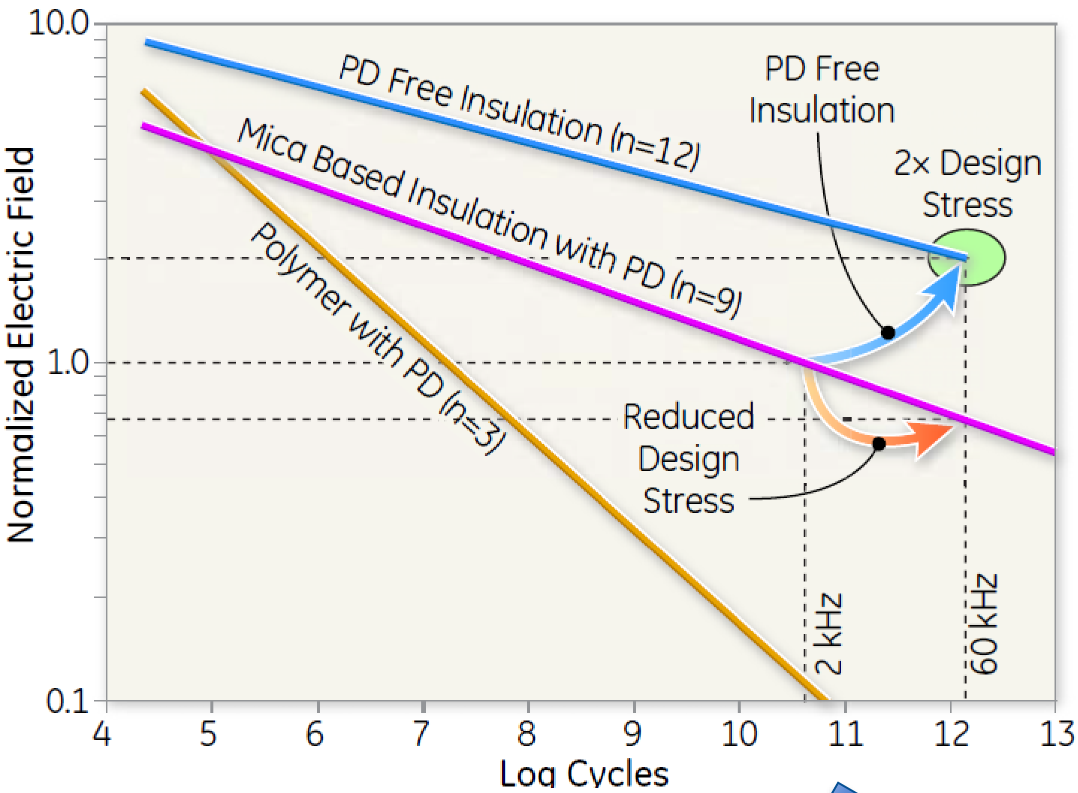






Fundamental problem: insulation degradation due to partial discharge (PD) in voids

Technical Innovation



This project: polymer films + resistive coating (PD-free)

State of the art: PD-resistant mica insulation

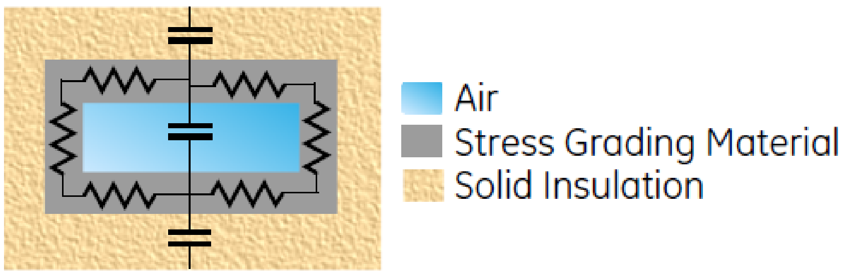
PD in polymer leads to rapid failure

Technical Approach

Multi-physics modeling
- Design for materials, structure, process
- Intemperate test results

Materials formulation
- Dielectric film
- Stress grading material
- Processing aids

Resistively-graded insulation



Key challenges:
- Shielding vs. loss
- Geometry of voids & resistive network
- Measure the effectiveness

Process development
- Enable desired structure
- Optimize quality
- Projection for scale-up

Validation tests
- Materials/structure characterization
- Voltage endurance

Transition (beyond DOE assistance)

- Targeted product - high performance rotating electric machines
- MV/HV industrial motors – large market; traditionally conservative towards new technologies; conscious of capital expense cost increases
- Overcome barriers to market transition through relevant applications:
  - Aviation (electric propulsion, starter/generator)
  - Transportation (locomotive traction motor)
  - Oil and gas (electric submersible pumps)
  - Power (turbo-generators)

Measure of Success

- Enable 5% - 10% electric machine energy savings from advance silicon carbide drive implementation
- Secures U.S. motors and drives industry global leadership in variable-speed, wide-bandgap device systems
- Paradigm shift in insulation systems:

Property	Goal	Improvement
Ramp rate	10 kV/µs	5x increase
Temperature	180°C	Class H
Fundamental frequency	2 kHz	8x increase
Switching frequency	20 kHz	10x increase
Design electric field stress	3 kV/mm	State of the art
Partial discharge inception voltage	$>U_0$	PD-free operation

Project Management & Budget

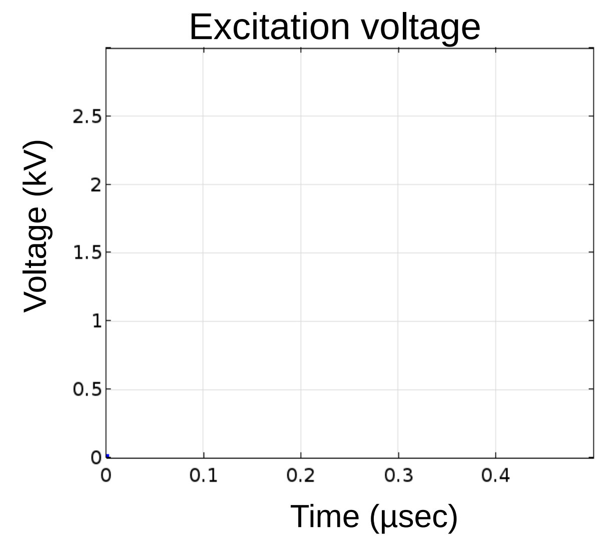
- One year project (06/2017 – 06/2018)

Time	Task & Milestone
Q1	• Component material properties selected based on analytic model
Q2	• Multi-physics model validated • Preliminary formulations for resistive material selected • Film vendor selected
Q3	• Final materials system selected • Materials produced for endurance test • Endurance test protocol determined
Q4	• Voltage endurance test completed

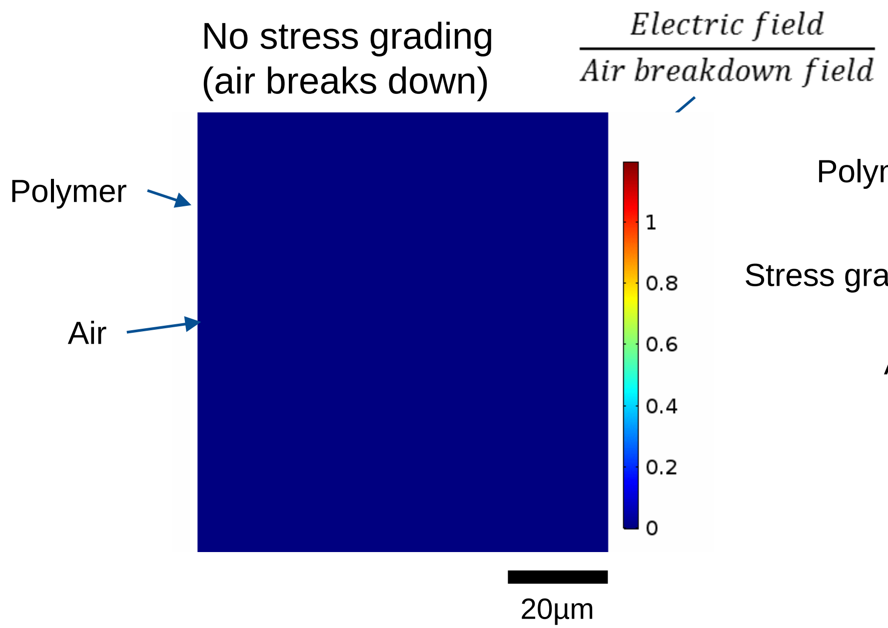
Total Project Budget	
DOE Investment	$749, 990
Cost Share	$187, 497
Project Total	$937, 487

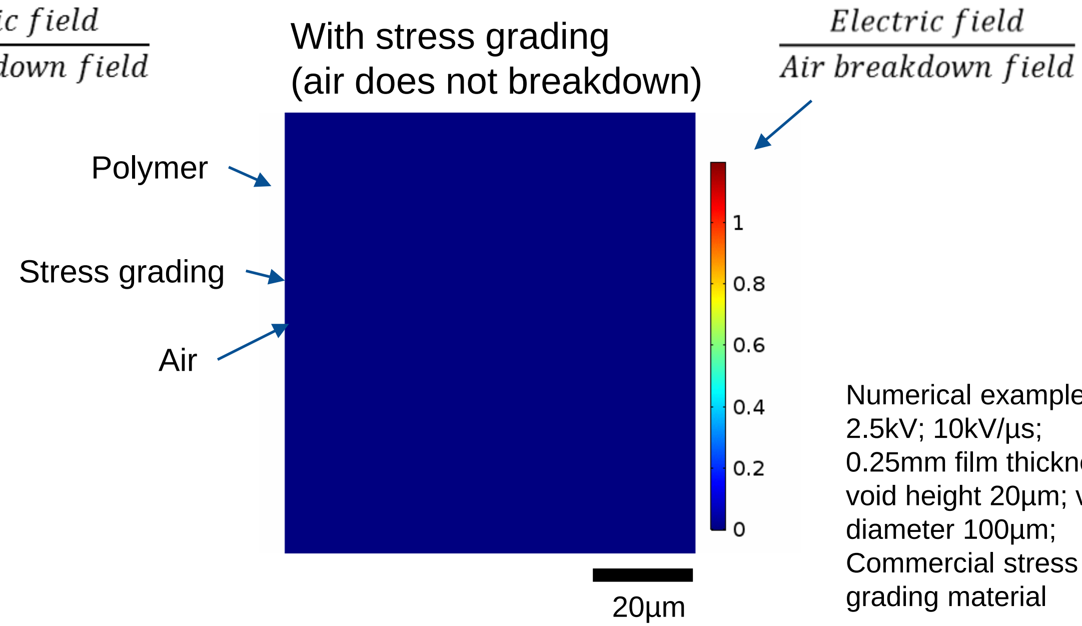
Results and Accomplishments

- Kicked-off meeting held
- Current focus: modeling; initial selection of materials, structure, and process



(View animations in presentation mode)





Numerical example:
2.5kV; 10kV/µs;
0.25mm film thickness;
void height 20µm; void diameter 100µm;
Commercial stress grading material