IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

External flooding PSA in IRSN
–
Developments and insights

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History/Background

History/Background

- In France, the safety case relies mainly on deterministic bases
- For French operating plants, PSA was not a regulatory requirement and compliance with probabilistic safety goals was not required
- However France has acquired a valuable experience in development and use of PSAs
- The probabilistic approach takes an important place in the safety decisions: PSAs are considered as useful for improving safety

History/Background

- Order of 7 February 2012 setting the general rules relative to basic nuclear installations:

→ *"The nuclear safety demonstration shall also include probabilistic analyses of accidents and their consequences, unless the licensee demonstrates that this is irrelevant"*

→ No quantified probabilistic objectives

Specifics of the French context

Specifics of the French context

- A rather large fleet of Nuclear Power Plants (NPPs): 58 in operation
- Standardized in 3 PWR series (900MWe, 1300MWe,1400MWe)
- Built by the same manufacturer (Framatome)
- Operated by the same licensee (Electricité de France: EDF)

→ Favorable situation for data collection

Specifics of the French context

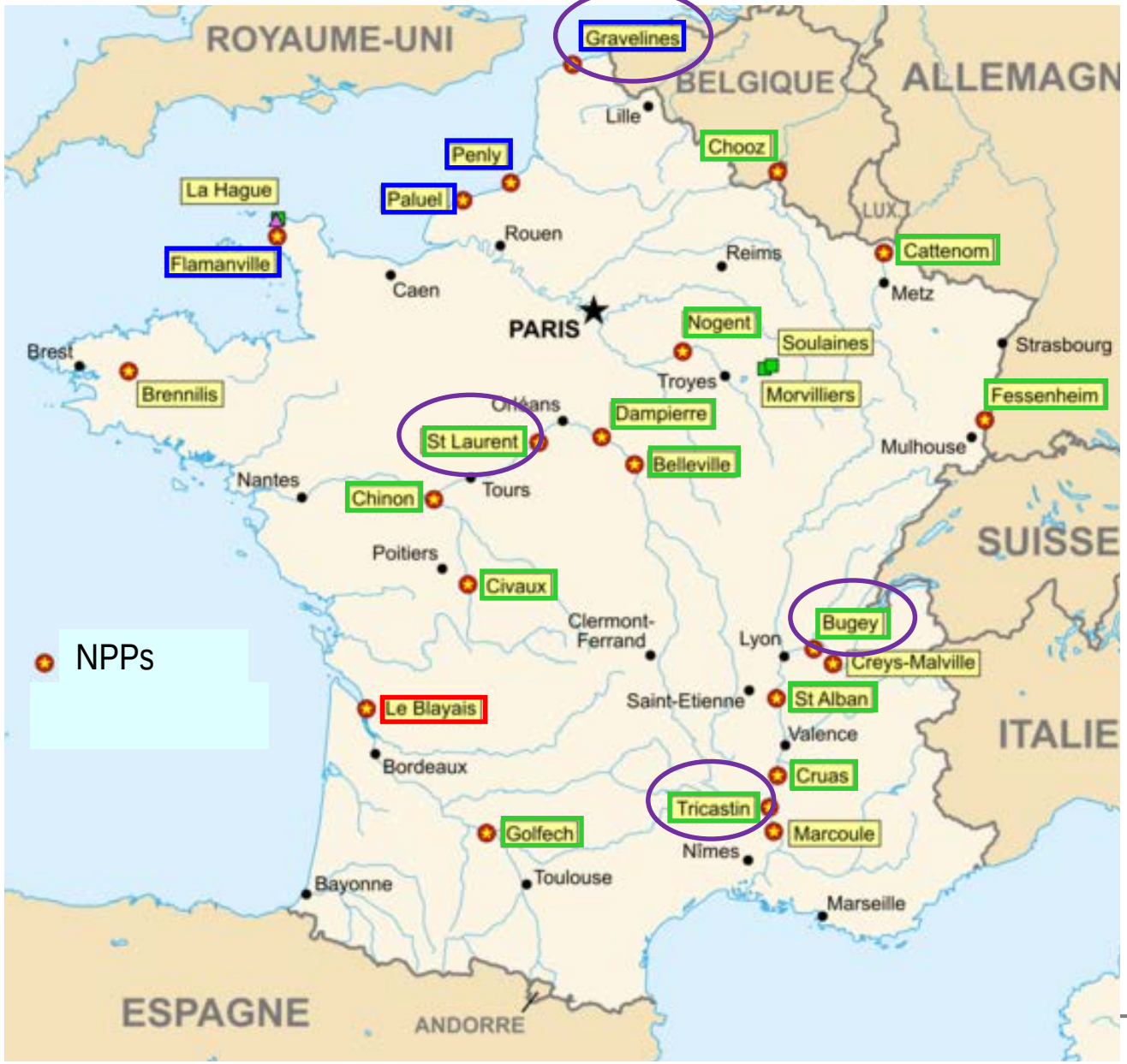
- At the request of the Safety Authority (ASN), IRSN reviews the PSA studies provided by EDF

- In addition, IRSN develops its own PSA:
  - Valuable knowledge
  - Independent analyses from EDF PSAs
  - Possibility to perform sensitivity analyses

External flooding PSA

External flooding PSA

- External flooding PSA is a relatively new subject in France
- First studies (4 PSA studies: coastal or riverine flooding) carried out by EDF around 2018
- IRSN reviewed EDF's studies in the frame of the Periodic Safety Review of 900 MWe plants (review ended in July 2019)
- IRSN is also developing its own external flooding PSA for Gravelines site (900 MWe) → coastal flooding study (simplified) which will be finalized by the end of 2020



NPPs location:

14 river NPPs

4 sea side NPPs

1 estuary NPP

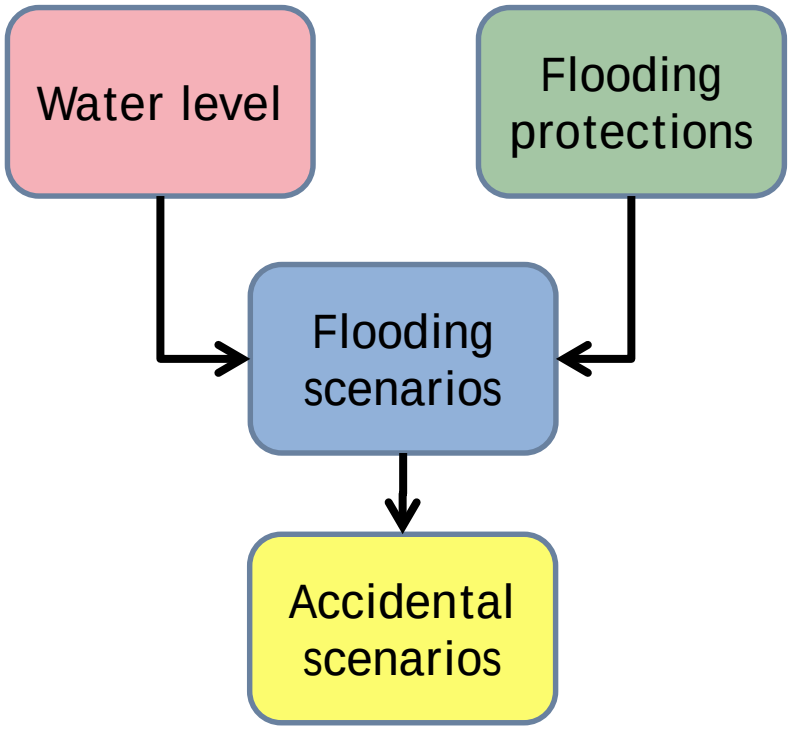
Ext Flood PSA (EDF)

Methodology

Methodology

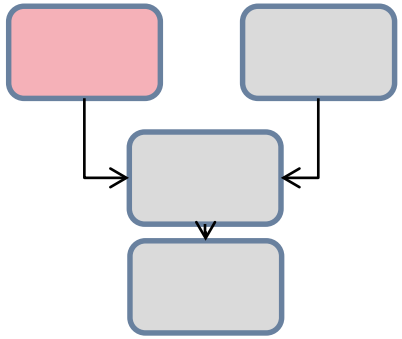
- Similar flooding PSA methodology followed by EDF and IRSN → The methodology is applicable for coastal or riverine flooding PSA
- Example for coastal flooding → applied to Gravelines site

Applied approach



Methodology

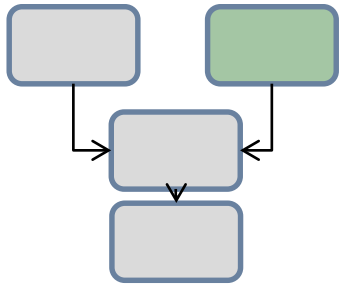
↗ water level



- Built of a curve “water level / frequency” by convolution between probability density of sea tides and probability density of storm surges
- Water levels of interest for PSA studies are those corresponding to the overtake or by-pass of protections against external flooding

Methodology

↗ Flooding protections

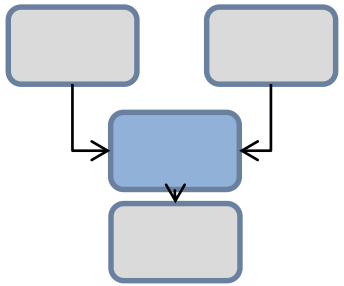


- Material protections
  - Peripheral protections (dams/dikes, walls)
  - Volumetric protection (all that is part of the external buildings envelope)
  - Building nearby protections (lower or higher protections, cofferdam type)

- Preventive human actions necessary to set up protections (cofferdams, closing of possible by-pass paths…)
  - →The success of these actions depends on the site alert system
  - →The failure of these actions induces external flooding scenarios for water levels lower than those overtaken the protections

Methodology

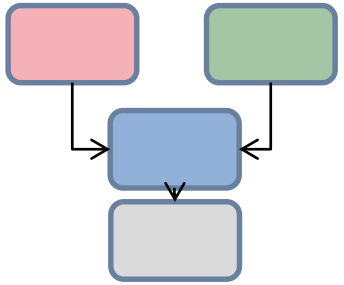
↗ Flooding scenarios



- Flooding scenarios are built for each relevant water level, by studying their consequences on the installation, and by taking into account the role of protections
  - Equipment vulnerable to flooding failures (electrical transformer, heat sink, diesels, post-Fukushima materials…)
  - Initiators occurrence or situations which are taken into account in « internal event » PSA (such as the loss of heat sink, loss of off-site power, etc.)

Methodology

↗ Quantification of flooding scenarios

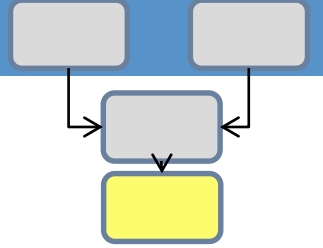


- Quantification of each of the flooding scenarios

  - Use of curves « water level / frequency »
  - Assessment of protections failure (human error probability to set up protections or SSC failure)

Frequency of initiating events of accidental scenarios

Methodology



↗ Quantification of accidental scenarios (core damage frequency and frequency to uncover fuel assemblies in the Spent Fuel Pool)

- Quantification carried out by modifying the « internal events » PSA model
  - Frequency of initiating events (frequency of flooding scenarios)
  - Equipment vulnerable to flooding are considered failed
  - Probability of failure of human post-accidental missions taking into account the flooding context
  - Post-Fukushima materials are considered
  - Fast Action Force (FARN) is considered

- The analysis considers that the flooding affects the whole site
  - Unavailability of shared equipment
  - Impact on human factor

Conclusions and Insights

Conclusions and Insights

- IRSN review :
  - Important work carried out by EDF
  - The approach is satisfying even if simplified
  - These results highlight the importance of Post-Fukushima means and intervention of the Fast Nuclear Action Force (FARN)

→ No additional NPP modifications necessary

Conclusions and Insights

- Methodological improvement identified by IRSN :
  - Systematic evaluation of the reliability of materials → taking also into account the available operating experience
  - Evaluation of the reliability of site alert systems
  - Assessment of the uncertainties related to the hazard evaluation (couples water level / occurrence frequencies)
  - Consideration of combinations of phenomena → for example, waves are not taken into account for the sea flooding

- Regarding the human factor evaluation, EDF used a method derived from pre-accidental human errors evaluation methods → acceptable as a first approach

IRSN PSA developments

IRSN PSA developments

↗ Ongoing study for Gravelines site

- The approach followed by IRSN is similar with EDF approach, but:
  - Reliability of materials is quantified (when possible)
  - Uncertainties on the phenomenon studied are taken into account
  - More external flooding scenarios have been taken into account

- IRSN study pointed-out some aspects related to post-Fukushima protections under implementation → discussions with EDF ongoing

IRSN PSA developments

↗ Future developments

- PSA for a 1300 MWe NPP site
- Riverine flooding hazard assessment
- Sensitivity studies on the alert system reliability
- Human factor assessment → working group created at IRSN (first meeting in December 2019) to develop new HRA methods: One of the subjects will be HRA for external events PSA including flooding → need for HRA method to take into account:
  - Hazard worsened conditions (Local actions, degraded environment, Actions in multi unit accident context…)
  - Crisis organization
  - Specific hazard procedures
  - FARN…

Thank You !