NEUP Nuclear Energy University Programs
U.S. Department of Energy

Development of optical fiber based gamma thermometer and its demonstration in a University Research Reactor using statistical data analytic methods to infer power distributions from gamma thermometer response

PI: Dr. Thomas Blue, The Ohio State University (OSU)
Program: NEET-2.3 Sensors and Instrumentation for Data Generation

Collaborators: Dr. Tunc Aldemir, OSU; Dr. Pavel Tsvetkov, Texas A&M University; Dr. Diego Mandelli, Idaho National Laboratory

ABSTRACT:

The proposed research has two Tracks: **Track 1-Sensor Development and Testing -** The objective of Track 1 of the proposed research is to build and test optical fiber based gamma thermometer (OFBGT) using two University Research Reactors (URRs). **Track 2- Modeling and Data Analytics -** The objective of the second track of the proposed research is to develop methods to process the data that is produced by OFBGTs to produce estimates of the power density in the volume of the reactor that surrounds the OFBGTs. By meeting these objectives, the project will accomplish everything that is requested in the Funding Opportunity Announcement. The project will: 1) develop a novel "Big Data" sensor, which uses an instrumentation technology that inherently includes data communications, 2) demonstrate the sensor's performance in a reactor environment, without disturbing the reactor, and 3) utilize Big Data analytics to process the output of the sensor.

Gamma thermometers (GTs) are presently used in General Electric (BWRs), and in some pressurized water reactors, to calibrate LPRM fission chambers. A patent in the U.S. Department of Energy (DOE) database describes a GT that utilizes an optical fiber for temperature measurements, but to the best of our knowledge, an OFBGT has neither been built nor constructed. OFBGTs will be designed and constructed by the University Lead Organization (ULO). The functionality of the OFBGTs will be tested in the ULO Research Reactor's (ULORR's). After their functionality is confirmed, multiple OFBGTs will be deployed and tested in the University Sub-Award Organization (USO) Research Reactor. The OFBGTs will be clustered about a fuel assembly in the USORR. As the OFBGTs are being developed and tested in Track 1, modeled data (from the USORR) of combined neutron and gamma power deposition, distributed along the fiber length, will be used to develop the data processing methods in Track 2. The output of the data processing code will be the power deposition profile in the USORR core as a function of axial height for the region of the core (in the transverse plane) that exists between the OFBGTs. The data processing methods, that will be developed using the modeled data, will be used to process the data that are generated using the OFBGTs that are installed in a cluster in the USORR.

The OFBGT sensor that will be developed and demonstrated is robust and resilient, and capable of producing "big data" scale of information, with the smallest possible sensor footprint in the core. The small footprint allows unique flexibility in sensor placement in cores, without disturbing internals and affecting performance; and the high temperature capability of the sensor allows for it to be a cross-cutting technology, that can be back-fit into existing light water reactors or employed in high temperature advanced reactors. Furthermore, the small sensor footprint inherently implies a small amount of radioactive hardware to deal with during decommissioning. State-of-art (SOA) GTs use thermocouples to measure temperature and are located in guide tubes in Boiling Water Reactors that also contain local power range monitors (LPRMs) that they are used to calibrate. Since an OFBGT has such a small footprint, it could be back-fit into a BWR guide-tube, without disturbing the facilities condition. Initially OFBGTs could be used in conjunction with SOA GTs to provide better axial resolution of the reactor power profile. Once OFBGTs have been successfully demonstrated in this way, they could replace SOA GTs in order to reduce the complexity of the LPRM calibration; since one optical fiber can be used to measure temperatures, at many locations (and for many OFBGTs) in the fiber; whereas in comparison, the thermocouples that are used in SOA GTs measure temperature, at only one point, and require two wires per thermocouple. The improved axial resolution with OFBGTs, compared to SOA GTs, will, with their associated data analytics, provide a long term, permanent, and safe solution to improved monitoring of the spatial power distribution within the core; thus leading, perhaps, to reduced design margin and improved plant efficiency and/or safety.