I-PRA Decision-Making Algorithm and Computational Platform to Develop Safe and Cost-Effective Strategies for the Deployment of New Technologies

PI: Zahra Mohaghegh, (Dept. of Nuclear, Plasma, & Radiological Eng., UIUC).

Program: RC-9.1 (Reactor Concepts).

Collaborators: Diego Mandelli (INL), Vaibhav Yadav (INL), Seyed Reihani (Dept. of Nuclear, Plasma, & Radiological Eng., UIUC), Ernie Kee (Dept. of Nuclear, Plasma, & Radiological Eng., UIUC), Fatma Yilmaz (South Texas Project Nuclear Operating Company).

ABSTRACT:

Due to increased competition and fluctuations in the commercial electric sales market, there has been a renewed focus on using risk-informed approaches for developing safe and cost-effective operational strategies for LWRs. Among these strategies are the use of new technologies to improve operational flexibility and efficiency while maintaining safety. It is important for decision-makers to understand the safety impact and net profitability of deploying new technologies before significant investment is committed and the regulatory review process is initiated. The evaluation of deploying new technologies has several challenges, e.g., unpostulated safety concerns, lack of operational data and procedures. In addition, scenarios associated with the deployment of new technologies most often, if not always, involves socio-technical phenomena that are highly complex and spatiotemporal in nature. Due to its static nature, classical PRA used at NPPs may not address these challenges appropriately and, hence, may generate misleading risk insights. Current dynamic PRAs, however, still have feasibility challenges that prevent them from being implemented for a full plant. As a more feasible alternative, the PI's team has developed the Integrated PRA (I-PRA) methodology to add realism to risk estimations by explicitly incorporating time and space into underlying failure mechanism models of the events in the plant PRA and integrating these simulation models with the plant PRA via a probabilistic interface while avoiding significant changes to PRA structure. This project proposes a new and complementary methodology to the PI's ongoing NEUP RC-9 Project (#17-12614) to support risk-and-cost-informed decision making related to the deployment of new technologies. To help the nuclear industry expedite the deployment of new technologies, this project will make the following contributions: (I) Developing an I-PRA Decision-Making Algorithm to support risk-and-cost-informed decision-making related to the deployment of new technologies, where additional resources can be allocated to the analysis of alternatives and scenarios that have large impact on the safety risk and cost estimates; (II) Making methodological and computational advancements to execute the I-PRA Decision-Making Algorithm for the deployment of new technologies, including: (i) modeling the spatiotemporal interactions between human performance and natural hazards, and contributing to External Control Room (ExCR) Human Reliability Analysis (HRA), (ii) advancing Probabilistic Validation methodology for validating simulation models developed in I-PRA without solely relying on empirical data (e.g., operational experience), and (iii) advancing the PI's model-based financial analysis methodology for new technologies; (III) Conducting a case study to evaluate the safety impact and cost-effectiveness of FLEX strategies in supporting operational flexibility of an NPP, where the I-PRA Decision-Making Algorithm, equipped with the advanced methodological and computational platform developed in this project, will be applied in the case study to evaluate different alternatives for deployment of FLEX equipment during normal operation. The developed algorithm is a practical problem-solving process that helps the nuclear industry execute I-PRA in an efficient way to support risk-and-cost-informed decision making, i.e., considering regulatory safety criteria and internal/organizational economic goals, to efficiently deploy new technologies.