Smart Multimodal Acousto-optic Sensors for Integrated Measurement of Advanced Reactor Process Parameters

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Program: NEET 2.3

ABSTRACT:

We propose to design and develop a multimodal sensor for measurements of critical process parameters in advanced non-light water-cooled nuclear power plants (NPPs), for the early detection and characterization of atypical operating conditions. The focus of the proposed work, from this interdisciplinary team from Pacific Northwest National Laboratory (PNNL) and the University of North Texas (UNT), will be to develop an integrated sensor concept that enables simultaneous measurements of temperature, pressure, and gas composition using a single sensor, thereby limiting the number of penetrations in the reactor vessel that would be needed. The proposed sensor concept is based on the use of surface acoustic wave (SAW) devices, and uses acousto-optic coupling for high-sensitivity, high-reliability measurements in a challenging environment. The proposed work will require an improved understanding of acousto-optic measurement physics in optically transparent piezoelectric devices, increased sensor survivability, and measurement deconvolution to quantify the parameters of interest from the measurements. The resulting technical advances in measurement science are expected to lead to the development and deployment of advanced sensor technologies for reliable, higher-resolution measurements in harsh operating conditions found in nuclear facilities.

Sensing mechanisms for measuring temperature, pressure, and gas composition will be designed into a single SAW sensor platform. This proposed sensor will leverage acousto-elastic and opto-acoustic effects, and temperature sensitivity of SAW speed. Since changes in any of the three parameters will have an effect on measuring the other two parameters, a primary technical challenge will be extraction and compensation methods for isolation of each measurement. Given these sensors and the reference problem, primary technical challenges addressed in this proposal are (1) designing and developing a multimodal sensor that is sensitive to changes in pressure, temperature, and gas composition on a single platform; (2) measurement extraction via optical fiber used for excitation; and (3) measurement deconvolution to separate measurement modes.

The specific objectives of the work proposed here are: (1) Developing an acousto-optic mechanism for measurement extraction from a SAW device; (2) Integrating a SAW and/or optical sensing-based mechanism for gas composition into a dual-mode SAW sensor; (3) Algorithms for deconvolving the effects of temperature, pressure, and gas composition to extract three measurements from an integrated multimodal sensor; (4) Test and evaluation for accuracy and reliability assessment of the sensor. The research tasks described below address these specific objectives.