Demonstrating Hybrid Heat Transport and Energy Conversion System Performance Characterization Using Intelligent Control Systems

PI: Akira Tokuhiro – University of Idaho

Co-PI: Milos Manic – University of Idaho

Vivek Utgikar – University of Idaho

Collaborators: Diana Grauer – Idaho National Laboratory

Michael McKellar – Idaho National Laboratory

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ABSTRACT

The Next Generation Nuclear Plant (NGNP) is a high-temperature helium-cooled, graphite moderated reactor with an anticipated core outlet temperature between 750□ and 850°C. These reactors are well suited for the co-generation of process heat and electricity, and for the production of H2 (from water) for industrial applications in the chemical and petrochemical sectors. NGNP is a part of the DOE-NE's gas-cooled very high temperature reactor technologies R&D program; its long term goal is to achieve outlet temperatures of 950°C. The NGNP R&D program is organized into a number of areas (NEUP RPA); here we are proposing a scope of work in response to NGNP-2, but also encompassing ARC-2. Beyond generating electricity, NGNP and similar next generation systems are expected to have advanced energy conversion, 'intelligent (process) control systems' (ICS) and 'energy products' foremost process heat. Thus the importance and relevance to NGNP objectives is in terms of heat transport, energy conversion, chemical products and nuclear heat applications that couple HTRs with a wide variety of process heat applications and importantly 'non-linear' load and transient demands.

Our overall objective will directly address via design, deployment and demonstration the load following capabilities of a '20-30kW-scale' energy conversion loop (ECL). The ECL will essentially consist of the following: high-temperature gas circulator (up to 650□C), a boiling water loop, heat exchanger, a small steam-driven generator, air and condensate tanks, and various thermal/electrical loads including a reversible chemical energy storage process. The 650°C specification is sufficient for many relevant HTR applications, for example: fuels drying, desalination, biomass pyrolysis, oil shale/tar sands and petroleum refining. The initial heat transfer medium will be air, as deployment is prioritized over working with helium. The ECL ICS will feature software-based models and simulation capability, thus amenable to validation and verification. Application of heuristic methods – applied neural networks (ANN), as part of the ICS enable us to characterize components and the ECL, and provide 'intelligent' I&C. We will thus investigate the following: (a) dynamic simulation and control of reactor-driven (simulated high temperature gas circulator) process heat processes, including interactions of multiple thermal and electrical loads, 'modules' and (b) simulation and analyses for the use of (interactive) I&C, data acquisition, prognostic and diagnostics —ICS (e.g. adaptive controllers, "fuzzy logic", ANN, genetic algorithms and related to handle combined interactions between the heat source, heat transport, energy conversion, and thermal and electrical loads.

Three university co-PIs are partnering with and leveraging a leading nuclear energy national laboratory's hybrid energy systems (HES), NGNP process heat and energy systems expertise to demonstrate an ICS-based ECL (multi-component). The ICS will demonstrate rudiments of advanced I&C such that it will facilitate understanding of non-linear, real component behavior, scaling and importance of virtual testing via an adaptive, trained ICS. We will consider extrapolation of results to BOP metrics under normal and off-normal events.