Physics-Based Probabilistic Model of the Effects of Ionizing Radiation on Polymeric Insulators of Electric Cables used in Nuclear Power Plants

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ABSTRACT:

The goal of the proposed project is to develop a probabilistic prediction model of time-to-failure of cable jackets subject to radiation caused polymer degradation manifested in change is tensile strength and resistivity. The main deliverable of the purposed program will be a C++ based simulation code for the probabilistic prediction of the degradation of polymeric insulators of electric cables due to ionizing radiation. The code will be readily compatible with the MOOSE/Grizzly framework developed at the Idaho National Laboratory (INL) for multi-physics simulations. The proposed project will conduct experiments to develop and verify more fundamental understanding of the degradation mechanisms and their effects on key functional properties of polymer insulators. The study will combine the experimental theoretical and findings during the course of the research to build a probabilistic predictive model of radiation caused degradation under environments consisting of air at different levels of relative humidity, various temperatures, as well as liquid water. Acknowledging the complexities and limitations of a fully physics based model, the proposed approach will take two promising technical steps. First, based on more fundamental understanding at molecular levels, we will introduce the notion of "damage precursor" as a key element in developing functional relation between dose levels and mechanical and electrical failure criteria. A damage precursor can be defined as any deviation from normal characteristics of micro-structural properties or any recognizable physical trend towards a failure-inducing threshold. Second, we use a hybrid modeling approach that fuses physics-based and data-driven approaches to produce better predictive power with reduced uncertainty. The form of the output form the hybrid model would be a probability distribution of "time to failure" reflecting aleatory and epistemic uncertainties of the modeling process, input parameters and environmental stressors. The assessment and propagation of uncertainties through the predictive model will be primarily based on Bayesian methodologies developed by the Co-PIs and widely used in nuclear and non-nuclear applications. The proposed project offers a truly interdisciplinary team of 4 participating universities and national laboratories with essential expertise and facilities to conduct experiments, develop and test predictive model, and implement it in a probabilistic simulation software.