Advanced Reactors-Intermediate Heat Exchanger (IHX) Coupling: Theoretical Modeling and Experimental Validation

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ABSTRACT

Advanced reactors from the Gen IV program are required to deliver electricity and process heat with high efficiency. The electric power production may be through a high pressure steam generator (Rankine cycle) or a direct- or indirect-cycle gas turbine (Brayton cycle). The process heat applications may include co-generation, coal-to-liquids conversion, and synthesis of chemical feedstocks. These applications of these advanced reactors are critically dependent upon an efficient intermediate heat exchanger (IHX), which is a key component transferring heat from the primary coolant to a secondary coolant which will then further transfer heat to a chemical process or a power conversion system. Several candidate designs for IHX are available, with the final decision still to be made. These designs include shell and tube, and compact heat exchangers: plate-and-fin, and micro-channel (printed circuit heat exchangers or PCHEs). The secondary heat transfer medium may be helium (power generation through Brayton cycle) or molten salts (process heat applications).

Despite its significance, the safety implications of the nuclear reactor-IHX-chemical process coupling have not received much attention. The complexity of the system requires the development of advanced techniques to ensure proper control of the system.

The goal of the proposed research is to model the behavior of the Advanced Reactor-IHX-Chemical Process system and develop advanced control techniques (based on genetic algorithms or neural networks) for off-normal conditions. The specific objectives are: 1.To develop mathematical models to describe the advanced nuclear reactor-IHX-Chemical Process coupling during normal and off-normal operations, and simulate the models using a multiphysics software such as Comsol; 2. To develop control strategies using genetic algorithm techniques and couple these techniques with the multiphysics software; and, 3. To validate the models experimentally using the existing facilities at The Ohio State University.

The proposed research will provide information on the thermal designs and advanced control strategies for different IHX types for various combinations of coolants and operating temperatures and conditions. The data and information obtained through the research will be valuable in understanding the coupled response of the reactor-IHX system to various transients and in the development of intelligent control systems for the next generation nuclear reactor systems.