Coping Time and Cost Analysis of Accident Tolerant Plant Design based on Dynamic PRA Methodology

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ABSTRACT:

New safety upgrades for existing Light Water Reactors (LWRs) are being developed, which include Accident Tolerant Fuel (ATF) and diverse and flexible coping strategies (FLEX). These safety features are expected to extend the plant's coping time and mitigation capability in an accident. This proposed project will evaluate the failure modes of ATF candidates within the U.S. DOE Advanced Fuel Campaign (AFC) directive, i.e. Cr-coated Zr-alloy, FeCrAl alloy and SiC/SiC composite. To understand the different ATF failure characteristics, this project strategically capitalizes on a Co-PI's on-going experimental activities supported by a previously awarded NEUP project.

Currently there is little evaluation of the coping time variation under uncertainties in accident mitigation efforts. Therefore, this proposed project aims to obtain a response surface of coping time by investigating the various uncertainties of accident mitigation in PWR and BWR reactors. Aging of passive and active components will be incorporated to realistically capture plant dynamics in current nuclear fleets in USA. Significant uncertainties are expected in FLEX mitigation strategy because of FLEX equipment portability and lack of operator's experience due to its recent introduction. Dynamic Probabilistic Risk Assessment (DPRA) and human performance uncertainty models will be utilized to systematically assess the different risk impacts of these uncertainties. This assessment will be conducted using the LOCA Toolkit for the U.S. (LOTUS). The LOTUS results will be incorporated into the overall plant PRA model using the DPRA integration process being developed in another Co-PI's on-going NEUP project. Risk measures and safety margin improvements will be quantified using this integrated PRA model.

The increased safety margin due to coping time extensions will be leveraged to relax quality assurance classifications of existing Structure, System and Components (SSCs) in compliance to the 10 CFR 50.69 regulation. Economic savings for each option will be calculated from SSC classification relaxations and other financial incentives, including the reduced fuel cycle cost incurred from the use of ATF. Therefore, a response surface of economic savings reflecting the variations in coping time will be generated.

Deliverables of the project include: (1) failure criteria of ATF candidates and respective affecting loads, (2) a complete list of uncertainty sources and their ranks for FLEX equipment in reference PWR and BWR plants, (3) computer models of ATF performance and damage progression, (4) integrated computer model of safety enhanced plant, (5) risk metrics for each plant-specific ATF candidate, (6) SSC classifications for each plant-specific ATF candidate, (7) response surface of coping time (8) response surface of potential economic savings. These outputs will aid the decision making process on the implementation of ATF and FLEX to existing LWR plants in USA from the perspective of risk reduction and economic feasibility.