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Evolving PSA Methodologies: Towards Dynamic Reliability in SMR Passive Systems

The emergence of new nuclear reactor generations, notably Generation III+ and IV, signifies a significant advancement in the industry. These reactors aim to reduce waste and enhance safety, driven largely by startups and private entities. However, their relative immaturity and lack of testing pose challenges, especially for First of a Kind Demonstrator projects. Additionally, the introduction of unfamiliar passive safety systems raises concerns among regulatory bodies. Addressing these challenges requires innovative licensing approaches from startups and private investors to expedite approval processes. Updating traditional Probabilistic Safety Assessment methodologies is crucial in this context.

This work underscores the importance of dynamic analysis in understanding and improving the reliability and safety of nuclear power plants. In response to limitations in conventional PSA, our study introduces a novel dynamic approach for the reliability assessment of Passive Isolation Condenser System in Small Modular Reactors (SMRs), a critical component in most SMRs, overcoming the limitations of traditional PSA. Leveraging the capabilities of the SAFEST tool to model and analyse dynamic fault trees, we enhance traditional PSA by incorporating dynamic aspects of passive systems like common cause failures, probabilistic functional dependencies, and failure ordering among components and systems, into failure models. This advancement facilitates a deeper understanding of the interactions and dependencies within the ICS, offering a significant improvement over static analysis methods.

Our findings reveal that by expressing instant failure probabilities of components (including any external factors) as functions of parameters like temperature, pressure, etc., a more comprehensive and accurate evaluation of reactor safety can be done. By addressing the dynamic nature of these systems, our approach allows for a more detailed and realistic representation of their operational effectiveness. The results of our study contribute to the field of nuclear safety by offering a more robust framework for the assessment of passive systems within SMRs.

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