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RELAP-7 Application and Enhancement for FLEX Strategies and ATF Behavior under Extended Loss of AC Power Conditions

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ABSTRACT:

One of the key lessons learned from the Fukushima Dai-ichi accident was the significance of the challenge presented by a loss of safety-related systems following the occurrence of a beyond-design-basis (BDB) external event. In order to increase defense-in-depth for BDB scenarios and to implement the U.S. Nuclear Regulatory Commission's (NRC) Fukushima task force recommendations, the nuclear industry developed diverse and flexible coping mitigation strategies (FLEX) and severe accident management guidelines (SAMG). Concurrently, the U.S. Department of Energy initiated research and development on the enhancement of the accident tolerance of light water reactors by the development of advanced fuels/cladding that, in comparison with the standard UO2/Zircaloy system, can tolerate loss of active cooling in the core for a considerably longer time period while maintaining or improving the fuel performance during normal operations.

In this proposed work, the advanced system analysis code RELAP-7 will be extended by adding and improving several important model components (e.g., mechanistic RCIC model). The code with the proposed new modeling capabilities would have a better prediction of system safety response during a postulated accident. The extended code can be used to predict and quantify emergency response equipment performance under BDB conditions. With the addition of more realistic models, the code is capable of providing expanded understanding of safety margin, which could form the technical basis for the successful implementation of the FLEX and SAMG measures under Extended Loss of AC Power (ELAP) conditions for BWR or PWR reactor designs.

A detailed RELAP-7 input model will be developed to simulate postulated ELAP scenarios in the Peach Bottom (PB) Atomic Power Station Unit 2 reactor. The study will focus on the thermal-hydraulic response of the reactor system in selected ELAP scenarios up to the initiation of fuel damage. The overarching goal of the proposed work is to perform a simulation study using RELAP-7, to model BWR ELAP scenarios with various mitigation measures and determine the range of time available for transition to portable FLEX equipment. In addition, analyses will be conducted to illustrate the impact of advanced accident tolerant fuel/cladding materials on core fuel heat-up under ELAP accident conditions. In order to quantify the uncertainties in key modeling parameters that affect the time to significant fuel damage for the simulated transients, the RAVEN software package will be used to perform parameter sensitivity studies. In addition, benchmark studies will be conducted with the NRC's reactor system analysis code TRACE and with MELCOR calculations of PB, to provide confidence in the RELAP-7 PB model and serve as a partial validation.