Advanced Models for Nondestructive Evaluation of Aging Nuclear Power Plant Cables

PI: Nicola Bowler, Iowa State University
Program: Nuclear Reactor Technologies

Collaborators: Scott P. Beckman, Samy Madbouly & Chien-Ping (Thomas) Chiou, Iowa State University; Kevin L. Simmons, Pacific Northwest National Laboratory

ABSTRACT:
Background: Nuclear power plant (NPP) cables must function correctly for proper power supply and control of the nuclear reactor. This is especially important for public and environmental safety at critical times such as during reactor shut-down following loss of coolant. Over extended periods of service, the cable insulation and plastic jacket suffer from degradation due to environmental exposures such as heat, ionizing radiation and immersion in water. The focus of this project is the development of new electrical techniques to monitor cable polymer condition nondestructively.

Objectives: The objectives of this project are i) develop advanced, validated models relating microstructural and chemical changes (due to thermal exposure, radiation exposure and water immersion) in cable insulation polymers to observable changes in dielectric, terahertz (THz) and infrared (IR) frequency spectra, ii) identify the frequencies which most sensitively indicate microstructural and chemical changes in these polymers, and iii) develop advanced, validated models of the response of novel cable nondestructive evaluation methods; capacitive, THz and infrared, to cable aging as a function of thermal, radiation and/or water exposure.

Methods: Accelerated aging will be performed on the two most common NPP cable insulation polymers (EPR and XLPE) under various conditions of elevated temperature, radiation dose and immersion in water. Aging mechanisms (if not already established in the literature) will be elucidated through extensive thermal, mechanical and microscopic characterization of the aged samples. Dielectric, THz and IR spectra will be measured on the aged samples. Validated models relating polymer microstructural and chemical changes to the spectral changes will be developed. These results will provide a foundation from which new electrical nondestructive test methods for cable polymer condition monitoring will be generated. Models relating dielectric, THz and IR nondestructive measurements on aged cables will be developed and feasibility of new test methods will be demonstrated.

Potential impact: Existing cable monitoring techniques do not deal successfully with all polymer types. This research will be transformational in launching the development of new test methods for cable insulation monitoring based on measuring electrical rather than mechanical parameters.

Collaboration: This project benefits from collaborators with extensive expertise in related aspects of materials science and engineering, materials modeling, electrical engineering, and nondestructive evaluation. The majority of the characterization measurements, and all modeling, will be carried out at Iowa State University. Irradiation of samples will take place at Pacific Northwest National Laboratory, where student interns from Iowa State and other research universities will also be hosted to conduct some characterization experiments. The project will benefit from regular involvement of a senior engineer in a US-based industry partner, with over 35 years of experience in NPP cable inspection technologies and application, and from regular participation of the project investigators in international workshops.