IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Use of PSA at Institute for Radiological Protection and Nuclear Safety (IRSN) for EPR licensing purposes

18 - 23 May 2008 / PSAM9 – Hong Kong, China

Presented by Gabriel GEORGESCU
IRSN, France

Key features of Institute for Radiological Protection and Nuclear Safety (IRSN)

- **Public expert body in charge of the scientific assessment related to nuclear and radiological risks**
- **Research, expertise and public service mission**
- **1,675 specialists: researchers, doctors, post-doctoral students**
- **11 locations in France, including 3 major sites: Fontenay-aux-Roses, Cadarache, Le Vésinet**

Introduction

- **At the Flamanville site, an European Pressurized Water Reactor (EPR) unit (named Flamanville 3) is under construction in France**
- **The creation authorization was granted by the French Nuclear Safety Authority (ASN) in April 2007. The commissioning is planned for 2012**
- **IRSN, as the ASN technical support organization, analyses the Flamanville 3 licensing support documentation. This documentation includes several PSA studies submitted by EDF during the licensing processes**
- **In France the PSA is developed and used according to the Basic Safety Rule "Development and utilization of PSA" in reference**

EPR Technical Guidelines

- **The EPR is a French and German next-generation 1600 MWe class PWR**
- **The technical guidelines governing the project's nuclear safety options are formalized in the document "Technical Guidelines for the design and construction of the next generation of NPPs with Pressurized Water Reactors" (formal in France in September 2004)**
- **The main safety objectives, compared with the existing reactors:**
  - reduction of the number of "incidents" by a better systems reliability and better consideration of the human factor
  - the core damage risk should be significantly reduced
  - the radioactive releases should be also significantly reduced:
    - no population evacuation in case of accident without core damage
    - practical elimination of the large early releases
    - limited protection measures (in time and in space) in case of late releases

EPR Design

- **Tight double containment**
- **External anti-aircraft crash shield**
- **Built-in severe accident features**
- **Diversified ultimate heat sink**

- **Four safety electrical trains including two series of diversified Diesel generators**
- **Four 100% trains, physically separated, for the main safety systems**
- **High quality human-machine interface, based on up to date technology**

Technical Guidelines requirements for EPR PSA

- **The safety demonstration for the nuclear power plants of the next generation has to be achieved in a deterministic way, supplemented by probabilistic methods**
- **Implementation of improvements in the defence-in-depth of such plants should lead to the achievement of a global frequency of core melt of less that 10^{-5} per plant operating year**
- **A PSA must be conducted, beginning at the design stage, including at least internal events**
- **This PSA would indicate the frequencies of core melt sequences with a view on the possible consequences of the different types of core melt situations on the containment function**

Additional IRSN requirements for EPR PSA

- **All initiators, including the external and internal hazards, have to be studied by using probabilistic methods, as far as possible**
- **Regarding the internal events Level 1 PSA, the fulfilment of methodological aspects included in the "Technical Guidelines" as well as in the PSA Basic Safety Rule is sufficient to allow a quality internal events PSA for the licensing process**
- **Regarding the treatment of internal and external hazards, these documents are not enough prescriptive, and consequently specific requirements were developed by IRSN**
  - Simplified hazard PSAs for commissioning application
  - Complete hazard PSAs after an initial plant operation period
- **The availability of a full scope Level 2 PSA is deemed necessary in the frame of application for commissioning.**
- **The mentioned PSAs should consider the safety of the reactor core as well as of the spent fuel pool.**

PSA developments for EPR

- **During the different phases of the EPR reactor design several PSA were developed by the EPR designer (AREVA) and then by the utility (EDF)**
- **In parallel, in order to dispose of the appropriate knowledge and tools for the independent verification of the EDF studies, IRSN develops its own limited scope level 1 PSA model**
  - the experience in development and using of PSA at IRSN is rather extensive (PSA for the 900 MWe and 1300 MWe plants, fire PSA, seismic PSA, HRA research activities, reliability data and CCF research activities, etc.)
  - the EPR PSA model, which first version is already available, deals with the internal initiating events. Simplified modeling of the external and internal hazards is foreseen in the next future
  - the Level 2 EPS will be also started in the next future

PSA during EPR design stages

- **The PSA was used from the beginning of the design by AREVA**
  - limited scope Level 1 PSA which developed with the design
  - this allowed identifying several design improvements, like: SBO Diesels, diversification of ultimate heat sink, diversification of support systems of the safety systems, etc.
  - simplified level 1+ PSA for the containment and the built-in severe accident features
- **The reliability of the systems needed to ensure the safety of the spent fuel pool was also investigated; this allowed identifying the need for a third cooling train with diversified power supply and heat sink**
- **In parallel, methodological developments were done for the Level 2 PSA, Fire PSA as well as for the PSA application for the assessment of the multiple failure situations**

IRSN

PSA for Flamanville 3 creation request

- **Level 1, internal events PSA related to the reactor core**
  - all reactor states, only the internal initiating events (nevertheless the loss of ultimate heat sink and the loss of external power supply are included)
- **Probabilistic assessments to support the "practical elimination" of large early releases**
  - containment by-pass scenarios
  - heterogeneous boron dilutions
- **Spent fuel pool PSA**
  - loss of cooling and loss of inventory situations
- **Level 1+ PSA**
  - a simplified version of the Level 2 PSA (a prolongation of the Level 1 PSA with the containment systems)

PSA for Flamanville 3 creation request

- **Multiple failure situations**
  - PSA application for the assessment of deterministic multiple failure situations, called Risk Reduction Categories (RRC-A)
  - the RRC-A list was firstly defined by the "Technical Guidelines" and it should be adjusted taking into account the results of PSA
- **Initial assessment of internal and external hazards**
  - simplified probabilistic assessments for credible hazards: internal fire, internal flooding, earthquake, airplane crash, industrial and transport hazards, extreme climatic hazards, etc.
  - *these assessments have to be supplemented by more complete PSA before the Flamanville 3 NPP commissioning*
- **Long term studies (all reactor states):**
  - long term loss of offsite power (8 days)
  - loss of ultimate heat sink (4 days)

IRSN

Expected licensee's PSAs for FLA3 EPR commissioning

- **Updating of the Internal Events Level 1 PSA for reactor core**
- **Hazard PSAs:**
  - internal Hazards PSA: Fire PSA, Internal Explosion and Internal Flooding
  - external Hazards PSA: Earthquake, Extreme winds, Extreme cold
  - limited assessment will be provided for the external flooding (only the pumping station) and heavy loads drop (limited to handling devices reliability assessment)
- **Updating of the Level 1 PSA for the spent fuel pool, integrating the loss of cooling and water drainage accident scenarios (internal initiating events and the internal and external hazards)**

Expected licensee's PSAs for FLA3 EPR commissioning

- **Complete Level 2 PSA (only internal events) in order to demonstrate the fulfillment of general safety requirements for the EPR reactor**
- **Updating of the probabilistic studies performed to support the "practical elimination" of the containment by-pass and of the heterogeneous boron dilutions**
- **Assessment of the multiple failure conditions (RRC-A) and the corresponding design features by using the updated PSAs**

Insights on development and using of a “design” PSA

- **Reliability data**
  - the assumption that the new components have the same reliability as the existing ones can be a reasonable initial assumption
- **Common cause failures**
  - the CCF groups and parameters should be carefully assigned in order to avoid the distortion of the results
  - the insufficient diversity of redundant systems have to be identified and improved if it is found as a dominant risk contributor
- **Hazard area events**
  - it is important that the design phase PSA incorporates useful information (like equipment location, fire compartments, etc.), even using simplified assumptions

Insights on development and using of a “design” PSA

- **Systems interdependencies**
  - the interdependencies between the safety systems, i.e. functional dependencies or induced by the support systems (power supply, cooling, ventilation, I&C, etc.) should be modelled as detailed as possible
  - conservative assumptions should be used if the information is not available
- **New design features**
  - the potential new initiating events, failure modes, event sequences and dependencies that may be introduced by new design features should be analyzed
  - the effects of the inadvertent actuation of the new automatic actions should be analysed
- **Preventive maintenance**
  - the foreseen preventive maintenance should be taken into account in the design PSA
  - the unavailability's due to the maintenance but also the system configurations for maintenance are particularly important.

Insights on development and using of a “design” PSA

- **Technical Specifications and Surveillance requirements**
  - these aspects should be modelled as accurate as possible since the PSA can be further used to define “risk-optimized” Technical Specifications and surveillance requirements
- **I&C failures (including software “failures”)**
  - the today PSA methods have limited capability to model “software based” systems
  - the EPR PSA incorporates this information by using the “compact model” (allows to identify the dependencies)
- **HRA**
  - a “screening” HRA model can be used, but with a careful consideration of the dependencies:
    - between the pre-accidental actions
    - between the post-accidental actions
    - between the operator actions and the automatic actions

Conclusion

- **The use of the PSA from the early design for the EPR reactor shows that the PSA is a very valuable tool to obtain an optimised and balanced design**
- **The development and the use of PSA should take into account specific methodological aspects of a design phase PSA**
- **The decision making process should consider the fact that PSA for a new plant design may contain substantial uncertainties. Extensive sensitivity studies should be performed and the uncertainties should be known and taken into account**

IRSN