# Embedded I&C for Extreme Environments

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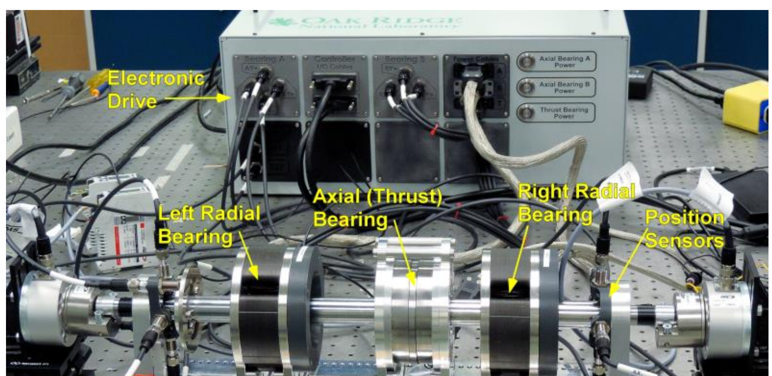
Description of project: This project uses embedded instrumentation and control (I&C) technologies to demonstrate potential performance gains of nuclear power plant components in extreme environments. Extreme environments include high temperature, radiation, high pressure, high vibration, and high EMI conditions. For extreme environments, performance gains arise from moment-to-moment sensing of local variables and immediate application of local feedback control. Planning for embedding I&C during early system design phases contrasts with the traditional, serial design approach that incorporates minimal I&C after mechanical and electrical design is complete. The demonstration application involves the development and control of a novel, proof-of-concept motor/pump design. The motor and pump combination operate within the fluid environment, eliminating the need for rotating seals. Actively controlled magnetic bearings also replace failure-prone mechanical contact bearings that typically suspend rotating components. Such as design has the potential to significantly enhance the reliability and life of the pumping system and would not be possible without embedded I&C.

Impact and value to nuclear applications: This project will yield cross-cutting sensor and control technologies for nuclear reactors, and a loop-scale embedded I&C testbed and demonstration platform for future research into embedded instrumentation and control technologies for extreme environments. Additionally, performance testing at the bench-scale and loop-scale will yield quantifiable measures of the performance improvements due to embedded I&C. Embedded sensors and controls can enable features, performance, and reliability not possible with legacy approaches. Future nuclear power plant reactor concepts include elevated temperatures and other extreme environmental factors that challenge materials and component designs. Embedding sensors and controls in nuclear power plant components is expected to increase their performance and reliability. A transition of component design and functionality from a static mechanical design to a flexible dynamic electromechanical system with embedded sensors and controls can realize components that can adapt in real-time to changing environmental conditions while sensors provide diagnostic and prognostic capabilities that increase component lifetime and reduce operating costs. Component design margins can be reduced because of tight coupling between sensors and control, resulting in lower mass and, hence, lower costs.



Bench scale test device incorporating shaft, magnetic bearings, and sensors shown with electronic drive. This system will be combined with a commercial canned-rotor pump for water-loop demonstration.

Recent results and highlights: A bench-scale test bed including magnetic bearings, custom-designed switched reluctance motors, sensors and real-time control hardware has been fabricated. The test bed provides an implementation environment for the remaining I&C tasks such as the development of advanced control algorithms and a sensorless position indication. A detailed design for a submerged loop pump system has also been completed. These results and further results over the next year are expected to show the path to improvement of crucial performance and reliability factors using deep embedding. Specifically, for the magnetically-levitated, canned-rotor fluid pump, a motor design will emerge that prevents physical contact between moving parts (except the coolant itself). The design eliminates the need for lubrication and eliminates bearing and seal wear. Being a canned rotor design, the pump and motor are submerged in the coolant stream, which permits greater flow path design flexibility. The potential of this design type is high reliability and low maintenance. Elimination of lubrication and bearing and rotating seal structures also makes possible lower cost manufacturing.