A Significance of Condition-Based Probabilistic Risk Assessment Using Data-At-Scale: A Case Study

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Presentation Only: An ongoing research at Idaho National Laboratory is developing a condition-base probabilistic risk assessment (CB-PRA) capability using aging and degradation data-at-scale, maintenance record information, and reactor operation cycle details. This is an enabling approach as it would advances current PRA models and tools to include diagnostic and prognostic outcomes. The paper presents a case study of using Advanced Test Reactor PRA models and updating them based on primary coolant pumps condition to perform online risk monitoring. The paper will present initial results obtained on CB-PRA based on degradation observed at one of the reactor pumps and its impact on overall risk. In particular, the paper will present discussion on application of Markov chain model for the motor-driven pump (MDP) four failure modes with and without repair rates was developed to obtain failure probabilities of the top event (in this case, pump failure). Among the four failure modes, Fail to Start of MDP was the most significant. In-depth analysis of Fail to Start failure mode based on U.S. Nuclear Regulatory Commission (U.S. NRC) Reactor Operating Experience Database (NROD) revealed this failure mode is dictated by breaker failure due to aging. The data analysis further showed that breaker failure increases due to aging and breaker aging must be incorporated to compute accurate estimate of the MDP probability of failure over time. The paper will also present discussion on novel hazard-rate based model developed to incorporate the impact of degradation on an existing MDP PRA model. The time-varying instantaneous hazard-rate of component is used to model degradation based on time-varying performance measures (vibration, temperature, and etc.). The paper in the end will discuss the challenges associated with integrating data-at-scale to develop an accurate estimate of plant equipment condition and suggest potential ways to deal with data-at-scale. The CB-PRA models aids both data-driven and risk-informed decision-making. The outcome of this research has crosscutting benefits: online risk monitors for light water reactors, new reactor technologies, and for other critical infrastructures.