In-Situ Condition Monitoring of Components in Small Modular Reactors

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Background

Small modular reactors have emerged as the future of nuclear power generation. SMR designs feature lower startup costs, greatly enhance safety, have longer fuel cycles, and can be deployed remotely. Before SMRs can be added to the nation's power grid, several key issues must be addressed. One of these important issues is the monitoring of components inside the reactor vessel.

Purpose

The current designs incorporate most of the critical equipment used for power generation inside the reactor vessel. Therefore, reactor coolant pumps, motors, and control rod drives among others, are in a hazardous environment and must be monitored remotely for long periods of time in order to keep the reactor operational. Conventional component instrumentation used in current reactors cannot withstand this harsh environment making electrical signature analysis (ESA) a viable option for ascertaining component condition. ESA was pioneered by Oak Ridge National Laboratory and takes advantage of a motor's inherent ability to act as a transducer through its varying loads. The changes in the pump motor's electrical signature (current drawn) can be then be related to other process variables such as flow or pressure to monitor the health of the pump.

Design Method

An existing experimental flow loop was modified with the addition of a submersible pump, new sensors, and data acquisition equipment. The loop consists of two coupled water tanks, computer controlled valves, a submersible pump, various flow meters, pressure transmitters, and accelerometers, all of which are hooked up to a data acquisition system. LabView is used to record the sensor data at both steady state and transient operating conditions and then imported into MATLAB for post processing in the time and frequency domain.

Results

Several test runs were made to establish the relationship between process variables and electrical signatures. It was observed that the pump outlet pressure and the motor current signals show similar behavior, in the transient region (start-up and shut-down) and during steady-state operation. It was also shown that when the supply frequency of the pump was altered, changes in the current were reflected in the process variables and were highly correlated with each other.

Conclusion

A fully instrumented flow control loop with a submersible pump and a variety of sensors has been developed to establish the feasibility of using electrical signatures for remote monitoring of reactor internals in a SMR. Preliminary results show a strong correspondence between current changes and process variables. Future work includes the development of models of an SMR and pump-motor dynamics to determine the sensitivity of electrical signatures as a function of process and pump conditions.