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Spent Fuel Pool Risk Analysis for Dukovany NPP

Presentation Outline

- PSA for Dukovany NPP
- The goal of spent fuel pool (SFP) risk analysis
- Internal event (IE) selection for SFP
- Treatment of long time to fuel damage
- SFP Level 2 PSA
- Ongoing and planned activities

PSA for Dukovany NPP

- VVER-440/213 type plant in the Czech Republic
- Living PSA
  - maintained in ÚJV Řež, a. s. and regularly updated
  - RiskSpectrum® PSA software
  - basis for PSA applications at Dukovany NPP
    - risk monitoring is extensively used
- PSA scope
  - Level 1 & Level 2
  - all plant operating modes, all four units
  - risk from reactor core as well as from SFP

SFP Risk Analysis

- SFP operating modes
  - plant operation with fuel in reactor
    - fuel stored in a single layer
  - reactor core completely relocated to SFP
    - fuel stored in two layers
- The goal of SFP risk analysis
  - recommendations for prevention and mitigation of SFP accidents
  - configuration risk management during operation with core completely relocated to SFP

Internal Event Analysis for SFP

- PSA approaches are generally the same as for reactor core
- Integrated model
  - no separate PSAs for shutdown or SFP operation
- IE selection
  - support analyses to assess credibility of events
  - the following types of internal events were finally selected
    - leakage from SFP
    - heavy load drops into open SFP
    - loss of SFP cooling (without SFP leakage)
  - each of those groups contains several IEs

Loss of SFP Cooling

- Fuel stored in a single layer
  - more than 72 hours to fuel damage
  - such operation was screened out from internal event analysis
    - the exception is heavy load drop into open SFP during fuel handling (removing fuel into cask, etc.)
- Fuel stored in two layers
  - core is completely relocated to SFP
    - separate plant operating state (POS) in PSA model
  - more than 40 hours to fuel uncovery
    - if no SFP leakage occurs

Long Time to Fuel Damage

- Loss of SFP cooling during plant operation with fuel stored in two layers can be screened out as well
  - on the other hand, screening based on time to fuel damage longer than 24 hours can hide some risk contribution
- Main issues
  - SFP is located in reactor hall outside containment
    - fuel damage frequency (FDF) should be lower to obtain acceptable release frequencies
  - scheduled maintenance on some support system divisions
    - reduces support system availability for SFP cooling

Screening Analysis for Loss of SFP Cooling

- Screening analysis for IEs resulting in loss of SFP cooling
  - representative event trees
    - all possibilities od SFP makeup modeled up to 72 hours
  - significantly decreased human error probabilities
    - simplified human error dependency model (common events)
  - simplified estimation of equipment recovery
- Screening criteria for FDF
  - IEs with time-averaged FDF > 1×10^{-8}/y were not screened out
  - IEs with instantaneous FDF > 1×10^{-6}/y were not screened out
    - typical maintenance postulated in system fault trees

Internal IE Contributors to SFP Risk, Unit No. 1

Initiating event	Impact on SFP operation	FDF [1/y]
Large circulating cooling water leakage in turbine hall (flooding of vital power supply busbars)	loss of SFP cooling	3.4×10^{-10}
Flooding of SFP cooling pumps in room A242 (due to SFP cooling piping rupture)	partial SFP drainage and loss of SFP cooling	4.9×10^{-8}
Heavy load drops to open SFP (all POSs), mainly due to SFP cover drop	loss of fuel cooling due to structural damage of fuel	4.0×10^{-6}
Loss of the operating essential service water train	loss of SFP cooling	1.3×10^{-10}
Loss of the operating reserve power supply busbar	loss of SFP cooling	3.9×10^{-8}
Loss of all SFP cooling pumps due to common cause failure	loss of SFP cooling	2.9×10^{-9}
All		**4.1×10^{-6}**

- FDF contribution from heavy load drops dominates
  - great uncertainty in determination of conditional probabilities of fuel damage

Risk Monitoring

- Configuration risk management during plant scheduled outages
  - prevention of risk significant configurations
  - heavy load drops are not a subject of configuration risk management
- SFP model was transferred to risk monitor (Safety Monitor™)
  - instantaneous risk from loss of SFP cooling accidents is not negligible
    - in contrary to time-averaged FDF
    - average fraction of POS duration is not included
    - many unavailabilities due to maintenance

SFP Level 2 PSA

- Delineation of SFP fuel damage sequences into plant damage states (PDSs)
  - to determine SFP or plant status on the onset of fuel damage
    - nine attributes applied to describe SFP/plant status
- Level 2 accident progression event tree (APET)
  - EVNTRE software
    - APET is not integrated with Level 1 model in Dukovany PSA
- Preliminary results
  - very high fraction of FDF with intact reactor building
  - risk from hydrogen combustion is low

Enhancement of SFP Risk Analysis

- Ongoing activities
  - calculation of magnitudes and frequencies of releases
  - SFP Level 2 PSA for external hazards
    - incorporation of Dukovany NPP measures from Post Fukushima National Action Plan
- Planned activities
  - integration of SFP Level 2 PSA results with Level 1 model
  - fully integrated model containing accident sequence delineation up to releases in a single software could be more appropriate