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Institution: **Oak Ridge National Laboratory**

Collaborators: **North Carolina State University, University of Tennessee**

Title: **A New Paradigm for Automatic Development of Highly Reliable Control Architectures for Future Nuclear Plants**

Nuclear reactors of the 21st Century will employ increasing levels of automation and fault tolerance to increase availability, reduce accident risk, and lower operating costs. Key developments in control algorithms, fault diagnostics, fault tolerance, and communication in a distributed system are needed to implement the fully automated plant. Equally challenging will be integrating developments in separate information and control fields into a cohesive system, which collectively achieves the overall goals of improved safety, reliability, maintainability, and cost-effectiveness. The objective of this research is to develop an example of a 21st century reactor control system, and to test and evaluate system performance in terms of these goals.

The long-range goal of the controls and information field of research is to develop the computer-aided systems, processes, and tools that automate the code generation, validation, and implementation of a control system for a fully automated nuclear power plant of the 21st century. This is the "moon shot" of control engineering problems. The fully automated plant is a far larger project than the Nuclear Energy Research Initiative can fund. The goal of automating the design process is even greater. Our research tasks focus on some of the first level breakthroughs in control design, diagnostic techniques, and information system design that will provide a path to enable the design process to be automated in the future.

The project consists of four tasks. The first two tasks provide unique and innovative contributions into the field of self-organizing strategies for diagnostics and control. The project also includes two tasks to simulate the system, analyze reliability and assess system integration issues. The latter two tasks are, in effect, implementation research. The research tasks in self-organizing strategies develop the tools that are needed to automate the controls system engineering process. The tasks that develop and analyze the system aspects of control system design verify that the automated strategies can be used in a design environment. It is important that, lacking new plant construction for possibly the next 10 to 15 years, that the research include implementation and testing of new concepts in a simulated practical application. The project is designed to cover the full life cycle of a control design development and make valid conclusions about the utility of the concepts in actual practice. The project works toward the long-term goal of requirements based design of the control and diagnostics system.

The development of new concepts for control and diagnostics for the nuclear field requires a unique combination of experience in nuclear plants, and the theoretical fields of control and diagnostics. The institutions, and the principle investigators, have that combination of experience. ORNL will lead the work by developing a new hierarchical and distributed instrumentation and control architecture incorporating a variety of both original and well-known techniques to a nuclear plant. The University of Tennessee will provide a suite of diagnostic tools that will enable the control system to anticipate and adapt to changing plant conditions including degraded sensors, actuators, and systems. North Carolina State University will develop tools to determine the reliability and level of fault tolerance of the new plant control architecture, thus providing an approach for evaluation and licensing the I&C systems proposed for future plants.

In the field of controls, as in other fields, it is imperative to reduce the engineering labor component of the cost. The challenge of the next century control theorist will be to utilize self-organizing strategies to automate design and adaptive techniques to automate the control system tuning.

Advanced control theories must move from academic exercises on idealized problems to routine techniques whose performance always meets expectations. Our concept of automated control design is to feed in requirements and plant data and to compute the design, the parameters, the setpoints, and ultimately the demands for the plant actuators. In this endeavor, the work in controls is not so much theory as application and qualification for the nuclear plant environment where reliability is of utmost importance.

It can also be expected that instrumentation and control technologies will change significantly with time. Examples of new possibilities include intelligent wireless sensors and actuators, uses of application specific integrated circuits, self-validating sensors, simultaneous fault detection and isolation of sensors and field devices, advanced control algorithms, on-line system and process diagnostics, and other developments in information processing and transmission technology. System level design and analysis tools need to be flexible with respect to technology and its influence on system architecture. The system should be capable of being readily reconfigured to accommodate new technology within the same overall framework. Software architecture concepts that segregate the environment dependent features of software from the functional or operational considerations are a key design consideration. The flexible architecture design can endure massive hardware changes while continuing to provide useful structure and much reusable code.

Successful completion of this research will provide future nuclear plant designers with a new paradigm for cost effective development and reliability assessment of new integrated plant control, monitoring and communication systems.