SITRON: Site risk assessment approach developed for Nordic countries

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RISK PILOT
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SITRON (SITe Risk Of Nuclear installations) project, 2017-18

Participants and

- Risk Pilot AB
- Lloyd's Register Consulting
- VTT Technical Research Centre of Finland Ltd
- IFE Halden

Financiers

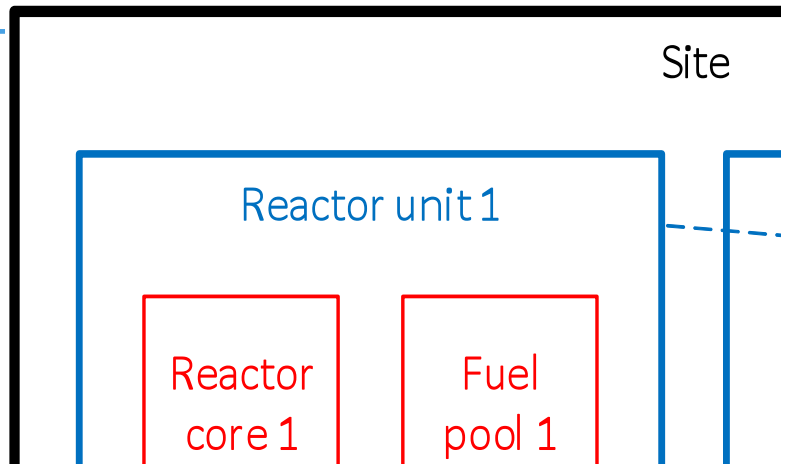
- Forsmark Kraftgrupp
- Ringhals AB
- Swedish Radiation Safety Authority, SSM
- Finnish Nuclear Safety Research Programme SAFIR2018
- Nordic Nuclear Safety Research, NKS

Objectives and scope

- To search for practical approaches for Nordic nuclear power utilities to assess the site level risk
  - Safety goals and risk metrics
  - Reactor and spent fuel pool
  - Level 1 and 2 PSA

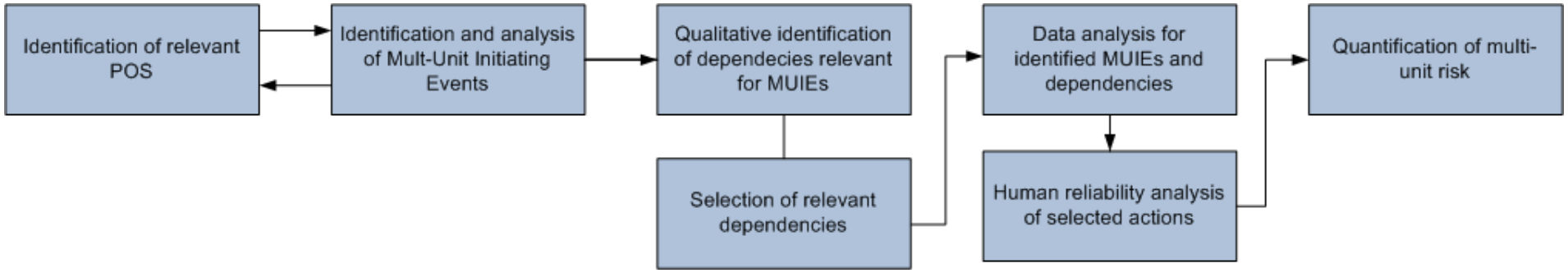
- To develop methods to assess risk for multi-unit scenarios
  - Methods to identify, analyse and model dependencies between the units
  - Should be based on the single unit PSAs as much as possible
  - Test the approach through pilot studies

Risk metric proposed



- The single-unit risk metrics proposed are:
  - per fuel location (source)
  - Integrated frequency for the reactor unit
- The multi-unit risk metrics proposed are:
  - Site damage frequency: frequency for any damage to occur at the site per year.
  - Multi-unit damage frequency: frequency of at least two damages occurring "simultaneously" per site-year
  - Site release frequency: frequency of a specific site release category (considering releases from any radioactive sources) per year.
    - Potentially simultaneous release could be interesting

Method / approach



- Scope is initially defined
- General screening principles should be defined

Dependencies

- Multi-unit initiating events
  - Simultaneous impact on multiple units
  - Propagating events
- Common systems, buildings and structures
  - Shared systems / Systems that can be cross-connected
  - Shared standby or spare equipment
- Identical components
  - Inter-unit CCF
- Human and organisational dependencies
- Spatial dependencies

picture from SKI Report 02:27

Qualitative identification process

- Dependencies are ranked as (qualitative critera):
  - Very important
  - Important
  - Less important
  - Insignificant
- Ensure all relevant dependencies are considered

Selection of relevant dependencies

- Unimportant dependencies and scenarios are screened out by quantitative screening
  - For example by using FV measure
  - Observe the potential slicing effect
  - Special focus on qualitative dependencies not considered in PSA

- Experience from the pilot studies is that screening will effectively reduce the scope of scenarios that need to be treated quantitatively

Quantitative analysis of dependencies

- *Basically: An evaluation of the conditional probability of an event at another unit given that a dependent event has occurred at one unit*
- For multi-unit initiating events, a full dependency is assumed
- Possibility of inter-unit CCFs are difficult to assess
  - A conservative assumption is that inter-unit CCF is equally likely as intra-unit CCF, but the question is what is a valid way for mapping-up CCF probabilities
  - An impact vector approach is currently suggested
- Analysis of multi-unit post-initiator operator actions requires an adaption of HRA methods

SITRON pilot studies

- Forsmark units 1&2 – two identical boiling water reactors
- Ringhals units 3&4 – two identical pressurised water reactors
- 2017
  - Level 1 PSA
  - reactor core damage
- 2018 (ongoing)
  - Level 2 PSA
  - also fuel pool
- Quantitative analysis restricted in Loss-of-offsite power (LOOP) initiating event (IE)

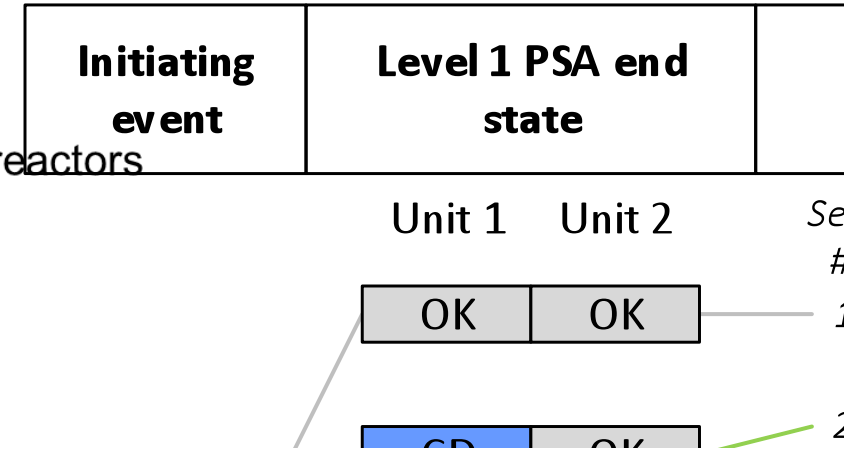
Preliminary findings from pilot studies

- Multi-unit IEs straightforward to identify = External hazards
- Propagating IEs require plant visits to judge the risk for multi-unit impacts (not included)
- Units have several shared systems with different degree of importance

- Multi-unit LOOP
  - Power operation is the only relevant plant operating state
  - PSA level 1: A few important operator action dependencies (e.g. use of mobile DGs)
  - Inter-unit CCFs have large contribution (difficult to assess due to lack of data)
  - PSA level 2 (ongoing):
    - Operator actions (not necessarily operator errors) should affect the results
    - Phenomena constitutes an interesting dependency

Selection of combinations for L2 PSA quantification

- Frequency of unacceptable release from multi-unit perspective is sum of frequencies of end states where one or two units cause an unacceptable release
- Sequence 9 is simultaneous release from two reactors
- RC_{12}= max$\{RC_1, RC_2\}$



Preliminary findings from pilot studies – quantification

Two slightly different approaches tested

- CCF approach: to split A_i into two exclusive events
- $A_i = A_i' \oplus A_c'$
  - Which gives:
  - $A_1 \cdot A_2 = (A_1' \cdot A_2') \oplus A_c'$,
- Decomposition approach: to decompose A_i as a product of a common event and unit-specific event as follows
- $A_i = A_i'' \cdot A_c''$
  - Which gives:
  - $A_1 \cdot A_2 = A_1'' \cdot A_2'' \cdot A_c''$.

- Quantification can in both cases be based on effective use of results from single-unit PSA

Preliminary findings from pilot studies – quantification

Results

- PSA level 1:
  - Forsmark 1&2: Multi-unit LOOP can be a significant event
  - Ringhals 3&4: Due to turbine-driven AFWS pumps, multi-unit LOOP is less important

- PSA level 2 in LOOP scenario
  - Simultaneous release from two reactors has very low frequency

Conclusions

- Multi-unit IEs straightforward to identify = External hazards
- Impacts mainly found on safety functions core cooling and residual heat removal
- Power operation is the relevant plant operating state
- Quantification: It is possible to utilize the existing PSA models
  - no need to build an integrated model
- CCFs, operator actions, seismic, phenomena may have significant uncertainties

Thank you

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