Shutdown PSA for Ringhals NPP Unit 3.

Insights, overview and results.

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Ringhals 3 PSA

Ringhals 3 is (after the first part of the power upgrade GREAT) a 3000 MWt PWR of Westinghouse design taken into operation in 1981.

PSA has been performed in different campaigns since the 1980:ies.

The current PSA study is plant specific and covers both the risk of core damage, PSA level 1, and the release of source term, PSA level 2.

Almost all relevant internal events have been considered together with important external events, like extreme weather conditions, and area events like fire and internal flooding.

Definition of Plant Operating Modes (POM/DT)

DT / POM	Description	Reactivity K_{eff}	Thermal power [%]	RC Temp. [°C]
1	Power operation	⩾ 0.99	> 5	N.a.
2	Start-up	⩾ 0.99	⩽ 5	N.a.
3	Hot-standby	< 0.99	N.a.	⩾ 177
4	Hot shutdown	< 0.99	N.a.	$93<T_{avg}<177$
5	Cold shutdown	< 0.99	N.a.	⩽ 93
5*	Static shutdown	< 0.95	N.a.	⩽ 60
6	Refuelling	N.a.	N.a.	N.a.
7	Unloaded core	N.a.	N.a.	N.a.

The Shutdown PSA

Both the refuelling period and forced outages are analysed with regard to the risk for core damage (PSA Level 1) and possible radioactivity release (PSA Level 2).

The considered sources of radioactivity are:

- fuel in the core
- fuel in the spent fuel pit
- transport between the core and the fuel pit

Outside core events were screened out in the initiating event analysis.

Initiating Events

The considered initiating events are:

- Internal Events
- Area Events (after screening only fire and flooding events were analysed further)
- External Events (screened out)

Identified Internal Initiating Events

- LORH – Loss of RH (except LOOP and CCI-SW)
- LOOP – Loss of offsite power
- CCI-SW – Loss of Salt Water system
- DD-RHPR – Pipe rupture in RH outside containment
- DHL-TB – Drop heavy load Turbine building
- DHL-DD – Heavy load drop – core damage
- DHL-RH – Heavy load drop both RH trains
- DD-OP – Erroneous draining resulting in loss of RH
- DD-RHSV – Spurious opening of 8708A/B
- HD – Homogenous dilution
- PERC – Pressurization enough relief capacity
- PIRC – Pressurization inadequate relief capacity

Sequence and System Analysis

The sequence analysis follows the same model as for the power operation.

It is illustrated by success block diagrams starting with an identified initiating event.

The system functions that may bring the plant to a safe state are taken into account. (Only system functions with operability requirements are credited.)

The end states are core damage (CD) or safe state (OK).

Human Reliability Analysis (HRA)

The analysis covers:

- Human errors leading to initiating events
- Human errors making equipment unavailable
- Human errors when performing recovery actions in accident sequencies

An expert panel has been used to select critical work tasks that might cause an initiating event.

For recovery actions the analysis is based on the time available and the degree of difficulty of the task.

Forced Outage

Forced outage is defined as an outage period caused by a situation when the plant is forced to go into shutdown.

The frequency for a specific component outage, and the probability that the repair time exceed the AOT, is quantified. This gives the frequency that the plant is in a specific forced outage configuration.

The plant is assumed to be taken to the appropriate POS where corrective maintenance can be performed and after the repair go back to power operation.

The total core damage frequency due to forced outages is calculated as the sum of all component specific core damage frequencies.

Results

The contribution to the CDF during the refuelling period is:

Initiating Event	Contribution
Internal Events	82 %
Area Events	18 %
External Events	< 1 %

Forced outage (assuming a frequency of one forced outage per year) contributes about the same as the refuelling outage.

Sequences which give important contributions to the result

For pressurization as initiating event, or pressurization as a secondary effect due to e.g. loss of RH, it is assumed that a pipe rupture in RH can occur, even if the RH pressure relief valves open.

Failure of the cooling by CC (e.g. failure of pumps or failure of SW cooling) in POS5*1 and POS5*2 together with failure in connecting FP to cool the CS pumps .

Failure in plant power supply (external grid and diesel generators).

Thank you for the attention

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