Adaptive Control and Monitoring Platform for Autonomous Operation of Advanced Nuclear Reactors

PI: Athi Varuttamaseni – Brookhaven National Laboratory
Program: NEET-2.2: Big Data, Machine Learning, and Artificial Intelligence

Collaborators: Shinjae Yoo – Brookhaven National Laboratory, R. A. Borrelli – University of Idaho, Ai Kagawa – Brookhaven National Laboratory

ABSTRACT:

This research seeks to develop a supervisory control platform for nuclear plant control systems that will allow autonomous operation of the plant. With autonomous operation, advanced reactors can reduce its operations and maintenance costs, operate more safely, and be more resilient to cyber-attacks. Advanced nuclear reactors encompassing small modular reactors (SMRs) and mobile microreactors, are designed to be constructed relatively quickly (compared to current-generation reactors) and with lower capital costs. Their designs rely on modern technologies such as digital control systems, field-programmable gate arrays, automation, and artificial intelligence (AI) for safe, cost-efficient, and secure operations. Current uses of AI in advanced reactors focus on operator support functions such as failure prediction, reactor vessel integrity surveillance, network monitoring, and plant state estimation. However, high-level control decisions are still relegated to human operators.

With current applications such as self-driving cars and spacecraft autonomous controls, AI technology today is at a state where it is sufficiently mature for consideration for use in autonomous nuclear plant operations. This will have the advantage of allowing remote plant operations for mobile micro-reactor, allowing electricity to be delivered to remote areas with minimal support and operating staff. For SMRs, this allows more time for operators to process all information and make informed decisions during abnormal and accident scenarios, thereby improving plant safety. It can potentially enable regulators to allow reduced staffing requirements, leading to more efficient operations at lower costs.

The AI platform developed in this project will be trained using reinforcement learning algorithms with sensor and plant response data generated by a NuScale SMR simulator. The platform will be designed to handle representative events from normal operations, anticipated operational occurrences, accident scenarios, and cyber-attack scenarios. AI development will be performed using a multi-GPU computing cluster, allowing parallel distributed algorithms to be leveraged. The work will include the evaluation of the platform to understand the degree of reduction in operating costs that can be realized with its deployment and any added risks associated with the platform (both cyber risks and risks from malfunctions).

Successful completion of the project will give a greater understanding of the capabilities of modern AI technologies when used in nuclear plant controls as well as potential risks and vulnerabilities that they can introduce. Understanding these benefits and limitations can direct future research in this area and bring autonomous nuclear plant operations closer to reality.