Abstract:
This paper presents a safety analysis of two proposed core loadings for 24-month Pressurized Water Reactor (PWR) fuel cycles. This analysis focuses on reactivity-initiated accidents (RIAs) and evaluates core safety performance impacts of rod-averaged burnup limits up to 75 GWD/MTU and less than 7 % enriched UO2. The capabilities of Polaris, PARCS, and RELAP5-3D are leveraged to evaluate the core neutronic and thermal–hydraulic behavior for normal-operation, uncontrolled control rod withdrawal (CRW) transients, and control rod ejection (CRE) accidents. The two core designs are compared to identify features of realistic high burnup/extended enrichment core design approaches which have significant safety impact, identify experimental data needs for high-fidelity predictive modeling, and provide recommendations for future high burnup core designs. The first core design evaluated in this study was developed by Southern Nuclear Company and used an ZrB2 Integral Fuel Burnable Absorber (IFBA) and B4C Wet-Annular Burnable Absorber (WABA)-based burnable poison strategy. The second core design assessed in this work used a Gd2O3-doped UO2 burnable poison, similar to that used in boiling water reactors or French PWRs. Results indicate that fuel thermal limits are maintained for limiting CRW and hot full power (HFP) CRE transients. Cladding failure is predicted for the highest energy deposition rods in each core during limiting hot zero power (HZP) CRE accidents (where maximum radially averaged enthalpy exceeds 120 cal/g), though licensing may be permissible with a limited number of failed rods. While concerns exist regarding high critical boron concentration during steady state for the IFBA core and large plenum pressures for the gadolinia core design, the analysis demonstrates adequate safety performance during limiting RIA accident scenarios for two representative high burnup core designs. Design changes limiting plenum pressures and implementation of accident tolerant fuel (ATF) cladding features which minimize hydriding and susceptibility to pellet-cladding mechanical interaction (PCMI) are recommended for future high burnup fuel concepts. To support the technical basis for burnup limit increases, high-fidelity fuel performance models are needed to address physical effects not considered in this analysis, and high burnup irradiated fuel tests are required to extend applicability of the fuel failure limits and validate existing and future models.