Evaluation of Semi-Autonomous Passive Control Systems for HTGR Type Special Purpose Reactors

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ABSTRACT:

A recent focus of the U.S. Department of Energy initiative for Advanced Reactor Technologies has been on the development and design of "special purpose reactors." Special purpose reactors (SPRs) are characterized by their low power, (e.g. < 20 MWth) and deployability. This class of reactors have the potential to fulfill needs in areas of national security, disaster response, or commercial and industrial use by providing deployable terrestrial power. Since a key objective for these reactors is to be able to deploy them broadly, confidently, and safely this means they should be able to operate robustly with minimal human interaction. Therefore, automatic passive control systems or semi-autonomous control systems are a necessary technology for enabling special purpose reactor deployment.

One commercial SPR being developed by HolosGen, LLC is the multi-module Holos Quad; a high temperature gas reactor-type concept that spatially positions subcritical modules to control criticality. This control system relies on a complex powered system of fast actuators originally developed for the airline industry. This system was adopted for its high technology readiness level and reliability which has the benefit of shortening time to market. The underlying design philosophy of this system is reminiscent of so called "active" systems employed heavily in Gen-III designs. An alternative approach that we propose to investigate is to develop semi-autonomous/autonomous control systems that build on the Gen-IV and beyond design philosophy of having so called "passive" systems. Passive systems are primarily characterized by relying on fundamental physical phenomena to drive system responses rather than manufactured or powered systems such as actuators, valves, switches or other energized circuits that may or may not require human intervention.

Specifically, in this work we will explore passive systems that aim to provide control of local heat removal rates for fine grained control of the reactor. Additionally, a new system for controlling the bulk criticality of the core that relies on a variable reflector between the subcritical modules rather than actuators will be analyzed.

To accomplish this design study the team will develop and couple a model predictive control algorithm to the advanced high fidelity neutronics code PROTEUS. Then the team will modify existing models PROTEUS models to characterize the design space, control strategies, and quantify system performance requirements. Given these design requirements, optimized designs will be developed. The optimized design will then be evaluated against ideal control responses for flexible power operation and accident scenarios.

The proposed project is significant for developing conceptual ideas of passive mechanisms for reactor control under operating conditions. These ideas employ technologies easily adaptable to other special purpose reactor designs and thus will contribute to the broader special purpose reactor R&D effort. This project also adds value to the overall NEAMS program by advancing the capability of the primary NEAMS deterministic neutronics code PROTEUS and the overall simulation capability for SPRs that