LOW POWER AND SHUTDOWN PSA FOR HIGH TEMPERATURE GAS-COOLED REACTOR

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About HTR-PM

- 200 MWe Demonstration Nuclear Power Plant
  - High Temperature Gas-Cooled Reactor (HTGR)
  - Pebble bed
  - Modular Design
    - NSSS module = 1 reactor + 1 steam generator
    - 2 NSSS modules + 1 steam turbine
  - Is under construction in Shandong, China
- The standard design plan of the 600 MWe HTGR was just announced by INET in the end of 2016

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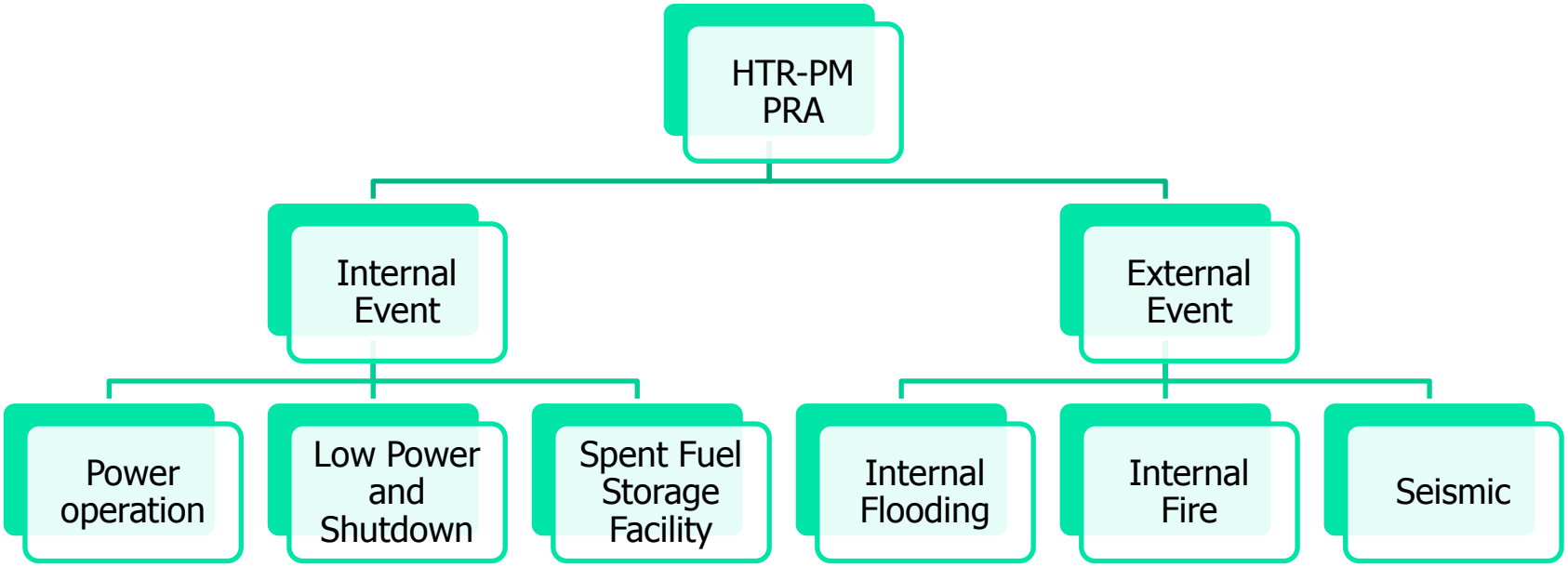
About HTR-PM PRA



PSAR : Preliminary Safety Analysis Report ---→ Construction License
FSAR : Final Safety Analysis Report ---→ Fuel Loading License
CLC: Construction License Conditions

About HTR-PM LPSD PRA

- Operation Mode
- LPSD PRA Modeling
  - Plant Operating State (POS)
  - Integrated modeling framework (Level + Level 2)
  - Initiating events analysis
  - Event sequence analysis
  - Release Category analysis
- LPSD PRA result
- LPSA PRA future work

HTR-PM Operation Mode

No	Mode	Reactivity condition, Keff	% Rated thermal power	Average coolant temperature
1	Power operation	≥0.99	>30	NA
2	Startup	≥0.99	≤30	NA
3	Hot standby	<0.99	NA	≥150℃
4	Shutdown	<0.99	NA	150℃≥Tavg≥50℃
5	Maintenance shutdown	<0.99	NA	＜50℃

* Continuous fuel loading

* Safe controlled concept

POS analysis

- Based on the above 5 operation modes defined by Technical Specification and the potential difference on safety system configurations

POS	POS definition
POS1	Primary heat removed by the steam turbine and the startup/shutdown circuit.
POS2	Primary heat removed by the startup/shutdown circuit
POS3	reactor shutdown
POS4	Using the helium blower to warm up the primary loop for startup
POS5	Pumping the absorption spheres back to the storage tanks from the core
POS6	Quick cooling of the Steam generator
POS7	Quick cooling of the core

POS analysis

- The duration of each POS is currently assumed based on
  - expert judgment
  - experimental reactor operation experience (HTR-10)
  - designers' estimation
  - will be refined by HTR-PM commissioning feedback

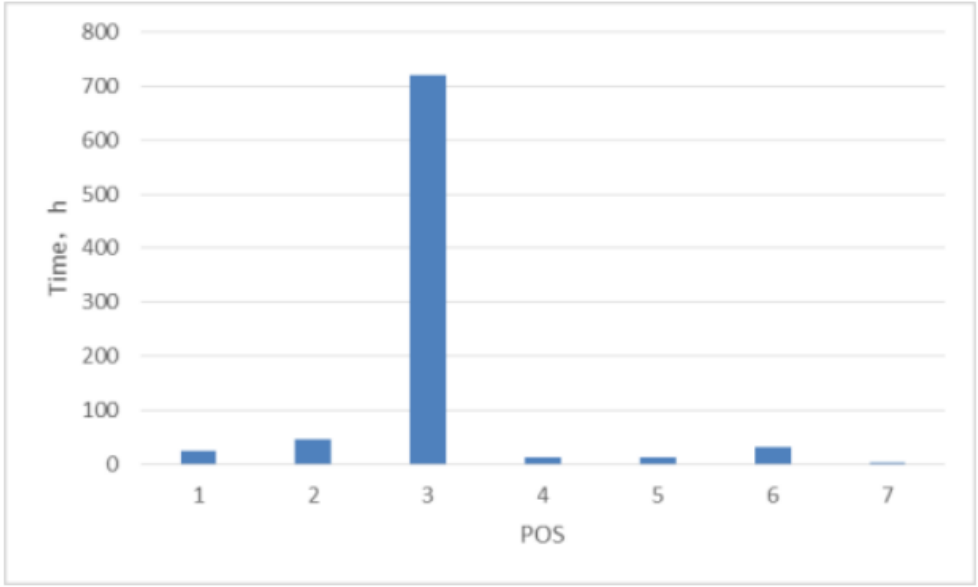


Fig.3 the duration of each POS

Integrated PRA framework

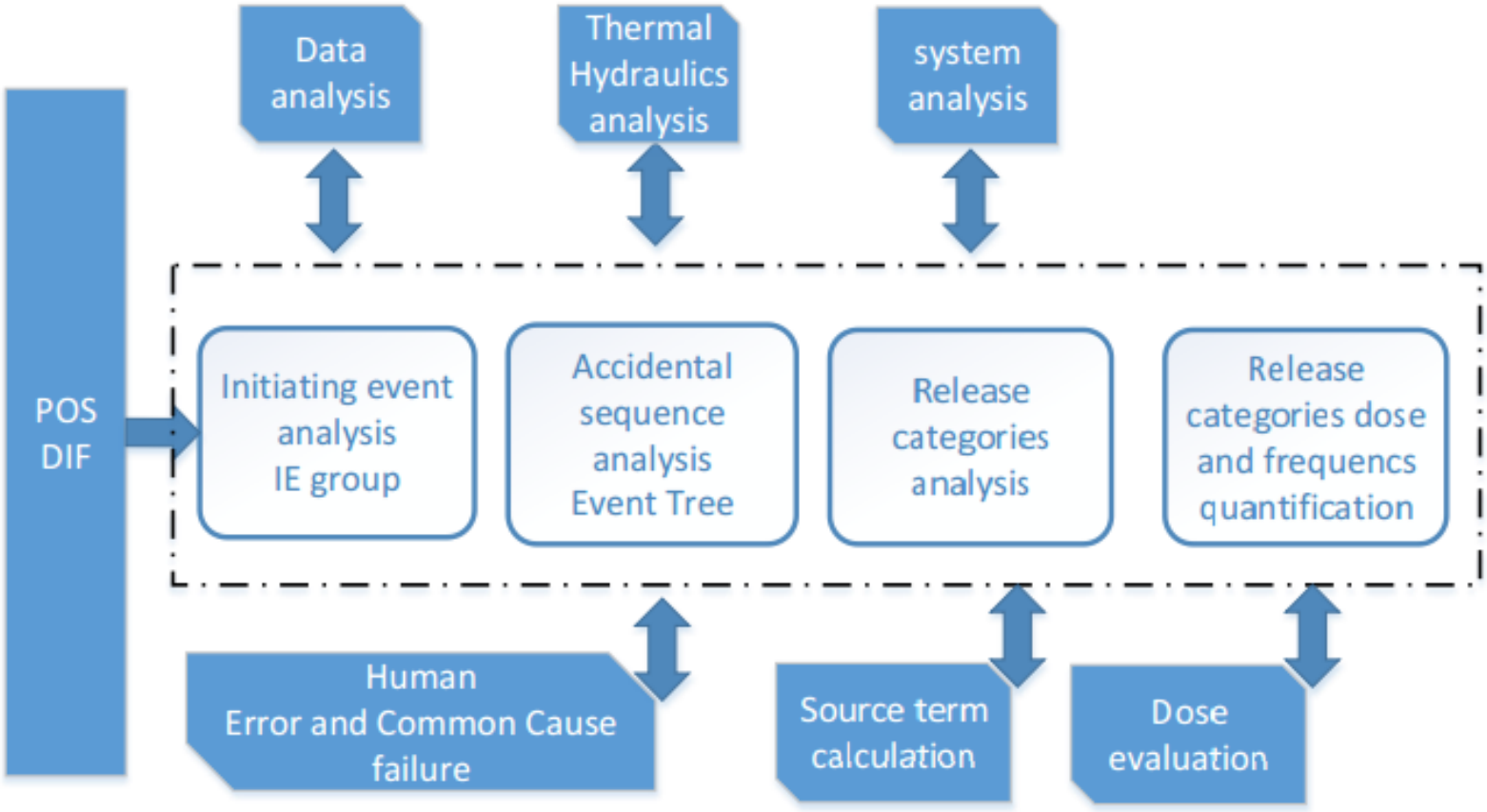


Fig.4. the Framework of HTR-PM PSA

Initiating Event Analysis

- Traditional approaches are applied
  - Initiating events list from available references, including LWR experience
  - Failure Mode and Effect Analysis (FMEA) for all the related systems
  - Master Logic Diagram （ MLD ）
- Matrix check for the applicability of each POS

Event sequence analysis

- Small Event tree / Large Fault tree approach is applied
  - Reactivity control
  - Residual heat removal
  - Primary boundary integrity
- Compared with power operation

Release Category Analysis

- Release quantity and mode
  - Balanced core conservatively assumed
  - Ground release
  - Considering the accident types (PPB break, SGTR, Transients)

HTR-PM LPSD PRA results

- Risk metric
  - The cumulative frequency of the accident sequences which might result in the offsite individual effective body dose (site boundary included) exceeding 50mSv
  - An 1E-6 target was set by the Chinese nuclear authority.
  - POS3 dominates the LPSD risk(2.74E-9) by ~60%

future work

- Explore the situation by considering the two modules as one plant
  - POS
  - IE
  - Multi-reactor accident sequence evolution
- Feedbacked by the commissioning experience

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Thanks for your attention!

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