Effect of Startup Ramp Rate on PWR Fuel Reliability

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Abstract

A wide range of startup strategies and restart times currently exists for commercially operated pressurized water reactors (PWRs). The variability in PWR restart strategies is a function of several factors, including reactor system instrument calibration, primary and secondary water chemistry control, and vendor specified fuel rod ramp rate limitations. Fuel vendors, as a means to mitigate pellet-cladding interaction (PCI) leading to fuel rod failures, specify reactor power ramp rate limitations following a refueling outage. Typical restart ramp rates range between 3% per hour and 4% per hour of full reactor power above a threshold reactor power level between 20% and 40% full power. This paper summarizes an analytical evaluation performed to assess the technical basis for PWR restart ramp rate restrictions and to provide the technical justification to propose less restrictive power ramp rate conditions. Two combinations of PWR reactor types (Yonggwang Unit 2&4) and fuel rod designs were used to evaluate the impact of ramp rate and threshold power conditions on the PCI behavior of once-burned and twice-burned fuel rods. The fuel rod condition at the reactor restart of interest was established using the ESCORE steady state fuel performance program. Detailed PCI calculations were performed using the FREY fuel rod behavior program. The assessment identified significant margin to PCI failure for current ramp rate conditions used in YGN Unit 2&4. Based on the analytical evaluation presented, ramp rates up to 5% per hour above threshold power levels up to 60% of full reactor power can be used without concern for fuel rod integrity during reactor restarts following a refueling outage.