Component selection for ageing trend analysis for Armenian NPP APSA

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Background (1/3)

- Safety significance of components
  - Safety significance of component
  - Conservatism in ANPP PSA
  - PSA importance analysis
  - Plant specific statistics
  - Changes to preliminary SSC list

- Ageing vulnerability of components (AFMEA)
  - AFMEA – an example
Selection of safety systems and components

Active components analysis

Data collection

Data analysis

Statistical models

DATA COLLECTION

Passive components analysis

Data analysis

Physical modeling

DATA ANALYSIS

Data collection mechanical, structural issues

AGEING TRENDS IDENTIFICATION

Background (2/3)

● Selection of component aimed to reveal those components which:
  ○ Have significant role for nuclear safety
  ○ Have potential to be seriously affected by ageing factor

● Following approaches and criteria's were used
  ○ Numerical risk importance criteria
    ➢ Aimed to address safety significance issue
  ○ Qualitative judgment
    ➢ Aimed to address ageing vulnerability issue

Background (3/3)
SAFETY SIGNIFICANCE OF COMPONENTS

Safety significance of components

- PSA importance analysis (Systems, components, IEs, CCFs)
- Information about plant specific statistics used in PSA
- Comparison of “risk-important” and “plant specific” components’ lists
- Incorporation of several recommendations made during co-operation in the frame of APSA network
Conservatism in ANPP PSA (1/5)

- Developed PSA model was reviewed by IPSART in October 2007
- IPSART mission and Risk Engineering peer review revealed that risk profile is affected by number of conservative assumptions
- Current activities aimed to eliminate over-conservatism (not finished yet)

Conservatism in ANPP PSA (2/5)

- Turbine Hall steaming factor
  - Following steam or feedwater line ruptures it was assumed that all equipment in Turbine Hall failed due to harsh environment
  - Additional analysis were not performed
- Factor of assigned value of reactor pressure vessel rapture
  - It was used $\text{IEV(RPVR)}=1E-05$ (TECDOC-749)
  - No structural analyses were performed
  - International experience showed that for WWER type reactors usually $1E-07<\text{IEV(RPVR)}<1E-06$
Conservatism in ANPP PSA (3/5)

- Factor of spray system
  - Highest FV importance for Spray system
  - "Fail to close" failure mode of downstream valves could bring to heating up of B-8/2 boric acid tank (water for ECCS)
  - Assumption was made, that following any of those failures during LOCAs, ECCS pumps failed to run due to their cavitation
  - For small LOCAs boric acid water solution temperature is still below ECCS pumps cavitation temperature

- Factor of assigned value of "Unprotected LOCA" IE frequency
  - LOCA IE frequencies were calculated based on segment method (WASH-1400)
    - Does not include LBB concept
  - Application of LBB concept could make Unprotected LOCA’s frequencies negligible

Conservatism in ANPP PSA (4/5)

Risk profile for the Armenian NPP
According quantification of changed PSA model the CDF for optimistic model (total elimination of conservatism) is equal to 3.46E-05 [1/y] (reduced by 54%).

Importance was calculated for 2 models:
- Current model (conservative)
- Revised model (optimistic)

Importance analysis for conservative and optimistic models allowed to **merge** results and reveal **entire** spectrum of components.
● Depending on their definition importance measures provide different insights regarding the SSC importance

● Taking into account suggestions made during previous APSA Network meetings it was decided to proceed with SSC selection using two type importance measures
  ○ Fussel-Vesely importance (F-V)
  ○ Risk increase factor (RIF)
PSA importance analysis (4/4)

- Fussel-Vesely importance
  - Provides with current contribution of SSC to overall risk
  - Selection criteria: $I_{[F-V]} > 0.5\%$ ($I_{[F-V]} > 0.005$)

- Risk increase factor
  - Shows potential importance of SSC, having that SSC totally failed
    - Ageing factors could have big impact on overall risk for SSC with high RIF importance
  - Selection criteria: $I_{[RIF]} > 1E+2$ (due to limited resources)
    - Few more components were added
    - About 900 components are met following criteria - ($I_{[RIF]} > 2E+0$)

Plant specific statistics

- Statistic was assumed as “enough” $N_f > 5$ (collection was done for 1996-2004 period)
- Comparison of “risk-important” and “plant specific” components’ lists shows that there is no “enough” statistics for following components
  - **Passive** - SG tubes, Deaerator, Primary non-isolable piping, Steam lines and MSH, FW lines. EMS discharge pipes (non-isoable part), Boron tank, Spray HXs
  - **Active** - Main isolation valves, EMS discharge check valves, FSIV1-7, Diesel FW pump, Spray pumps, Steam dump valves to the atmosphere and condenser, RHR pumps, NMS pumps
Changes to preliminary SSC list

- It was also concluded to exclude from ageing trend analysis SSC which were newly installed at Armenian NPP
  - Essential service water system
  - Fast steam isolation valves
  - Diesel feedwater pump

AGEING VULNERABILITY OF COMPONENTS (AFMEA)

Example of experimental application of AFMEA
AFMEA – An Example (1/11)

- The main problem of risk-based analysis presented above is lack of information regarding equipment which
  - is not in PSA model
    - screened out due to low significance
    - not explicitly modeled
  - is in PSA model and not safety significant,
    - potentially could have significant risk importance due to ageing-based decrease of reliability parameters

AFMEA – An Example (2/11)

- AFMEA procedure is used to address ageing vulnerability issue during component selection activity
- Main difference between AFMEA and traditional FMEA is appearance of new elements
  - From practical point of view results from FMEA performed within PSA model development could be extensively used for AFMEA procedure
- Implementation of “yellow” boxes requires significant effort and resources
AFMEA – An Example (3/11)

- In addition to risk significant components AFMEA procedure is used to identify those components, which would comply to the given safety significance criteria due to ageing degradation.
- It was decided to use RIF>2 criteria for components subjected to AFMEA procedure.
- AFMEA gives information:
  - to select potential safety significant components
  - to provide information for further analysis of ageing effects

AFMEA – An Example (4/11)

- AFMEA basically includes following stages:
  - Grouping of similar safety-related equipment
  - Selection of representative component for each group
  - Investigation of possible ageing mechanisms for each representative component
  - Identification of failure modes which could occur and develop due to ageing mechanism influence
  - Characterization of ageing control effectiveness (monitoring, periodical tests, etc.)
  - Results documentation
- The key point of the procedure is qualitative set of criteria allowing to assign effectiveness category for particular ageing mechanism control procedures as well as it's likelihood estimation.
AFMEA – An Example (5/11)

- Check valve on EMS system discharge line was selected as a representative component for experimental application of AFMEA.

![Figure 3: Emergency make-up system principal scheme](image)

AFMEA – An Example (6/11)

- Characteristics of check valve on EMS discharge line are following:
  - **Type**: Check valve
  - **Diameter**: D=100mm
  - **Temperature of water**: T=55°C
  - **Pressure of water**: P=140kg/sm²
  - **Operating environment**: borated water

- Experimental component selection bypasses 1&2 tasks in AFMEA.
AFMEA – An Example (7/11)

- During normal operation check valves OK012 and OK022 are working under primary pressure
  - from primary circuit side pressure is 125 kg/sm²
  - from EMP side - 1 kg/sm²
- Taking into account this fact check valves OK012 and OK022 were considered representative as they are much more loaded than OK011 and OK021

AFMEA – An Example (8/11)

- Information about possible ageing mechanisms was taken from Ageing PSA Network Task 3 report
- From whole list of ageing mechanisms only following were considered applicable for representative component
  - Fatigue
  - Corrosion
  - Wear
AFMEA – An Example (9/11)

- In existing PSA model 2 failure modes where considered
  - Failure to open
  - Failure to remain open
- Failure to remain closed of both check valves could lead to leak from primary side to EMS system’s piping.
  - In existing PSA model 2 or more sequentially located valves failure was not took into account (having low likelihood)

AFMEA – An Example (10/11)

- Monthly test
  - recirculation mode by closing 2B-6,7/1,2 valves and supplying water to boron tank
  - check valves are not operating, so this test can not provide information about check valves condition
- 1 per 4 years test
  - supplying of water from EMPs to primary circuit
  - assures checking that water will pass through check valves with desirable flow rate
  - however even this test does not allow revealing presence and progress of ageing mechanism
- Based on this information it was stated that effectiveness of control methods belongs to category 6
  - reflects insufficiency of existing control methods
Concluding above presented judgments

- It was stated that effectiveness of control is practically insufficient to catch propagation of ageing mechanisms
- Control process should be improved
  - though impact of ageing on check valve have low likelihood to bring to failure

Hence ageing trend analysis for this component is necessary