Recent PSA developments and use of PSA applications in Belgium

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- **Nuclear energy in Belgium**
- **Status of PSA Development in Belgium**
  - Evolution of PSA
  - Current PSA
  - Influence of WENRA Reference Levels
  - Internal Fire and Flooding PSA development
- **Use of PSA for Belgian NPP**
  - PSA Applications developed by the Licensee
- **Perspectives and conclusions**

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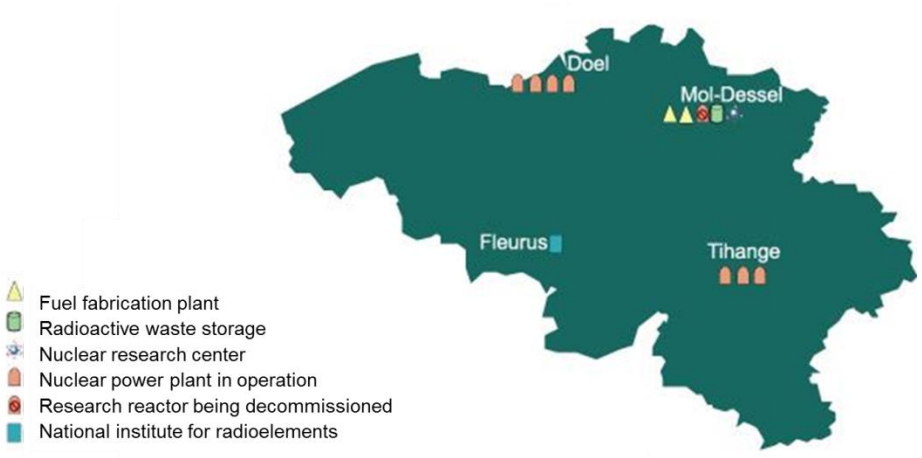
Nuclear in Belgium



Unit (PWR)	Power (Mwe)	Start date
Doel 1*	433	1975
Doel 2*	433	1975
Doel 3	1006	1982
Doel 4	1033	1985
Tihange 1	962	1975
Tihange 2	1008	1983
Tihange 3	1038	1985

Permanent shutdown planned for 2025

* Twin-unit

Stakeholders

PSA development : ENGIE-Electrabel (**licensee**)
Tractebel Engineering (**architect engineer**)
PSA review: Bel V (**TSO**) subsidiary of the Federal Agency for Nuclear Control-FANC (**Safety Authority**)

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Initial phase of PSA development (1990-2006)

- **Framework:** Periodic Safety Review (PSR)
- **Objective**
  - ➢ design re-evaluation, complementary to the deterministic approach
    - confirm robustness of deterministic design
    - identify and address potential design and operational weaknesses
- **Scope**
  - PSA Level 1 (*all units*): internal events, nearly all POS
  - PSA Level 2 (*3 units*): limited study, power states and containment failure modes only (no source term)

First Major Update of PSA (2007-2011)

- **PSA Update**
  - **Framework:** PSR
  - **Scope extension**
    - PSA Level 1: all POS, additional initiating events
    - PSA Level 2: full scope for 4 representative units (all POS, containment failure and release categories)
  - **Updated input** plant modifications, operational feedback, reliability data, methodologies, generic APET, containment isolation system analysis, …
  - **In-depth analysis of L1 and L2 PSA results**

Current PSA

- **Regulatory review of the PSA**

  On-line review + Final evaluation with recommendations by Bel V

- **Peer review of the Doel 3 PSA (2011)**
  - By an external consultant company hired by the licensee
  - Review against ASME Standards (Level 1, LPSD) and requirements based on IAEA guides for Level 2
  - Peer review findings and recommendations:
    - confirmed several findings of the regulatory review by Bel V
    - lead to additional findings and recommendations
  - External peer review **complementary** to regulatory review

PSA Update in recent PSR (2007-2011)

- **Examples of recommendations**
  - improvements of thermal-hydraulics studies
  - assessment of mission times other than 24 hours
  - modelling of additional dependencies between SSCs
  - improvement of type A human errors (CCF-type)
  - use of a new HRA methodology for type C human errors for PSA L1 and L2 (including identification of errors of commission)
  - MELCOR supporting calculations for representative accident scenarios during the APET quantification process
  - modelling of fission product retention in the Nuclear Auxiliary Building
  - more detailed source term modelling

Influence of WENRA Reference Levels

Western European Nuclear Regulators Association ➔ co-operation amongst regulators from E.U. and Switzerland (17 countries)

- **WENRA Reference Levels (RL)** for Nuclear Safety of NPP (2008)**:**

  includes RLs for PSA (issue O for PSA + issue S for Fire PSA)

- **Belgian Action Plan** (to comply with RLs):
  - ***Legal framework*** *for nuclear safety requirements:*
    - *Royal Decree of 30 November 2011: transposition of WENRA RLs*
    - *high-level requirements for PSA and PSA applications*
  - ***Implementation of RLs****: actions defined for 9 RLs related to PSA (e.g. scope extension) or PSA applications (RL O.3.x)*

Development of Internal Fire and Flooding PSA

- **Framework:** WENRA Reference Levels (O 1.1, S 3.4)
- **Scope:** Level 1 F&Fl PSA for all units and Level 2 F&Fl PSA for one unit
- **Methodologies**
  - **Flooding:** EPRI TR-101914 *"Guidelines for Performance of Internal Flooding Probabilistic Risk Assessment"* with few adaptations:
    - Pipe rupture frequencies to account for specificities of Belgian NPPs
    - Evaluation of maintenance-induced flooding was less detailed than intended by the EPRI guidance
  - **Fire:** NUREG/CR-6850 and supplement 1 *"EPRI/NRC-RES Fire PRA Methodology"* + NUREG-1921 *(HRA)* with some adaptations:
    - No consideration of the explosion phenomenon
    - No consideration of seismically-induced fire
    - Detailed quantification of the human errors probabilities

Development of Internal Flooding PSA (2012-2017)

- **Evaluation** by Bel V and recommendations
  - obtain realistic pipe lengths
  - consideration of Operational Experience Feedback
  - more systematic consideration of all standby systems
  - improvements related to the flood simulation time and the associated hypotheses
  - improved flood specific HRA methodology.

Development of Internal Fire PSA (2008-2017)

Preceded by a (deterministic) Fire Hazard Analysis

- **Main difficulty:** data collection
- **On-line review and evaluation by Bel V**
  - Consideration of the use of other sources of data for the ignition fire frequencies
  - Use NUREG/CR-7150 for expert elicitation for detailed circuit analysis
  - Benchmark for the choice of the methodology used for the detailed quantification of human error probabilities
  - Errors of commission resulting from erroneous indications in the MCR

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PSA Policy and Applications by Licensee

- **PSA Policy of the Licensee (Electrabel)**
  - ensures licensee's ownership of PSA / active involvement in PSA
  - ensures PSA updates
  - launches a set of PSA applications to support decision-making in risk management
  - creates a "PSA Standing Committee" to realize the PSA updates/upgrades and PSA applications

PSA Policy and Applications by Licensee

- **Influence of WENRA RL: examples:**
  - WENRA RL O 3.2: use of PSA to identify the need of modifications to the plant and its procedures
  - WENRA RL O 3.4: use of PSA for assessment of the adequacy of plant modifications, changes to operational limits, conditions and procedures and to assess the significance of operational occurrences
  - WENRA RL O 3.5: insights from PSA used for development and validation of training programs

  These RL are introduced into the Belgian law and have been very instrumental in obtaining the licensee's commitment to a broader and better use of the PSA models of Belgian NPPs.

Example of use of PSA in PSR: design re-evaluation

- **Plant and procedural modifications** resulting from detailed analysis of L1 and L2 PSA results
- On the initiative of the licensee or its architect engineer or Bel V
- Examples:
  - Mid-loop operation during shutdown: audible alarm and flashing light for inadvertent primary level drop
  - Improvement of accident procedures (power and LPSD, introduction of Feed & Bleed in FRGs) and SAMGs
  - Improvement of design (e.g. compressed air system, back-up CVCS pump for primary pump seal injection) and installation of PARs and Filtered Containment Venting System

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Perspectives and conclusions

- Maintenance of an up-to-date PSA
- PSA applications are gradually implemented by the licensee
- Regulatory review of PSA by Bel V
- Regulatory oversight of PSA applications by Bel V
- **WENRA Reference Levels are instrumental for the extension of scope and applications of PSA**
- **WENRA Reference Levels 2014 (including SFP and external hazards as seismic PSA)**
- Political context (permanent shutdown foreseen by 2025)

Thank you for your attention

Any Questions ?