New developments and applications of PRA (NAPRA)

Presentation at SAFIR2022 interim seminar

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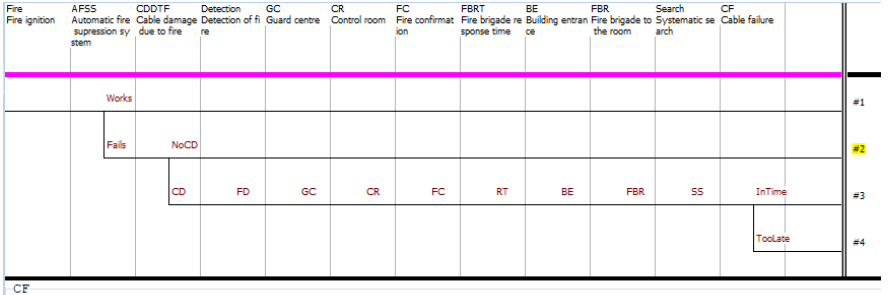
A new fire PRA model integrates reliability, plant response, human aspects

- Simulation-based event tree: reliability aspects and accident progression
- Fire dynamics simulator: results of deterministic fire analyses
- Simulation scripts: model of fire brigade actions (timings)
- Provides an example of a fire PRA model that is
  - integrated
  - dynamic
  - Lightweight and easy to implement
- Realistic and cost-effective fire PRA helps risk-informed decision making



CF

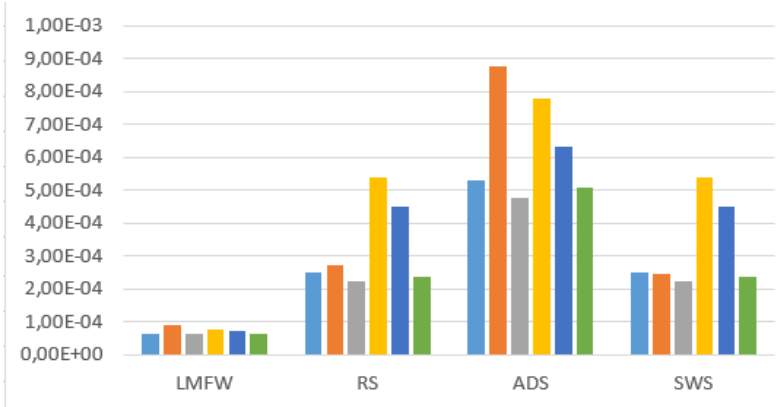
```
function real TooLate
  $ Operation time from the detection to the beginning of the systematic search is calculated
  t_oper = t_co+t_v
  if t_cr < t_gc+t_rt+t_be+t_re then
  begin
    t_oper = t_oper+t_gc+t_rt+t_be+t_re
  end
  else
  begin
    t_oper = t_oper+t_cr
  end
```

PROSAFE project lays groundwork for PRA with long time windows

- Long time window (> 24 hours) accident scenarios
  - Severe accidents
  - Spent fuel pool (SFP) accidents
  - Some pre core damage scenarios (Fukushima 3)
- PROSAFE project with Nordic partners
  - Literature review and stakeholder survey
    - Information on safe, stable end states, mission times etc.
  - VTT's pilot model: 2 simulation-based event trees of SFP
    - Integrates deterministic SFP behavior and probabilistic analysis
    - Takes into account repairs and recoveries (both main PRA and HRA)
    - Results consistent with two other advanced PRA models
- Results help make long time window models more realistic

International digital I&C PRA benchmark clarifies modelling issues

- Digital I&C PRA models overly simplified and conservative
  - Modelling and quantification of software failures
  - Modelling of fault-tolerance features
  - Common cause failures: postulation, parameter estimation
- OECD/NEA WGRISK task DIGMAP
  - benchmark study on PRA modelling of digital I&C, 6 countries
  - PRA models of a fictive reactor protection system
  - VTT's modelling approach: simple fault trees, perform complex computations in the background
  - Conclusions
    - Understanding the diversity of RPS important
    - Identification of common cause failure groups important
    - Level of modeling detail doesn't greatly impact the results
- Results help improve realism of digital I&C PRA models



Survey and example help conducting failure tolerance analysis

- Failure tolerance: the system will fill safety requirements even though some parts of it have failed
- Failure tolerance analysis (FTA): a framework to organize individual analyses (e.g. failure modes and effects analysis) to demonstrate that a system is failure tolerant
- Survey
  - Objectives: clarify issues related to FTA, clarify the role of PRA as a part of FTA
  - Findings
    - PRA is not a promising approach to FTA
    - Results of individual FTA analyses have many uses in PRA
- Example
  - Some FTA analyses applied to a cooling division of a fictive boiling water reactor
  - Model checking is a viable and promising approach to certain FTA tasks
- Results may help license applicants and holders in understanding and conducting FTA

beyond

the obvious

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