NUCLEAR ENERGY UNIVERSITY PROGRAMS

A Distributed Fiber Optic Sensor Network for Online 3-D Temperature and Neutron Fluence Mapping in a VHTR Environment

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Abstract

Advanced instrumentation capable of operating in high-temperature/high-radiation environments is required to fully map the temperature and neutron fluence distributions in the proposed very high-temperature reactor (VHTR) cores. This project will develop a highly reliable, distributed fiber optic temperature and fluence sensor network operable under high-temperature/high-neutron fluence conditions and located throughout the reactor core. The project scope encompasses fabrication of the sensor hardware, test article design and fabrication to support in-core testing, sensor hardware demonstration at a university TRIGA research reactor, 3D modeling in a VHTR configuration, and scaling from the TRIGA test environment to the anticipated VHTR operating conditions. The project will also perform corresponding temperature/neutron field map reconstruction techniques and optimization of in-core detector positioning to minimize uncertainties. The proposed in-core monitoring is expected to reliably perform under extreme conditions that allow on-demand positioning in the reactor vessel. This results in direct in-core monitoring in prismatic core configurations and an opportunity to position detectors at innermost outer reflector locations or inside the central graphite column of the pebble bed system.

Online temperature and fluence mapping provides real-time assessment of reactor performance, benchmarks simulation and analysis codes used in core design and modeling, and allows optimization of operating margins. Existing instrumentation either fails prematurely due to combined effects of high temperatures and radiation and cannot perform reliably for the entire 18-month refueling cycle, or does not provide sufficient real-time information. The current near-term VHTR design has a projected coolant outlet temperature ranging from 750°C to 950°C, with nominal fuel temperatures ranging from 700°C to a maximum of 1,250°C. These conditions, combined with the high-radiation environment, create extremely harsh operational conditions that pose tremendous challenges for in-core monitoring system design. These challenges are currently mitigated by providing out-of-core monitoring capabilities and applying corresponding reconstruction techniques to determine temperature and neutron fluence rate profiles across the reactor core. These techniques cannot predict local phenomena due to significant uncertainties and, hence, result in higher safety margins.