In-situ Condition Monitoring of Components in Small Modular Reactors Using Process and Electrical Signature Analysis

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For reliable and economic long-term operation of Small Modular Reactors (SMR), it is imperative that continuous in-situ monitoring of critical equipment must be developed and incorporated in the reactor design phase. This capability is attractive for remote deployment of SMRs with longer fuel cycle duration and for minimizing forced outages, thus enhancing the utilization of these power generating systems in small electric grid environments. These issues were highlighted in a report on Instrumentation, Controls, and Human-Machine Interface Technology Development Roadmap for Grid Appropriate Reactors (ORNL). The DOE Workshops on On-Line Monitoring and Small Modular Reactors (held in June 2010) further emphasized the need for the development of continuous non-invasive approach for reactor surveillance. These technologies contribute to smart condition-based maintenance, reduced human resources, and remote monitoring of reactor components. In integral primary system reactors (IPSR) and other designs of SMRs, the pressure vessel incorporates most of the critical equipment used for power generation. Examples of such plant components include: motors, coolant circulation pumps, motor-operated valves, solenoid-operated valves, compressors, control rod drives, in-core instrumentation, and reactor internal structures.

The objective of the proposed project is to develop and demonstrate in-situ equipment monitoring methods with applications to reactor components such as coolant pumps and control rod drive mechanisms. The goal is to integrate electric signature analysis (ESA) and process measurements to perform remote monitoring of reactor components. Both steady-state and transient signal processing techniques will be incorporated into an on-line monitoring toolbox. This research, specific to the SMRs, is necessary because of their special features. SMRs have components that are somewhat different from conventional PWRs. For example, the coolant pumps are internal to the vessel, and therefore component instrumentations are limited, making ESA the only viable method for ascertaining component condition.
An experimental flow loop, with typical motor driven devices, will be developed as part of this project. ESA takes advantage of the inherent capabilities of motors, generators, and solenoids to sense the varying load on the system and act as transducers by reflecting these changes in the electrical signals. The innovative features of the proposed project include in-situ electrical signature analysis for remote monitoring of reactor components, development of stationary and transient signal analysis.

The objectives and the anticipated deliverables of the project are relevant to the mission of the DOE-NE in promoting innovations in nuclear engineering research and education. The project plans to draw upon the expertise of the PI, the Co-PIs and the collaborating national laboratory on equipment on-line monitoring, diagnostics, and electrical signature analysis for machinery condition monitoring.