IRSN point of view on plant long term operation assessment

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Abstract:
Long term operation of existing nuclear power plants is probably the most economical way to ensure the transition to a next generation of safer power reactors. However the decision to extend the lifetime of existing plants should be balanced by a significant enhancement of their safety features.
Long term operation (LTO) decision for the 900 MWe NPPs is expected by the end of this decade. For EDF, the main objective of the fourth periodic safety review (PSR) is to prove its capacity to operate its NPPs up to 60 years. At that time, the plant safety will have to be assessed in the framework of the PSR as it is the rule in France. Beside this regulatory milestone, the IRSN is emphasizing on two topics which deserve special attention: ageing management, and enhancement of radiological mitigation of accidents. As a matter of fact, the perspective of an extended operation will need substantial efforts not only on the ageing management programme but also on the enhancement of the safety level with the aim to reach safety objectives similar to those expected for a Gen III reactor like the EPR.
Beyond the assessments provided for as part of the fourth periodic safety review of French NPPs, the point of view of IRSN on the question of the lifetime extension beyond 40 years has raised two major key issues.
The first one is the need for an extended ageing management programme including a large research programme to support the knowledge on ageing mechanisms. The second is the need for a consequent safety enhancement programme designed to reach, when achievable, the EPR safety objectives, and based on hardware modifications so as to reduce the radioactive releases as low as reasonably achievable not only for design basis accidents (DBAs) but also for severe accidents.

1 INTRODUCTION

In France, plant lifetime is not established once and for all by a decision of the regulator. So, a nuclear power plant (NPP) could operate theoretically as long as the safety requirements are met. But every 10 years, the operator (EDF) has to perform a Periodic Safety Review (PSR) for each plant. The objectives of the PSR, its programme and its results are submitted to the French nuclear safety authority (ASN), and finally assessed by its technical safety organisation, the IRSN (Institut de radioprotection et de sûreté nucléaire). After this step, ASN issues an agreement to continue operation for a further 10 years period. The first 900 MWe PWR NPPs were erected in the eighties in France; they are now celebrating their 30th anniversary and then should be allowed to operate up to 40 years.

In this context, the French safety authority will have to authorize the long term operation (LTO) of 900 MWe NPPs by the end of this decade. EDF has already annonced its main objective to extend their lifetime from 40 to 60 years, in the framework of the 4th PSR. LTO implications on the plant safety will have to be systematically addressed as it is the rule for a PSR in France. But the IRSN is putting emphasis on two topics which deserve special

attention: ageing management, and enhancement of radiological mitigation of accidents. As a matter of fact, the perspective of an extended operation will need substantial efforts not only on the ageing management programme but also on the enhancement of the safety level with the aim to reach, when achievable, a level similar to that expected for Gen III reactors like EPR.

LTO is also already concerning French research reactors (RRs). For these facilities, safety improvements and component replacements are often considered easier than for NPPs. Nevertheless, some of them have been constructed in the vicinity of increasing populations; their long term operation deserves thorough attention towards radiological consequences of accidents.

This paper details the IRSN point of view concerning the work to start or to be carried out over the next 10 years on these issues.

2 PERIODIC SAFETY REVIEW

Thanks to efforts of IAEA and groups of regulators like WENRA, the periodic safety review has become a good practice adopted in many countries. It is an instrument for reviewing the safety of plant operation throughout its service life and addressing requests by the operator for authorization to continue plant operation for a further period (10 years in France). For many years, IRSN has promoted such an approach for the PSRs of NPPs and RRs, in which account is taken of:

- compliance of the Structures, Systems, and Components (SSCs) with the updated safety reference documents (SAR, etc.),
- outcomes of surveillance programmes,
- outcomes of the operating experience,
- outcomes of updated probabilistic safety assessments,
- reassessment of hazards (intensity of earthquake, floodings, etc),
- significant changes in regulation, safety standards, etc.
- technical developments, new safety-related information from relevant sources.

For the next generic PSR which will concern the series of 1300 MWe NPPs, IRSN pursues two main goals:

- to look after the good implementation of the PSR approach as mentioned above, by focusing on the qualification of equipment to accidental conditions,
- to keep the same objectives as those retained for the 3rd PSR of 900 MWe NPPs,

3 PLANT LONG TERM OPERATION ASSESSMENT

Beside the regulatory works conducted in the framework of the PSR, IRSN is starting studies and discussions with the operator and the nuclear safety authority for all the NPPs (900 MWe, 1 300 MWe, 1 400 MWe). The conclusions of which should be first implemented for the 4th PSR of 900 MWe, but could also be implemented on others reactors without waiting for their 4th PSR.

3.1 Ageing management

The major objective of an ageing management programme is to check the assumptions that all the components involved in an ageing mechanism remain within their design and safety criteria. Three important principles should guide an ageing management programme:

- maintaining the Structures, Systems and Components (SSCs) within the safety demonstration,
- preventing failures of critical SSCs,
- improving the knowledge on degradation mechanisms with the support of research programmes.

The ageing management procedure has been proposed by EDF in a generic guide. It consists of three main steps:

- Selection of safety-related SSCs concerned by an ageing mechanism,
- Review of all the pairs “SSCs / degradation mechanism” selected by experts and synthetic analysis performed in order to allocate a ‘status’ for each pair. A decision table is used to define the status of each pair depending on the answers to the following questions:
  - Is the maintenance programme adapted or difficult to adapt?
  - Is the repair and/or replacement difficult or not difficult?

This guide should be coherent with the guidance proposed by the IAEA in document [1].

The results of this work lead to identify 12 sensitive components including two among non-replaceable components (reactor pressure vessel and reactor building containment) for 900 MWe NPPs. For each sensitive component, a detailed report has been prepared in agreement with French regulation where different actions are identified in terms of surveillance, maintenance, modification, repairs, replacement, operating conditions and R&D actions.

This ageing management procedure will have to be reassessed for continued operation beyond 40 years with a perspective at 60 years. In this context, EDF will have to revalidate decisions made on all the components important to safety, taking consideration the effects of ageing degradation and the additional loadings of operation induced by long-term operation.

This suggests that the reduction of these loadings and the use of more flexible operating procedures may be conditions for accepting lifetime extension, but also that, for some SSCs, the use of more refined methods for the safety case may be inevitable.

3.1.1 Qualification

Equipment qualification ascertains that equipment will be capable of performing its intended functions at any time in the worse design conditions (seismic and/or accident conditions, etc.). It is therefore expected by IRSN that the qualified status of the equipment, in particular to accident conditions, will remain valid over the expected period of LTO. The operator will have to bring the technical justification that the material degradation and ageing effects are managed effectively.

3.1.2 Maintenance

IRSN deems that a continuous improvement of reactors safety should be seeked even in LTO context. This implies that EDF will have to make consequent investments to improve safety, larger than those necessary for a short-term economical vision. It is also important to develop a *proactive industrial strategy* for repairing and/or replacing some components important to safety in the most appropriate way (e.g. steam generators).

The NPP maintenance policy is a key factor for both safety level improvement and lifetime extension from 40 to 60 years. An effective maintenance policy can be developed along three axes:

- “corrective and preventive” maintenance,
- “operational exceptional” maintenance,
- “anticipative exceptional” maintenance.

The objectives of “corrective and preventive” maintenance are to ensure the functional capacities and increase the availability of the units in accordance with safety requirements.

On the other hand, the “operational exceptional maintenance” is applied to generic hazards or degradation concerning the whole fleet of NPPs or part of it. IRSN considers that beside the replacement of steam generators with 600 MA tube bundles or cast steel elbows on the primary circuit, the replacement of other heavy components in LTO context could be found necessary from cost versus benefice analyses.

Finally, the “anticipation exceptional maintenance” objective is to anticipate potential ageing phenomena and to be ready on time to repair or replace components important to the safety or to the performance of the units. For example, IRSN is thinking about the replacement of Chemical and Volume Control System (CVCS) charging line nozzle by anticipation of thermal fatigue phenomenon and replacement or the repair of the reactor vessel instrumentation penetration.

In addition, a special attention should also be paid to the management of spare parts, made more and more difficult over time due to equipment obsolescence.

3.1.3 In-service Inspection

In the context of long term operation, in-service inspection (ISI) should aim at **:**

- confirming analysis results showing absence of risks (defence in depth),
- detecting degradation at the earliest stage on zones identified at risk,
- detecting and characterizing ageing defects.

Consolidation of the understanding of ageing degradation mechanisms will require to increase the frequency and performance of non destructive examinations.

3.1.4 Research programmes

As a result of the ageing management programme, new research programmes should be put in place to provide continuous improvements of the understanding and predictability of ageing mechanisms and the causes of ageing. In view of LTO, a strategic approach should be adopted to promote relevant long- term research and development programmes in order to:

- improve the knowledge on ageing mechanisms,
- improve predictive models,
- qualify enhanced methods of justification by a better assessment of uncertainties and safety margins,
- improve techniques for the control of degradation,
- develop methods of repair and replacement of equipment.

A large research programme is developed in France by EDF in order to prepare the regulatory files which will support LTO, and also abroad, for example through the NULIFE project.

For its part, IRSN has to perform confirmatory research on the most important safety relevant issues in order to maintain or to get capacities for an independent judgement. IRSN has also the objective to promote research work on issues where the involvement of EDF is not judged satisfactory. A large effort is ongoing to prepare the updating and extension of the IRSN's research programmes on ageing and LTO.

Indeed, LTO of reactors is identified as a priority and a specific programme has been created in the Mid and Long-Term Plan. This programme is divided into four parts:

- Ageing of the main metallic components: the topics addressed are the irradiation embrittlement of reactor pressure vessel (RPV), irradiation-assisted stress corrosion cracking of internal structures of RPV, stress corrosion cracking of nickel alloys, thermal ageing, fatigue taking into account the effect of the environment, etc.
- Ageing of concrete structures: the assessment of long-term behaviour of concrete buildings including creep and shrinkage and the concrete pathologies such as Alkali-Aggregate Reaction or Internal Sulfate Attack.
- Ageing of polymeric materials: the topics addressed are electrical cables, seals, elastomer bearing pads and epoxy coating systems.
- Advanced methods: a more in-depth understanding of the ageing mechanisms and simulation of degradation of material properties due to irradiation will be initiated with the development of models to simulate the material behaviour (RPV, internals). Furthermore, a better assessment of uncertainties in probabilistic models is needed.

3.2 Radiological mitigation of accidents

Beside the challenge posed by SSC ageing, IRSN considers that one of the most challenging issue of LTO is the possibility to enhance safety of ageing NPPs, even if this ageing is managed efficiently. In fact, even if the core damage frequency has theoretically decreased by a decade or two, through significant safety improvements made on French plants since their original design, IRSN's opinion is that the real state of an ageing plant cannot be described precisely by its Probabilistic Safety Assessment.

Consequently, it should be understood that the reflection on LTO should address considerations to reduce the radiological consequences of accidents. IRSN has always considered that the objectives in terms of radiological doses, as usually retained by designers and operators, were not criteria to assess the acceptability of consequences of accidents.

More generally, IRSN invited EDF to adopt - for each PSR - a global approach aimed at increasing plant safety, by identifying not only the accidents leading to the most important consequences for the people and the environment, but also the paths of releases and the main radiological exposure in order to study possibilities to implement technical devices and arrangements allowing reducing the consequences of accidents. IRSN paid special attention to the accident of steam generator tube rupture, which is, for the fleet of NPPs in operation, the accident which leads to the most important releases among “design basis” accidents (DBAs). IRSN is eager to see EDF define more stringent radiological objectives for plant long term operation and implement solutions to achieve them.

Although significant modifications have already been implemented by EDF on the NPPs in operation to minimize the radiological consequences of accidents, e.g. by strengthening the bolts of equipment hatches through reactors buildings, increasing the reliability of the pressurizers valves and using hydrogen recombiners, IRSN intends to encourage EDF to study additional arrangements in order to reduce more radically the consequences of severe accident, such as:

- passive systems for the heat removal inside the containment building without using the venting system with sand filter (“U5”),
- others venting systems than “U5” (systems using mixing/filtration elements, etc.),
- systems allowing the discharge of “U5” releases in dedicated capacities,
- solutions to avoid concrete basemat meltthrough,

and a revision of the operator’s severe accident management procedures, particularly concerning water injections and management of the containment aspersion taking into account the safety objectives defined for the plant long term operation.

Besides, a new experimental programme on the behaviour of fission products in severe accidents (STEM) will be proposed as an international OECD joint research programme.

Concerning Research Reactors, IRSN started discussions with the operator of the High Flux Reactor at Grenoble (“Institut Lauë Langevin”), and the nuclear safety authority, in the prospect of the next PSR scheduled in 2017, after approximately 46 years of operation. Important modifications have already been made in the frame of previous PSRs (replacement of the primary circuit in 1994, seismic reinforcement in the last years), but, for the IRSN, the next stake is the reduction of radiological consequences of fuel melting accidents, considering the high rate of urbanization in the vicinity of the reactor. The safety objectives have first to be established, then technical and organisational arrangements have to be studied. IRSN intends to incite a large reflection and studies on this issue.

4 CONCLUSION

Long term operation of existing nuclear plants is probably the most economical way to ensure the transition to a next generation of safer power reactors. However the decision to extend the life of existing plants should be balanced by a significant enhancement of their safety features.

Beyond the assessments provided for as part of the fourth periodic safety review of French NPPs, the point of view of IRSN on the question of the lifetime extension beyond 40 years has raised two key issues.

The first one is the need for an extended ageing management programme including a large research programme to support the knowledge on ageing mechanisms. The second one is the need for a consequent safety enhancement programme designed to reach, when achievable, the EPR safety objectives, and based on hardware modifications so as to reduce the radioactive releases as low as reasonably practicable for design basis accidents as well as for severe accidents.

These two questions will naturally take benefits from the results of probabilistic safety assessments which highlight points for which design or operating changes can be examined or even judged necessary and contribute to the demonstration of the required safety level.

The confrontation of knowledge and application of the defence in depth concept should allow IRSN to state the relevant conditions for extending the lifetime of NPPs.