Assessment of the periodic safety review related to the third ten yearly outage of the French 900 MWe nuclear power plants

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ABSTRACT: The periodic safety review (PSR) related to the third ten-yearly outage of the 900 MWe nuclear power plants was launched in 2002. This PSR will have the same main objectives as the previous PSRs related to the second ten-yearly outages of the 900 MWe and 1300 MWe nuclear power plants :

- To verify the conformity of the nuclear power plants to their current safety requirements, by means of standard safety studies valid for all the 900 MWe nuclear units and of a conformity verification performed at each 900 MWe nuclear unit;
- To enhance the 900 MWe nuclear power plants safety level taking into account more recent safety requirements.

The first step of the work consisting in defining the program of the PSR has been completed. From November 2002 technical discussions took place between the radioprotection and nuclear safety general directorate (DGSNR), IRSN and Electricité de France about the scope and objectives of the PSR. In June 2003, IRSN presented to the standing group of experts the assessment of Electricité de France PSR program proposal. This text presents the main conclusions of this assessment and of the standing group of experts meeting.

INTRODUCTION: In relation to the continuous analysis of operating experience feedback, a periodic safety review (PSR) makes it possible to assess the areas for which only little information can be learned from this feedback.

The position of the radioprotection and nuclear safety general directorate (DGSNR) is to require that the nuclear operator performs a PSR of its installations approximately every ten years. One of the objectives of the regulator is the nuclear operator to improve the safety of existing nuclear power plants.

The PSR related to the third ten-yearly outage of the 900 MWe nuclear power plants (900 MWe VD3 PSR) was launched in 2002. At the request of DGSNR, IRSN evaluated the Electricité de France 900 MWe VD3 PSR program and presented its evaluation to the standing group of experts (12th and 18th of June 2003) in order to get its advice and recommendations concerning the safety studies to be performed and the safety objectives to be reached.

The following gives an overview of the process that will be followed to perform this PSR and also of the main topics that will be analysed in this framework.

1 OVERALL PSR PROCESS

The 900 MWe VD3 PSR is the fourth PSR that will be performed in France by Electricité de France if the on-going PSR related to the second ten-yearly outage of the 1300 MWe nuclear power plants is taken into account. The PSR general process is well established and has shown its efficiency. This process has not been put into question since either by Electricité de France or by IRSN / DGSNR and has been approved by the standing group of experts (meetings of June 2003).
The main steps of the PSR illustrated by figure N° 1 are given in more details in the following paragraphs.

1.1 Build-up of the program and objectives and identification of the safety referential to be used for the safety conformity examination

The build-up of the program and objectives of the PSR is strongly influenced by the knowledge and safety practice evolution as well as by the operating experience feedback analysis. This PSR first step is very important to avoid any misunderstanding between the nuclear operator and the Regulator during its performance and is also a strategic phase because it must define the scope of the studies to be performed as well as the safety level to be reached. The assessment of the program and objectives started in 2002 and was completed in June 2003 which led to two meetings of the standing group of experts. The conclusions of these meetings will be summarized further on in the chapter describing the scope of the 900 MWe VD3 PSR.

The identification of the set of reference safety requirements (called “safety referential in the following) constituted by the rules, criteria and specifications applicable is also a significant phase of the PSR. It is important to notice that for the first French PSRs, this phase led to long debates between the Safety Authorities and Electricité de France. It highlighted the importance of having before the start-up of a PSR an updated and approved version of the safety analysis report. The safety requirements referential is constituted by a number of regulatory documents and accompanying texts that follow a hierarchy (regulatory pyramid) that places the following documents at the top of the list :

- Laws, decrees,
- Approved safety analysis reports,
- Approved general operating rules and associated documents (internal emergency plans),
- Surveillance rules of operating mechanical equipment.

1.2 Conformity examination

The conformity examination consists of a comparison of the safety level of the installations with their initial level, i.e. the level for which the operating licence was initially granted, which makes it possible to check that this level has not changed and that therefore, the requirements of the operating licence are still being met. This examination is intended to identify any deterioration of the installation, and to examine the weak points of the safety evaluations that require additional analysis or justifications.

Therefore the conformity examination is split in two parts:

- The verification of the conformity of the reference safety studies, as described in the safety analysis report, with the applicable safety requirements (conformity studies),
- The verification of the actual state of the nuclear power plants against the reference state given by the safety analysis report (nuclear power plants conformity check).

In addition to the verification of the actual state of the nuclear power plants against the reference state, a complementary investigation program is put in place. The objective of this program is to check the conformity of equipment not included in the preventive maintenance programs and eventually to identify maintenance domains to be completed. The investigations are implemented on site at the time of the ten-yearly outages.

The scope of the conformity examination (in all its aspects) is defined on the basis of the operating experience feedback analysis (national and international), of the expertise evolution in safety analyses and of the feedback of the previous periodic safety reassessments.

1.3 Safety referential reassessment

The objective of the safety referential reassessment is to bring the safety of the units up to a higher level than that of the initial design and that achieved by continuous analysis of operating experience feedback, taking into account, as much as possible, progress resulting from the changes in knowledge.

Safety reassessment applicable to the nuclear power plants to be examined differ somewhat from those applicable to the newest nuclear power plants in operation and from those planned. Therefore, to launch the safety reassessment studies the identification and analysis of such differences must be conducted in the most exhaustive possible way.

Then, the need to fill the identified gaps must be examined on a case-by-case basis, in order to evaluate the importance of each gap in terms of the global safety level of the installation. The advantage of changing the safety referential and eventually the installations must be examined taking into account on one hand the potential safety benefit and on the other hand the technical and economic feasibility.

1.4 Definition and implementation of the ten-yearly modification batch

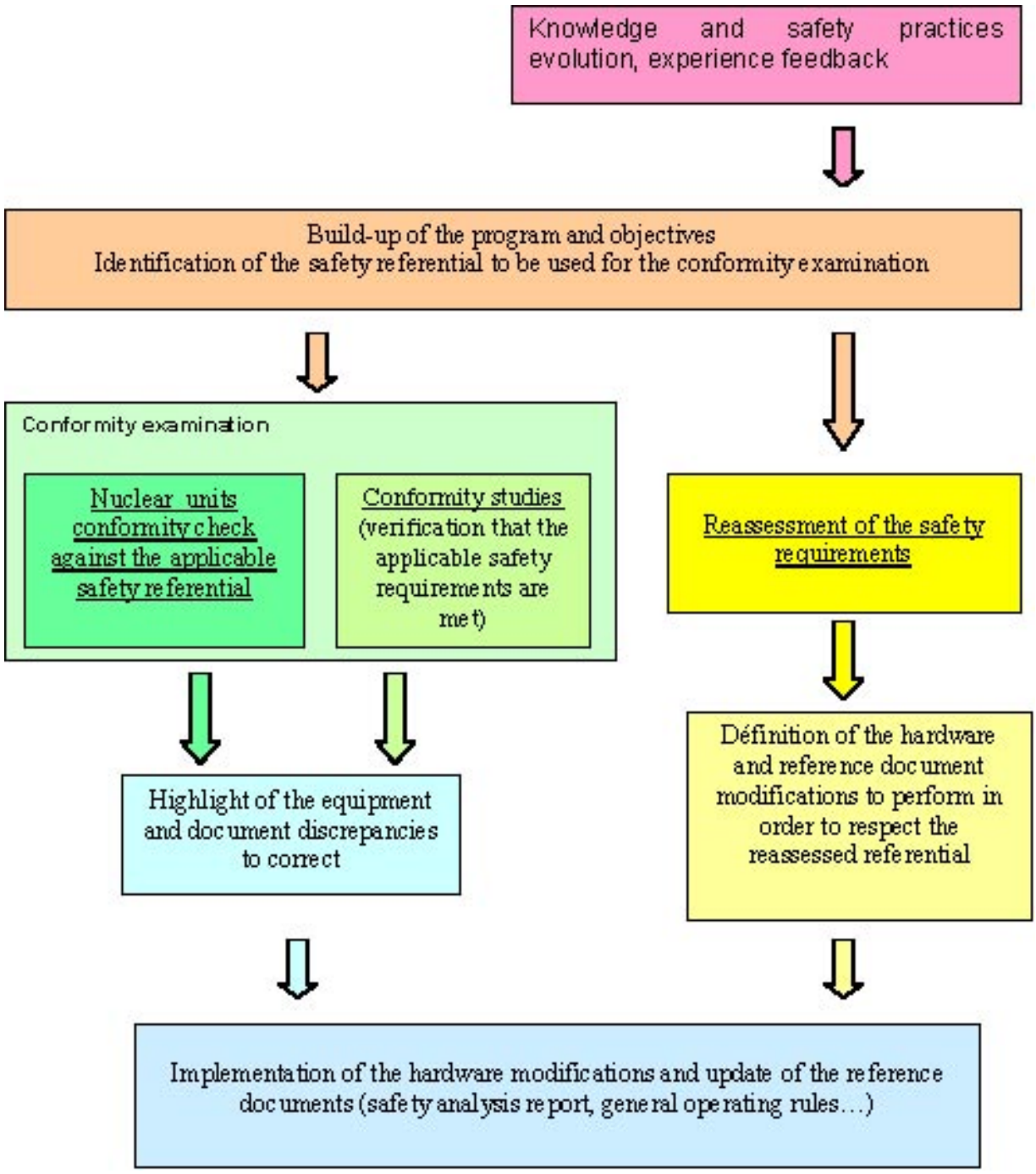
After completion of the safety reassessment studies (safety referential reassessment and conformity examination), the operator sends the Safety Authorities a document that describes all the modifications (hardware and document) to be performed in order to satisfy the conclusions of the safety studies. A need for additional modifications may appear beyond the framework of the PSR as for example modifications deemed necessary to be implemented through the analysis of operating experience feedback.

The PSR process is designed as to enable the operator to plan the modification implementation during the ten-yearly outages. However some of the modifications can be implemented earlier if they are selected as very high in terms of safety or address generic discrepancies detected on the units.

1.5 Safety analysis report

The main objective of the safety analysis report is to present to the Safety Authorities, the nature of the installation, its intended use, the safety evaluations performed to check that there is no unacceptable risk to the health or safety of the population. The safety analysis report is a contractual document between the nuclear operator and the Safety Authorities, which has to be fully respected by the operator.
Within the framework of the PSR the operator has to write a new edition of the safety analysis report. This new edition must be sent to the Safety Authorities early enough for it to be assessed and approved before the ten-yearly outages.

Figure 1 : Periodic Safety Reassessment process



3 SCOPE OF THE STUDIES

The scope of the studies that will be performed covers the following topics: applicability of the European pressurized reactor (EPR) safety requirements to the 900 MWe reactors, external and internal hazards (explosion hazards inside and outside the nuclear island, seismic design verification according to the 2001-01 fundamental safety rule, fire protection…), systems and civil engineering design, accident studies and radiological consequences (SGTR, severe accidents…), probabilistic safety assessment, operation.

2.1 Applicability of the EPR safety requirements to the 900 MWe reactors

As a guideline for the safety requirements reassessment, IRSN proposed to consider the safety objectives associated to the EPR project. To this purpose IRSN examined the technical guidelines for the design and construction of the project of nuclear power plant with pressurized water reactors adopted during GPR/German experts plenary meetings held in October 19th and 26th 2000. For each safety requirement given in this document IRSN evaluated the possibility to adopt it in the re-assessed 900 MWe VD3 safety referential. Obviously, because of design differences between the 900 MWe reactors and the EPR project this work has been done in a realistic way in order to balance, as much as possible, for each safety requirement the safety benefit and the possibility of its application.

As a result of this work, IRSN proposed to include in the VD3 900 MWe PSR program additional safety reassessment topics. Through technical exchanges and discussions Electricité de France agreed to consider some of these topics in its PSR program, others have been recommended by the standing group of experts.

To give examples, some of the EPR safety objectives which evaluation led to ask Electricité de France to perform additional safety studies are given below :

- **To consider internal hazards at shutdown states**. In general the consequences of internal hazards are only evaluated against design operating conditions. Given that for the 900 MWe reactors operating conditions at shutdown states were not considered in the original design, internal hazards at shutdown states have never been properly taken into account. The scope of this topic being very large it has been decided to border the study and to ask Electricité de France to verify that rooms which contain equipment required to assure safety functions at shutdown states have been considered in the studies related to high energy pipe ruptures and internal flooding,

- **To consider the links between internal and external hazards**. The scope covered by this safety objective is also very large. After discussion it has been considered feasible, during the 900 MWe VD3 PSR, to evaluate the consequences in terms of internal flooding of the simultaneous rupture of all the non-seismically designed tanks located in the nuclear auxiliary building,

- **Steam generator tube rupture**. In order to limit radioactive releases after a steam generator tube rupture (SGTR), the EPR safety objective is to avoid steam generator over flow during the transient. It is also required that the transient calculations take into account conservative assumptions. Following long discussions about mechanical robustness of main steam

lines (after SGTR) DGSNR already requested (January 2003) Electricité de France to find technical solutions to respect the objective of no steam generator over flow during a SGTR transient - the calculations being performed without single failure criterion. In order to make a step further towards the EPR safety objective the standing group of experts recommended Electricité de France to examine technical solutions that would increase the grace delay given to operator in the safety studies to perform its actions.

2.2 External and internal hazards

Concerning external and internal hazards the following gives examples of topics that will be covered:

- **Seismic design verification**. The first part of the studies to be performed consists of recalculating the seismic spectrum of the safe shutdown earthquake for each nuclear site. These new calculations will have to be done following the methodology given in the 2001-01 fundamental safety rule put in force in 2001 by the Safety Authorities. If the new seismic spectra are more penalizing than the design seismic spectra, Electricité de France will have to evaluate the consequences of this exceed. The second part of the studies consists of verifying the seismic resistance of some nuclear island buildings taking into account parameters that were not originally taken into account in the calculations, as building torsion effects and flexible floors vibrations. Moreover, in order to apply (as for the 1300 MWe and 1450 MWe reactors) the “seismic event approach” to the nuclear island buildings, Electricité de France will analyse the risk of aggression, in case of earthquake, of the electrical building by the turbine hall building.

- **Risk of explosions due to explosive gas on site.** For risks of explosion outside of the buildings, Electricité de France will record the possible sources of explosions and analyse their potential consequences. For risks of explosion inside the buildings Electricité de France will check the measures taken to reduce the risk of explosion taking into account operating experience feedback. If the studies put in evidence unacceptable risk, Electricité de France will have to take appropriate actions to improve the safety level.

- **External hazards due to extreme weather conditions.** Electricité de France will examine the following hazards: winds, tornadoes, fires (forest), snowfalls, drought, high heat sink temperatures (cooling water), and high air temperatures. For each hazard, robustness analyses of the installations must be performed according to the following steps:

    - Data acquisition and reassessment of the climatic loads,

    - Statement of the actions taken on site regarding the potential climatic loads and analysis of the recorded experience feedback,

    - Analysis of the safety impact of the potential climatic loads and, if necessary, study of prevention means improvements or management of the hazards consequences.

Moreover, Electricité de France will evaluate the capability of the nuclear units of a same site to cope simultaneously with external hazards that can have a common cause (earthquake, floods, snowfalls, winds…). This evaluation will concern in particular situations like “total loss of heat sink” or “total loss

of heat sink cumulated with loss of external electrical power supplies".

2.3 Systems and civil engineering design

Concerning systems and civil engineering design the following gives examples of topics that will be covered:

- **Design review of the safety injection system**. Following the standing group of experts meeting related to the study of the loss of primary coolant accident (intermediate break) that took place in 2002, Electricité de France was asked to include in its 900 MWe VD3 PSR program the assessment of the safety injection system functional capacities. The objective of this review is to perform a global evaluation of the safety injection system performances in order to check existing margins. On IRSN proposal, Electricité de France agreed to review the methodology followed to determine the safety injection flow rates taken into account in the safety studies. The review will have to consider:
    - The safety injection system periodic tests (safety injection circuit configurations, periodic test criteria coherence and associated uncertainties)
    - The methodology used to calculate the safety injection flow rates in accident operating conditions (hydraulic circuit calculations, uncertainties associated to the verification of the periodic test criteria…)
    - The search of possible cliff edge effects in design basis accident studies.

- **Debris impact on emergency coolant recirculation**. IRSN considered that, in case of primary coolant circuit or secondary circuit ruptures, the risk of reactor building sumps clogging can impact simultaneously the safety injection system (SIS) and emergency containment spray system (ECSS) availability. Taking into account this risk the standing group of experts stated that this phenomenon had to be studied in priority and for all the French PWRs. It has also been stated that the debris impact on emergency coolant recirculation assessment must take into account all the different sizes of primary or secondary pipe breaks inside containment. All the studies to be performed will have to evaluate the risk to loose SIS and ECSS pumps due to head loss or by air ingestion as well as the consequences on the SIS and ECSS equipment and on the reactor core.

2.4 Accident studies and radiological consequences

Concerning accident studies and radiological consequences the following gives examples of topics that will be covered:

- **Severe accidents studies.** The examination of the topics related to severe accident studies is a continuous work supported by research and development actions. Since 1994 five standing group of experts meetings dedicated to severe accident studies took place. At the request of DGSNR, all the adopted conclusions must be gathered in a "severe accident safety referential" that will be examined by the standing group of experts (by the end of the year 2003). The work to be done by Electricité de France in the framework of the 900 MWe VD3 PSR is to build a safety file that will demonstrate the robustness of the 900 MWe nuclear power plants against the set of safety requirements constituted by the "severe accident safety referential". The build-up of this safety file leads in particular to perform additional studies about: reactor vessel thermal shocks, reactor building sumps clogging,

massive heterogeneous dilution…

- **Operability of equipment required during beyond design operating conditions.** The examination of the operability of equipment required to cope with accident beyond design operating conditions was performed in the framework of the periodic safety review related to the second ten-yearly outage of the 1300 MWe nuclear power plants (1300 MWe VD2 PSR). Taking into account the important results of this examination and the similarity between the 900 MWe and 1300 MWe nuclear power plants regarding these operating conditions, Electricité de France will address this topic and study the transposition of the 1300 MWe VD2 PSR conclusions to the 900 MWe nuclear power plants.

2.5 Probabilistic safety assessment

- **Level 1 probabilistic safety assessment (PSA)**. IRSN already sent Electricité de France and DGSNR the results of the updated level 1 900 MWe PSA. New sequences leading to direct bypasses of the containment (in particular through the thermal barrier of the primary pumps) or to primary circuit dilutions have to be investigated in detail by Electricité de France. Moreover, Electricité de France will update the level 1 900 MWe PSA to build a 900 MWe VD3 reference model (reliability and operating data update, taking into account second ten-yearly outage modification batch, state oriented procedures, better considering risks at shutdown states…). Its use in the framework of the 900 MWe VD3 PSR will have to follow the prescriptions of the 2002-01 fundamental safety rule related to the development and utilisation of probabilistic safety assessments. Moreover, for the first time Electricité de France will develop a PSA model specific to the first series of French 900 MWe nuclear power plants (CP0 series that concerns Bugey and Fessenheim nuclear power plants).

- **Level 2 probabilistic safety assessment** The objective of Electricité de France is to build a reference level 2 PSA model in a time frame compatible with the milestones of the 900 MWe VD3 PSR to be used for severe accidents assessments. The study will consider accidents at power and specific studies at shutdown states. Moreover, it will take into account the most important physical phenomena and present numerous sensitivity studies, in accordance with international practices.

- **Probabilistic safety assessment related to internal/external hazards.** Concerning fire hazard probabilistic safety assessment, IRSN pointed out the interest that Electricité de France evaluate the importance, regarding the core melt frequency and possible early radioactive releases, of the critical rooms highlighted by the fire hazard PSA performed by IRSN. This evaluation should allow focusing on some fire zones and safety volumes having common mode causes or equipped with fire protection devices participating to the safety demonstration.
  Concerning other external/internal hazards PSA, it has been stated that the introduction of earthquake and flooding studies in the PSA models would be profitable. Nevertheless, taking into account the difficulty and complexity of such studies the standing group of experts considered that these studies could be performed, at the earliest time, in the framework of the 1300 MWe VD3 PSR.

3 MILESTONES OF THE PSR

The milestones of the 900 MWe VD3 PSR are directly linked to the PSR process itself and to the third ten-yearly outages planning. The main PSR steps are shown in figure 2.

3.1 Conformity studies and safety referential reassessment

The minimum time needed by Electricité de France technical departments between the time of the modification batch definition and its implementation in a nuclear power plant is about three years (time period necessary to perform the detailed design studies and the implementation files). Therefore, given that Electricité de France planned the first third ten-yearly outage in 2008 (at Fessenheim 1 unit) the definition of the 900 MWe VD3 modification batch must be completed by 2005. Ten, all the safety analyses to be performed (presented in the paragraphs here above) that are supposed to lead to hardware modifications must be completed by 2005.

The assessment by IRSN of the studies performed by Electricité de France will be presented to the standing group of experts in different meetings planned in 2004 and beginning of 2005.

Different safety studies, because of their importance, will lead to specific standing group of expert meetings as for example severe accident studies, probabilistic safety assessment or debris impact on emergency coolant recirculation. Therefore, the workload during the years 2004 and 2005 will be important and the different parties involved highlighted that they will have to pay attention to respect the PSR milestones in order to be able to take into account the conclusions of all the safety studies in the definition of the 900 MWe VD3 modification batch.

3.2 Nuclear units conformity check

Electricité de France plans to submit its program proposal by the end of 2003. This timing should allow sufficient time for IRSN/DGSNR to assess this program and then for Electricité de France to launch it in the different 900 MWe nuclear units.

Figure 2 : Milestones of the PSR