DYNAMIC PROBABILISTIC RISK ASSESSMENT AT A DESIGN STAGE FOR A SODIUM FAST REACTOR

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Track 3. Fast Reactor Safety

ABSTRACT

The design of a new reactor is an iterative process. At a design stage, each reactor system may exist in several variants : combined together, these variants give different reactor designs.
Probabilistic risk assessment is a tool that gives a measure (risk, and risk space) that may help to compare different reactor designs. Conservative or macroscopic way to perform probabilistic risk assessment at a design stage may be insufficient to provide enough information to distinguish between different design variants.
The classical way to construct a PRA model with boolean Event Trees/Fault trees (ET/FT) is well applicable for a PWR type reactors at a design stage. Nevertheless ET/FT formalism finds its limits for a Sodium Fast Reactor if one considers long mission times and possible system recoveries. Due to thermal inertia and simplicity of thermal-hydraulic behavior, the decay heat removal function of a Sodium Fast Reactors (SFR) is a good candidate for dynamic probabilistic risk assessment.
In this paper, we present a new approach to construct the dynamic probabilistic model of the Decay Heat Removal (DHR) system of a Sodium Fast Reactor using Stochastic Hybrid Automata with PyCATSHOO modeling tool.The proposed approach allows to construct a dynamic probabilistic model of a SFR DHR system that incorporates the time evolution of physical parameters and dynamic changes of DHR system state (failure or recovery of DHR system components) and presents enough flexibility to be applied at the design stage.
Below, we list the important properties of a dynamic models in more details:
- We define core damage as function of primary sodium temperature during an accidental sequence. The evolution of primary sodium temperature follows the simplified equations that can be validated by a qualified thermohydraulic code. Evolution of primary sodium temperature is automatically calculated for every accidental sequence to predict the end state of the sequence (OK/Core Damage).
- We explicitly treat the dependency of DHR system trains on different support systems: electrical, I&C, ventilation etc.
- We explicitly model Common Cause Failures between different DHR components.
- We explicitly model component recoveries.

Our modeling approach allows to:
  - have a detailed model e.g. it can be as detailed system components,
  - easily change the system architecture to test and compare in a realistic way different design variants,
  - perform an uncertainty analysis of the risk as a function of uncertainty in reliability and physical parameters

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