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Development of Thermal Power Dispatch Simulation Tools for BWR Flexible Plant Operation and Generation

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ABSTRACT:

In the United States, nuclear power plants (NPPs) generate around 20% of total electricity output, accounting for about 56% of total emission-free electricity output. Nuclear energy will remain as an important energy contributor to the nation, providing the most reliable non-carbon-dioxide-emitting source of baseload power. Due to the extension of the license of nuclear plants beyond 60 years of the initial licensing, improvements in the productivity of the nuclear power plants are sought after to support the nation's growing energy demands. One of the identified approaches is by repurposing the plants during certain periods to sell electricity directly to large industrial process plants to maintain a very high capacity factor. As a result, it is of great interest to extract up to 50% of the thermal power from the plants to deliver the required energy through a process called thermal power extraction (TPE). Recent investigations under the support of the Light Water Reactor Sustainability (LWRS) Program have shown that the current fleet of light water reactors can provide cost-competitive energy required for hydrogen production and industrial hydrogen users. In the U.S. domestic LWR fleet, about one-third of operational nuclear power reactors are boiling water reactors (BWRs). Therefore, it is of great importance to develop TPE technologies for BWRs.

This study proposes investigating the thermal and electric power dispatch and required control algorithms for dynamic heat dispatch of up to 50% of the thermal energy from a BWR plant to a hydrogen plant. To determine the licensing pathway based on the existing NRC operating licenses, we propose to identify major contributing parameters such as hydrogen plant siting, operating conditions, and engineering measures by performing a probabilistic risk assessment (PRA) evaluation of electricity connections and thermal-energy extraction and coupling to a hydrogen plant. We will perform design verification for the TPE system and TPD loop as well as system engineering analysis to identify potential issues during thermal extraction. In addition, a thermal-hydraulics analysis of the TPE system and TPD loop under different operating scenarios will be implemented using RELAP5. We will develop a full-scope heat dispatch BWR simulator consisting of a generic BWR power plant simulator and control logic, TPE and TPD models that will be modified from those in a heat dispatch PWR simulator, and a hydrogen plant model. To align our research goals with the LWRS Program plan, we will leverage the existing modeling capabilities and current efforts to incorporate thermal power dispatch into a PWR simulator at Idaho National Laboratory (INL). In addition, we propose to develop necessary control programs, controllers, and algorithms for integrating operations of the BWR power plant, TPE system and TPD loop, and hydrogen plant. To test the overall control algorithms, we propose to simulate different operating modes and transitions to evaluate their impacts on the nuclear power plant operators. The developed heat dispatch BWR simulator will be operated and tested by a team consisting of one BWR operator and multiple graduate students from three collaborating universities. The performance of the overall control algorithms, design requirements of the TPE system, and plant operation limits will be determined.