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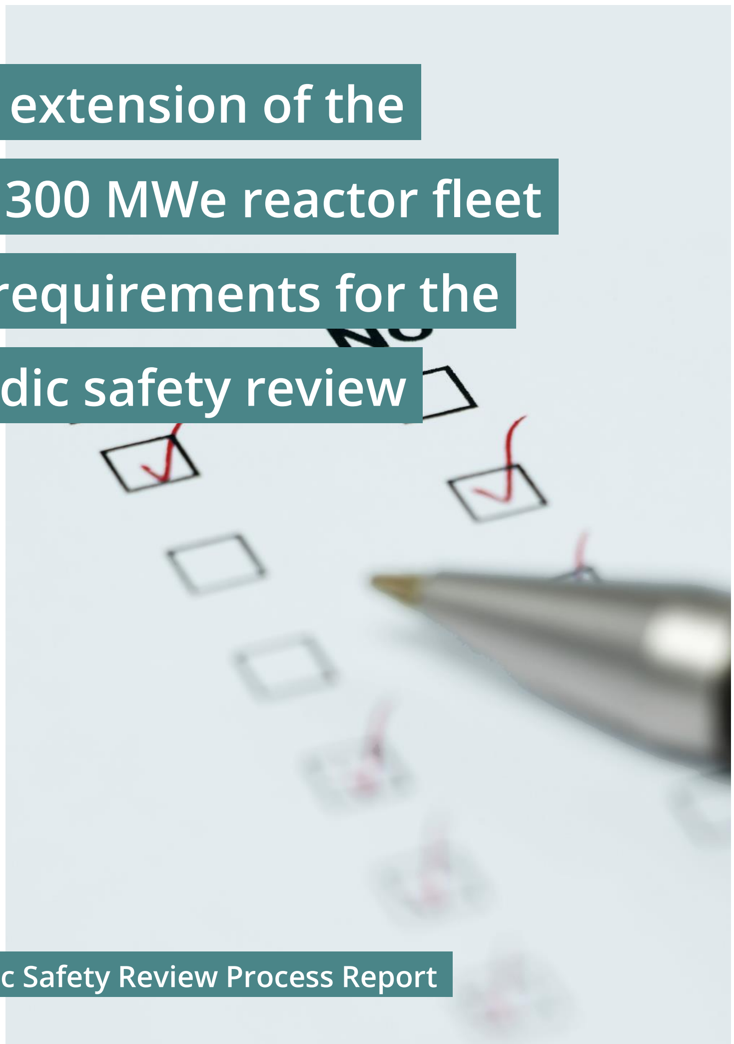

Task 1: Periodic Safety Review Process Report

Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

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Lifetime extension of the French 1300 MWe reactor fleet generic requirements for the 4th periodic safety review

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CONTENTS

SUMMARY

Twenty nuclear reactors of 1300 MWe installed capacity in France are now approaching forty years of operation, the end of their design life. The operator EDF intends to extend the lifetime of those plants. In France, once the design life-time of 40 years is reached, and the utility plans extending operation of a nuclear power plant (NPP) beyond its design lifetime, a comprehensive reassessment of the status of the plant is needed within the fourth periodical safety review (PSR4).

The French High Committee for Transparency and Information on Nuclear Safety (HCTISN) is organizing a public consultation process with the possibility to provide opinions on the generic phase of the PSR4, which covers topics relevant to all the 1300 MWe reactors. In case of a severe accident in a French NPP, significant impacts on Austria cannot be excluded. Therefore, Austria is participating in this consultation. For this participation, four task reports and a synthesis report have been prepared. The report at hand is task report no.1 focusing on the French PSR system.

The operating license of a nuclear power plant in France is not limited in time. In principle a NPP can be operated as long as it is considered safe, which means, as long as it fulfills the regulatory safety requirements, which are proxy criteria to limit the residual risk to values accepted by the French society. In addition to day by day inspections of the regulatory authority, every ten years EDF has to perform a comprehensive review of its NPPs against the current set of standards and against the state of the art, to show that the safety margins available at the plants guarantee the safety requirements for the next ten years of operation as well. This PSR is a regulatory prerequisite for long term operation.

The design life-time of the French reactors is forty years. Therefore, the PSR4, which allows operation beyond forty years up to fifty years, is of particular importance and extended in scope. Currently, the French 1300 MWe reactor fleet is subject to the PSR4.

In this report we looked at the legal requirements for the periodic safety review in France as well as the results of previous periodic safety reviews – especially the PSR3 of the 1300 MWe reactor fleet, and the PSR4 of the 900 MWe reactor fleet.

Main topics and results of the 1300 MWe reactor fleet PSR3 were update of the safety demonstration and improvements. Regarding the safety demonstrations, e.g. primary circuit dilution risks, failure of passive components of the safety injection systems, risk of cold overpressure in the primary circuit was looked at. The design of safety-critical systems and civil engineering structures was under investigation, including equipment qualification in general and looking at specific systems and processes, like the safety of fuel stored in the spent fuel poo, the handling of fuel transport casks and the seismic reassessment of structures and equipment. The probabilistic safety assessment (PSA) of the plants was revisited and broadened in scope.

Main results of the 900 MWe reactor fleet PSR4 were a new look at the overall safety objectives of the plants and a comparison of the plants with the state of the art with the aim to identify reasonably achievable safety improvements.

One of the key conclusions of the work, leading to a recommendation, was, that in the past deviations from the safety requirements occurred. Improvements can be implemented, but there will always be a gap to state-of-the-art nuclear power plants. As a matter of transparency, the meaning of such deviations and deltas should be evaluated and the consequences explained. Such evaluation, an assessment of the residual risk compared to the residual risk of a state-of-the-art NPP, is currently not required, however, it would add considerably in fostering understanding in a public consultation process.

1 INTRODUCTION

In mid-2017, EDF started the process of the PSR4 of its 1300 MWe reactors by filing to the French nuclear safety authority, ASN, the Dossier d'Orientation du Réexamen périodique VD4 1300 MWe, presenting its planned working programme related to the 4th decennial visits (VD4) of the reactors, with a view to the continued operation of French 1300 MWe nuclear reactors after 40 years. (EDF 2017)

On 11 December 2019, the ASN took a position on the orientations of the generic phase of this PSR4 (ASN 2019a) and setting the objectives of the projected PSR4. In 2023, EDF filed its "Note de réponse aux objectifs" (NRO) (EDF 2023a) presenting its responses to the objectives, together with a summary of the methods used and the main results known to date for each topic covered, on a generic level for all of the concerned reactors (apart from a few topics only applying to specific sites or units).

The 1300 MWe reactors are a fleet of 20 units located at 8 sites (2 sites with 4 units, at Cattenom and Paluel, and 6 sites with 2 units, at Belleville, Flamanville, Golfech, Nogent-sur-Seine and Saint-Alban), totaling 27.4 GW out of the 61.3 GW of total nuclear capacity installed in France.

They have been connected to the grid over 10 years, between June 1984 and June 1993, and have been operated, as of mid-2024, for more than 36 years on average.

The 1300 MWe reactors have all been built mostly based on the same standard, although two different versions exist (respectively P4 and P'4, with slight differences, e.g. regarding the transfer of fresh fuel into the fuel building or spent fuel out of it for transport), and the design has been adapted to the specificities of each site, on the coast or on river sides.

The life extension of the 1300 MWe reactors is formally to be decided as the outcome of their PSR4. As for the French 900 MWe reactors, of an older standard, before, the PSR will be split between two phases: the generic one, which is open for consultation, will precede a site by site, unit per unit implementation.

The present report focuses on the details of the PSR process, including an overall view of the process, from a regulatory and technical perspective, a summary of the known outcomes of past relevant PSR processes applied to French reactors, and an overview of the main issues discussed in the PSR4 NRO for 1300 MWe reactors, and the main expected retrofits related to these issues.

2 THE PSR FRAMEWORK IN FRANCE

Unlike in many countries where nuclear reactors are operated, the license is granted for a predefined period, with an explicit deadline, the operating license of French reactors has an open end, i.e. it is granted for an unlimited period of time. In return, the compliance of the plant with requirements is reviewed every ten years during the periodic safety review, which is a condition of the decision by the French nuclear safety authority, Autorité de sûreté nucléaire (ASN) to authorise continued operation, in principle until the next review.

One specific feature of this process is that it comes with an upgrade of safety requirements prior to each periodic safety review, so as to guarantee a so-called "continuous improvement of safety".[1] Moreover, thanks to the standardized nature of the French nuclear fleet, the process of periodic safety review is split for each standard of reactors between a generic phase, where the overall safety requirements applying are defined, and a case-by-case implementation to each of the plants and units concerned.

Periodic safety reviews therefore encompass two global objectives. On one hand, they provide the opportunity for an extensive assessment of the conformity of the plant to existing requirements, including general nuclear safety regulations, the specific terms of its operating license and the various prescriptions by ASN it must comply with. On the other hand, they are used to introduce enhanced requirements, taking stock of the evolution of regulations, knowledge and know-how, and the French and international return of experience. The operator, EDF, proposes a series of studies and actions accordingly, which need first to be approved by ASN on a generic level before it proposes their specific implementation, unit per unit. These are mostly implemented through a dedicated outage called decennial visit. EDF then establishes a periodic safety review report that has to be approved by ASN before continuous operation up to the next periodic safety review is formally considered granted.

The current consultation comes after more than 6 years already of technical work regarding the generic phase of this PSR4, which started in 2017 when EDF proposed some generic guidelines and objectives, which the ASN took a first position on at the end of 2019, after a first round of voluntary public consultation. The technical analysis of the studies that EDF files to comply with that decision is going on, and ASN plans to take a position around 2025 on the outcome of this generic phase, with specific requirements for additional inspections or modifications to the facilities. The first tests and works were expected to take place during decennial controls preparatory to the PSR4 before October 2017 at Cattenom-3 and Penly-1 and 2.

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[1] This is explained for instance in this article by two ASN commissioners: Lachaume, J.-L., Cadet-Mercier, S., "La doctrine en matière de sûreté nucléaire : une amélioration continue intégrant mieux la gestion d'un accident nucléaire", in Annales des Mines - Responsabilité et environnement 2020/2 (N° 98), pages 60-64, April 2020. See http://bit.ly/penf0106

The understanding of the PSR process, from its objectives to its scope, and the way the different issues it covers are assessed and discussed up to final decisions by ASN needs therefore to draw from a two-fold experience:

1) The PSR3 applied to 1300 MWe reactors. Since the first ones at Paluel-1 and 2 and Cattenom-1 in October 2017, all P4 and P'4 reactors have undergone their PSR3 apart from Cattenom-4, for which it was due before the end of 2023, but ASN granted an extension until October 2024, and Penly-4, for which the PSR is due to be complete by November 2024. Although it encompassed a broader set of issues, this PSR was mostly similar to those already run for different standards of the French nuclear fleet, essentially comprising two parts.

The first is about conformity and its guarantee over time. It consists of an examination of the compliance of the installations with the safety rules applicable to them and their ageing, which means, in operational terms, a series of desk and on-site examinations, plus additional studies about ageing:

- design reviews,
- compliance checks and overall tests,
- specific, regulatory tests (hydraulic test of the main primary circuit, tightness test of the reactor containment),
- identification, monitoring and treatment of ageing phenomena.

The second part is reassessing safety and environmental protection, which means in operational terms:

- the incremental increase of safety objectives,
- the reassessment of the assumptions made in accident studies and the hazards taken into account for in the light of operating experience and advances in knowledge and techniques,
- reviewing existing studies and carrying out new ones,
- definition of related modifications to facilities and their operating procedures.

Both parts of the PSR came with the need for specific work, whether it is about heavy or diffuse maintenance – the former including the replacement of steam generators – or for the sake of safety reinforcements.

2) The PSR4 that was started for 900 MWe reactors about 10 years ago and is still being implemented, with many reactors yet to run their PSR. ASN's review of the generic case started as early as 2013 and was completed when it granted

EDF a generic approval in Decision No. 2021-DC-076 of 23 February 2021,[2] completed by a technical report.[3] Meanwhile, as the deadline set for completing the PSR process on the first concerned reactor came close, the "first of a kind" PSR4 of a 900 MWe reactor had to start, at Tricastin-1, before these generic conditions where eventually set. Since then, to date, a total of eight CP0 and CP1 reactors have been subject to this review process. Nevertheless, as of the end of 2023, ASN only released an approval for the extended operation of Tricastin-1, in its Decision No. 2023-DC-0764 of 29 June 2023[4] (completed by a short technical report on the conditions for continued operation of the reactor)[5].

The PSR4 for the 900 MWe reactors is of a particular importance, as some of its framing conditions and objectives will also apply to that of 1,300 MWe reactors:

- The lifetime extension of these reactors beyond 40 years means that they will operate over a period that was not considered when assessing their initial design – in the sense that this was the assumption considered to assess the safety of the plants against critical ageing factors, such as the cumulated neutronic irradiation of the reactors' vessel. For 900 MWe reactors, ASN emphasized that "their 4th periodic safety review [was] of particular significance, because their design postulated an operating lifetime of 40 years", meaning that "their continued operation beyond this period requires the updating of design studies and equipment replacements";[6]
- Since this lifetime extension process coincided with projects to build new reactors, based on a so-called evolutionary PWR design such as the EPR in Flamanville. From the start of the process, in 2013, ASN notified EDF that "in the years to come, existing reactors will coexist, worldwide, with reactors of the EPR type or equivalent, the design of which meets significantly

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2 ASN, Décision n° 2021-DC-0706 de l'Autorité de sûreté nucléaire du 23 février 2021 fixant à la société Électricité de France (EDF) les prescriptions applicables aux réacteurs des centrales nucléaires du Blayais (INB n° 86 et n° 110), du Bugey (INB n° 78 et n° 89), de Chinon (INB n° 107 et n° 132), de Cruas (INB n° 111 et n° 112), de Dampierre-en-Burly (INB n° 84 et n° 85), de Gravelines (INB n° 96, n° 97 et n° 122), de Saint-Laurent-des-Eaux (INB n° 100) et du Tricastin (INB n° 87 et n° 88) au vu des conclusions de la phase générique de leur quatrième réexamen périodique. See http://bit.ly/penf0095

3 ASN, Phase générique du quatrième réexamen périodique des réacteurs de 900 MWe d'EDF – Rapport d'instruction de l'Autorité de sûreté nucléaire, CODEP-DCN-2021-007968, March 2021. See http://bit.ly/penf0108

4 ASN, Décision n° 2023-DC-0764 de l'Autorité de sûreté nucléaire du 29 juin 2023 fixant à Électricité de France (EDF) des prescriptions complémentaires applicables à la centrale nucléaire du Tricastin au vu des conclusions du quatrième réexamen périodique du réacteur n°1 de l'INB n° 87 et modifiant la décision n° 2011-DC-0227 du 27 mai 2011 et la décision n° 2015-DC-0494 du 27 janvier 2015 de l'Autorité de sûreté nucléaire. See http://bit.ly/penf0109

5 ASN, Centrale nucléaire Tricastin - Conditions de la poursuite de fonctionnement du réacteur n° 1 après son quatrième réexamen périodique – Rapport à l'attention de Madame la ministre de la Transition énergétique, CODEP-LYO-2023-039447, July 2023. See http://bit.ly/penf0110

6 ASN, "Conditions for the continued operation of the 900MWe reactors", in ASN Report on the state of nuclear safety and radiation protection in France in 2020, 2021, pages 24-25. See http://bit.ly/penf0107

enhanced safety requirements. Existing reactors must therefore be upgraded in line with these new safety requirements, the state of the art in nuclear technologies and the operating lifetime projected by EDF".[7] The objective set by ASN regarding the safety of existing reactors through their life extension was therefore to "bring the level of safety of the 900 MWe reactors close to that of the most recent reactors (third generation)".[8]

- The technical discussion on the generic requirements of the PSR4 run in parallel with an extensive programme started by ASN after the Fukushima catastrophe of 11 March 2011. The process, which started with Complementary safety assessments (CSAs) run by EDF for each nuclear power plant and a global report by ASN by December 2011,[9] followed a generic position by January 2012[10] and specific prescription and minor complementary prescriptions to implement post-Fukushima reinforcement, respectively issued in June 2012 and January 2014.[11] Although the post-Fukushima CSAs and the PSR remain two distinct regulatory processes, the ASN clarified by 2016 that "this fourth periodic review is an opportunity to complete the incorporation of the modifications resulting from the ASN's requirements issued following the additional safety studies (ECS) carried out following the accident at the Fukushima-Daiichi power plant (Japan)".[12]

Extending the operation of reactors beyond their PSR4 is part of an overall strategy for managing the nuclear fleet, which must take into account the technical, industrial and financial challenges and guarantee that safety is maintained at the required level in all circumstances. This issue is being tackled under conditions of pressure, due to the lack of anticipation of any alternative to extension.

- The governance of the decision-making process following the PSR4 should ensure that the absence of an alternative does not lead to an extension by fait accompli.

[7] ASN, "Programme générique proposé par EDF pour la poursuite du fonctionnement des réacteurs en exploitation au-delà de leur quatrième réexamen de sûreté", letter CODEP-DCN-2013-013464 of 28 June 2013 to the President of EDF – translation by Institut négaWatt. See http://bit.ly/penf0096

[8] ASN, Report 2021, pages 24-25, op. cit.

[9] ASN, Évaluations complémentaires de sûreté – Rapport de l'autorité de sûreté nucléaire, December 2011. See http://bit.ly/penf0030

[10] ASN, Nuclear Safety Authority (ASN) opinion n° 2012-AV-0139 of 3rd January 2012 concerning the complementary safety assessments of the priority nuclear facilities in the light of the accident that occurred on the nuclear power plant at Fukushima Daiichi. See http://bit.ly/penf0112

[11] ASN resolution 2012-DC-0275 of 26 June 2012 instructing Électricité de France – Société Anonyme (EDF-SA) to comply with additional requirements applicable to the Le Blayais NPP (Gironde département) in the light of the conclusions of the Complementary Safety Assessments (CSAs) for BNIs 86 and 110, and similar resolutions applying to other nuclear power plants. See http://bit.ly/penf0111

[12] ASN, "Orientations génériques du réexamen périodique associé aux quatrièmes visites décennales des réacteurs de 900 MWe d'EDF (VD4-900)", letter CODEP-DCN- 2016-007286 of 20 April 2016 to the President of EDF – translation by Institut négaWatt. See http://bit.ly/penf0054

- The decision-making process on the possible terms and conditions for extending operation must make it possible to guarantee safety independently of any consideration of EDF's industrial and financial capacity.
- The safety requirements regarding a possible extension of operation should not only be about revised safety objectives but also encompass the need to demonstrate a certain margin of confidence, and to maintain resources according to the level of compliance and quality of implementation of the required work.

Since EDF embarked on the LTO strategy, the generic terms and conditions of this extension have only been addressed in voluntary consultation processes outside of legal requirements, focusing on the provisions proposed by EDF rather than on the objectives and resources to be set for it.

- The absence of any real consultation on the appropriateness of extending reactor operation beyond the PSR4 should not prevent this extension from being made conditional on actual compliance with stringent safety enhancement requirements.
- The generic consultation, devoted to the provisions planned by EDF for continued operation beyond the PSR4, does not encompass the conditions under which such extensions should be authorised. Further clarification is required to provide the necessary guarantees.
- The public enquiry process applicable to the PSR4 for its reactor specific phase is covering the results of the PSR4 after their implementation, when it could only be relevant if applied prior to this implementation.

3 RESULTS OF PSR PROCESSES

3.1 PSR3 of 1300 MWe reactors

3.1.1 UPDATE OF THE SAFETY DEMONSTRATION AND IMPROVEMENTS

Studies of operating conditions and their radiological consequences

Rules, methods and accident studies in the Safety Report (RDS)

In order to update the safety demonstration associated with the design basis operating conditions, EDF has modified several study rules or methods, data and assumptions, the impact of which differs depending on the studies considered. Further analysis of these changes led EDF, during the appraisal, to make several commitments considered satisfactory in principle, but which can only be analysed once the associated deliverables have been received. In particular, EDF is continuing to examine the studies of category 4 accidents involving bundle ejection and steam pipe rupture (STB) with shutdown of the primary pumps, which require additional information.

Four IRSN recommendations remained at the end of the instruction concerning the risks of criticality return during hot shutdown, the incident involving a reactor bundle falling on power, the accident involving the rupture of a category 3 steam generator tube (RTGV3) and the uncontrolled withdrawal of a power control bundle (R1GP).

Primary circuit dilution risks

EDF's handling of the risks of primary coolant dilution, which could lead to uncontrolled divergence of the reactor at power or an uncontrolled return to power in the shutdown state, linked to homogeneous dilution accidents, heterogeneous dilution of external origin or inherent in the Loss of Primary Coolant Accident (LOCA), requires a major addition to the safety demonstration and possibly new modifications. In particular, the safety demonstration associated with the risks of homogeneous dilution needs to be completed on several points.

Passive failure of the safety injection system (RIS)

The passive failure of the RIS currently considered for design basis accidents involves a leak of 200 l/min which occurs at the time of switching to recirculation and which is isolated in 30 minutes. EDF has shown that there is no cliff effect associated with penalising the leak isolation time (one hour instead of 30 minutes) on the performance of the RIS system and the radiological consequences of the category 4 LOCA.

Risk of cold overpressure in the primary circuit

The studies carried out by EDF have made it possible to identify, analyse and quantify several families of accident scenarios that could lead to a risk of cold overpressure in the primary circuit in all states of the reactor and that could call into question the strength of the vessel due to its flow. While a large proportion of these scenarios have a residual frequency of occurrence, scenarios involving breaches in the shutdown reactor coolant system (RRA) generate a significant risk of overpressure. In addition, IRSN has identified an increase in the frequency of "cold vessel shock" situations, when the SCR circuit is not connected, due to different initiators, which led to consider that the provisions against overpressure in the primary circuit should be strengthened and that EDF should provide additional justification for the risks of "cold shock".

Impact of secondary circuit valve behaviour on coverage of design basis transients

The rapid closure of all the steam isolation valves (SIVs) on the steam generators (SGs) constitutes a reference incident with regard to the risk of overpressure in the secondary circuit and is a dimensional factor for the protection valves on this circuit. The studies carried out by EDF did not find any need for modifications other than those in the action plan to reduce the number of spurious VIV shutdowns highlighted by experience feedback, which are not specific to this review.

However, IRSN considered that it is difficult to predict, using a calculation code, the local effects associated with valve dynamics and the consequences of a transient untimely VIV closure in terms of the number of valves activated. In this respect, EDF should complete the analysis of the impact of the behaviour of secondary valves on the operating conditions of the safety demonstration.

Containment, extension of the third barrier and compliance of iodine filtration systems

The studies carried out by EDF in this area are aimed at improving the containment safety function for design basis situations and severe accidents.

The studies carried out under this theme focused in particular on:

- the approach associated with the "containment" safety function;
- the condition, behaviour and monitoring of double-walled enclosures and penetrations;
- the vacuum and filtration system for the space between the enclosures (EDE system);
- the extension of the third barrier;
- containment of the buildings surrounding the reactor building;
- the risks of containment bypass.

The conclusions of an initial review of the studies devoted to this topic were presented to the Standing advisory group in June 2013 and led to requests from the ASN.

IRSN considered that the studies presented and the modifications declared by EDF represent improvements, some of them significant, in the safety of 1300 MWe reactors with regard to the "containment" safety function. However, the demonstrations still awaited from EDF could lead to further modifications. This also stressed the need, on a number of points, to continue beyond the VD3 1300 review to advance knowledge and seek safety improvements relating to containment.

Prevention and mitigation of severe accidents

The studies conducted by EDF on the prevention and mitigation of severe accidents focus mainly on increased prevention of the risk of severe accidents, in particular with regard to scenarios involving early loss of containment. The conclusions of IRSN's examination of these studies, supplemented by those dedicated to level 2 PSAs, which led EDF to propose around ten material modifications and update its "severe accidents" baseline, were presented to the GPR in March 2013. The measures adopted by EDF to prevent and mitigate severe accidents were considered satisfactory. However, EDF is expected to take further action in response to its commitments and the requests made by ASN in this context.

Radiological consequences of accidents other than severe accidents

EDF's assessments of the radiological consequences of the design basis operating conditions (excluding the Category 4 steam generator tube rupture accident - RTGV4) and of the complementary field were considered satisfactory, with certain additions still need to be made, in accordance with ASN's requests. In addition, IRSN considered that the modifications proposed by EDF within this framework are helping to reduce the radiological consequences of certain accidents.

Examination of the RTGV4 accident, the radiological consequences of which are the highest among the scenarios without core meltdown, has led IRSN to make two recommendations concerning its inclusion in the safety demonstration and the iodine-131 equivalent thresholds requiring the reactor to be shut down.

Design of safety-critical systems and civil engineering structures

Clarification of safety classification rules for non-classified IPS equipment (IPS-NC)

EDF's consideration of the requests made by ASN in this context, particularly concerning the assignment of appropriate classification and requirements to equipment identified as potential stressors under the seismic-event approach, would enable it to satisfactorily meet the objectives set for this topic when the VD3 1300 review was oriented.

Equipment qualification

Significant progress has been made in demonstrating that equipment is qualified to meet the requirements assigned to it, but that the additional information expected from EDF in response to ASN's requests is necessary in order to rule on the satisfactory nature of the qualification, particularly with regard to the vibration behaviour of certain pumping equipment, the earthquake resistance of certain valves and pumping units and the use of programmed electrical components on equipment important to safety.

Baseline associated with the risk of criticality of fuel in deactivation pools and the reactor building when the vessel is open

EDF's studies on controlling the risk of criticality of fuel in the reactor building when the reactor pressure vessel is open and in the deactivation pool were found satisfactory. However, EDF needs to complete its studies by examining scenarios where an assembly could fall into the pool and leak out. According to IRSN, studies of the situations considered by the criticality baseline in the reactor building with the vessel open (i.e. uncontrolled dilution of boric acid, accidental withdrawal of all the bundles and incorrect positioning of a fuel assembly in the core) should be included in the studies of operating conditions and should follow the same study rules. In addition, IRSN considered that the acceptability criteria that characterize the reactivity margins adopted in relation to criticality should be defined and mentioned in Chapter III of the safety report in the same way as the other criteria applicable to the design basis operating conditions.

The application of the criticality baseline to 1300 MWe reactors at the time of the VD3 safety review did not lead EDF to identify any particular modification to be implemented, apart from the installation of a redundant, diversified system independent of the existing boron concentration measurement system.

Safety of fuel stored in the Fuel Building (BK) spent fuel pool

The modifications planned or already incorporated under the VD3 1300 safety review and the post-Fukushima supplementary safety assessments were found likely to significantly improve the safety of the stored fuel. However, additional measures to control accidents affecting the storage pool have yet to be defined and that studies of the vulnerability to hazards (fire, explosion, internal flooding, earthquake, etc.) of the systems involved in preventing the uncovering of assemblies stored or handled in pools need to be carried out. This point was the subject of an IRSN recommendation.

Handling of fuel transport casks

The studies and verifications transmitted at the date of the review by EDF, which do not identify any particular need for modification, were found satisfactory. However, further demonstrations are required, in particular concerning the risks of loss of mechanical containment of the package on train P'4 and containment of the Fuel Building on train P4 in the event of the package falling during handling operations.

Design review of the reactor's digital integrated protection system (SPIN)

The SPIN helps to protect the reactor core by monitoring the minimum Critical Heat Flux Ratio (CHFR) in the core and the Linear Power Index (LPI), which are the variables of interest with regard to the risks of a maximum boiling crisis for the former, and fuel meltdown and Pellet-Cladding Interaction (PCI) for the latter. The main objectives of the SPIN design review were to verify the conservative nature of the SPIN calculations, under both normal and incidental operating conditions categories 1 and 2, and to re-examine the associated uncertainties.

With regard to the "low PLIN" chain, IRSN considers that the justification for the overall conservatism of the protection has been provided, but that it still needs to be consolidated, particularly with regard to the uncertainties. However, with regard to the "high PLIN" chain, IRSN considers that the conservatism of the SPIN should be strengthened in view of the intrinsic lack of conservatism of the reconstructed power distribution under certain incidental operating conditions. In this respect, IRSN considered that the modification proposed by EDF is not sufficient to cover all category 2 situations presenting a risk of under-conservatism of the PLIN assessed by the SPIN.

Electrical disturbances of internal or external origin

The studies and the modification envisaged by EDF were found satisfactory with regard to the dreaded situations induced by these initiators.

Safety review of the effluent conditioning and treatment auxiliary buildings (BAC/BTE)

In the light of the analysis produced by EDF in this context and those presented by other operators, as well as feedback from the operation of these facilities, EDF still needed to complete its demonstration by taking into account the requests made by ASN on this aspect.

Verification of the design of civil engineering structures

On the whole, the checks carried out by EDF on the design of civil engineering structures for the 1300 MWe series were found satisfactory, but with additional work still required, concerning in particular the integrity of steam clamp structures with regard to the overpressure effects associated with external explosion sources, the robustness of the retention structures of the PTR bunds of the P'4 train and the overall stability of the Paluel H building with regard to the risk of attack on the galleries of the raw water back-up system (SEC).

Internal and external events

Seismic verification process

Reassessment of seismic hazards

For each 1300 MWe reactor site, EDF has reassessed the maximum historically likely earthquakes (HHVS) and the resulting increased safety earthquakes (HSE) in order to determine, when the reassessed HSE exceeds that of the safety demonstration in force, the need to carry out a partial (limited to certain structures) or global (extended to all structures on the site) seismic reassessment and to identify the necessary reinforcements.

EDF has formalised the assumptions used for seismotectonic zoning, the choice of reference earthquakes and the calculation of magnitude-distance pairs in a generally satisfactory manner. However, EDF has neither systematically quantified the uncertainties, nor explored alternative hypotheses (zoning, choice of earthquakes and magnitude-distance pairs), nor justified the spectra used with regard to the uncertainties associated with the application of the Fundamental

Safety Rule (FSR) 2001-01 approach. In addition, EDF has not implemented a methodology to address the problem of site effects.

Nevertheless, although EDF's method appears to be perfectible, IRSN considered that the reassessment of spectra carried out as part of the VD3 1300 safety review is acceptable, with the exception of the spectrum for the Saint-Alban site, which will have to be revised.

Seismic reassessment of structures and equipment

The scope of the reassessment adopted by EDF, on the basis of the reassessed SMS, concerned the Backup Auxiliary Buildings and the Electrical Buildings (BAS/BL) and the machine rooms (under the seismic-event approach) at the Flamanville and Penly sites, to which some structures at these sites have recently been added but for which the studies have not yet been forwarded. The studies examined by IRSN did not call for any comment, apart from the fact that EDF has taken into account assumptions on the damping coefficient of certain structures which lead to an arbitrary reduction in seismic forces. In this respect, IRSN considers that it has not been demonstrated that the machine rooms will not attack buildings important to safety. In addition, the seismic reassessment of EDF's equipment is currently underway.

Feedback from the Kashiwasaki-Kariwa earthquake

Taking into account the earthquake that affected the Kashiwasaki-Kariwa nuclear power plant in Japan in 2007, EDF examined the effects and consequences for safety of a significant transformer fire and waves in the pools with regard to the hydrodynamic loads induced on structures and equipment. EDF's studies show that the facilities are correctly sized in terms of the lessons learned from this feedback. Details of the transformer fire are currently being examined.

"Extreme heat" standard

Taking into account external temperatures higher than those used in the design and the modifications envisaged by EDF in application of the "very hot" standard should help to significantly improve the resistance of 1300 MWe reactors to such situations. However, EDF will have to take into account all the requests made by the ASN with regard to this standard before it can decide whether the modifications planned by EDF as part of the VD3 1300 review are sufficient.

Frazil

In view of the measures put in place and the countermeasures planned by EDF on the sites most sensitive to this phenomenon, EDF's handling of frazil was found satisfactory. However, the justification for the lack of vulnerability of certain sites to this risk needs to be completed. Lastly, certain frazil protection provisions need to be improved.

Extreme winds and projectiles generated by these winds

EDF's studies on the "extreme winds" hazard, which cover both the direct and indirect effects of wind on safety-critical equipment located outside buildings and the equipment needed to manage a total loss of heat sink (H1) or external voltage failure (MDTE) situation, have led EDF to define several modifications aimed at providing better protection for certain equipment. IRSN considered that these modifications improve the safety of the installations with regard to these risks, but that several justifications still need to be provided concerning the classification and requirements associated with these provisions and the protection of other structures and equipment.

Tornadoes

The definition by EDF of a "tornado" baseline, an aggression that had not been considered until now, is a significant step forward but does not lead to an improvement in the level of reactor safety, since EDF has not assessed the consequences of a tornado on reactor safety, despite the ASN's request at the time of the VD3 1300 review. IRSN considers that EDF must define and implement any measures required to control the safety consequences of a tornado within a timeframe compatible with the VD3 1300.

Lowest safe water level (LSWL)

EDF's studies, which relate to the identification of phenomena likely to lead to so-called "LLW" situations and to the methods used to define them, and to verification of the correct operation of the pumps of the emergency raw water supply safety system (SEC) in such situations, do not fully meet the objectives set by ASN when directing the VD3 1300 review.

The aspects relating to the duration and kinetics of the "PBES" event were not taken into account, and the cumulative phenomena that could lead to the cold source level being too low were not systematically analysed.

Lastly, as EDF has not applied its new methodology to 1300 MWe reactors, no new provisions for protection against PBES have been defined, with the exception of a change announced for the Belleville site.

External flooding

IRSN considered that the "REX Blayais" methodology, which is the current reference for protection against external flooding, has been implemented satisfactorily at the 1300 MWe sites, supplemented by the points for improvement identified in 2007 when IRSN examined this methodology.

Oil slick drift

EDF has made significant progress in dealing with the risks associated with "hydrocarbons", particularly in understanding the impact of hydrocarbons on cold source equipment, thanks to all the studies and tests initiated as part of the VD3 900 review and continued for the VD3 1300 review. However, IRSN has identified that improvements are needed to guarantee adequate protection of vulnerable sites against this type of attack (seaside sites and the Saint-Alban site).

Unit and site autonomy with regard to common mode hazards

EDF still needed to revise or complete certain safety studies in order to demonstrate the adequacy of the provisions provided for in VD3 1300, necessary to control the consequences of a total loss of heat sink (H1) or external voltage failure (MDTE) situation and their accumulation (H1+MDTE) induced by an external event affecting an entire site.

Fire within the installations

On the basis of its studies, EDF has not identified any need for new fire risk provisions. However, EDF's demonstration of the absence of a common mode in the event of fire was found to need to be supplemented with regard to the effectiveness of safety fire zones and the effect of smoke for certain equipment. In addition, IRSN considered that EDF should identify the safety fire volumes in which a fire is likely to cause pressure variations that could impair fire segregation. Lastly, EDF is expected to provide additional information on premises for which the objective of a ten-minute margin between the significant duration of a fire in a room and the degree of fire resistance of the Minimum Means of Control (MMC) and Common Cabling Modes (MCC) protections has not been met.

Explosion inside the installations

With regard to the risk of explosion inside and outside the nuclear island, the modifications planned by EDF under the VD3 1300 safety review were found satisfactory. However, EDF still needed to provide several additional details to confirm that the planned provisions are adequate. In addition, several elements of the studies carried out by EDF (assumptions, analysis tools, etc.) needed to be better justified in order to assess their relevance to the situations analysed.

Internal flooding and high-energy pipe rupture (HEDR)

The studies conducted by EDF on this subject, which have not led to the identification of any necessary modifications, enable verification of the targeted safety level with regard to these risks, but a justification still needed to be provided concerning the taking into account of reactor shutdown states.

Control of industrial and aviation risks

EDF's approach to assessing the risks associated with the industrial environment and land and air transport routes as part of the VD3 1300 safety review is acceptable, although certain assumptions and methods still need to be completed. EDF's approach to assessing the risks associated with the internal transport of hazardous materials also needs to be completed.

Lastly, the need to carry out or not to carry out modifications, beyond those envisaged by EDF for certain sites with regard to the risk associated with the internal transport of hazardous materials, will have to be examined site by site after EDF has taken into account the expected additions.

Probabilistic safety assessments (PSA)

Level 1 PSAs - New complementary domain (NDC)

The review of the update of Level 1 PSAs associated with internal initiators, as well as the development of new PSAs dedicated to hazards (internal flooding and fire) and the risk to fuel stored in the deactivation pool, was presented to the Standing Group of Experts in May 2012.

The PSAs carried out by EDF for the VD3 1300 safety review highlighted the need for modifications to the facility to reduce the risks associated in particular with a fire occurring in the Controbloc premises, leading to the opening of a primary circuit protection valve, and with initiating events affecting the BK pool.

In addition, EDF has undertaken to study and implement, following the analyses carried out by IRSN during the appraisal:

- modifications aimed at reducing the risk associated with a rupture of the thermal barrier of the primary pumps, in order to significantly reduce the risk of core meltdown with containment bypass;
- design or operating improvements to reduce the risk associated with flooding in the electrical rooms at the Penly site.

The additional measures adopted by EDF under the NDC are satisfactory, but that other countermeasures should be adopted as additional measures.

Level 2 PSA

The level 2 PSA presented by EDF shows a significant reduction in the frequency of major releases, particularly in the event of a total loss of electrical power. In particular, this PSA highlights the relevance and the safety gains associated with the modifications relating to the pressuriser valves and the early order of closure of the containment isolation valves in the event of a loss of electrical power. Nevertheless, IRSN considered that EDF's level 2 PSA needs to be modified to reflect realistically the state of the installations, their operation and the risks of releases in the event of an accident, in accordance with ASN requests.

3.1.2 COMPLIANCE AND CONDITION OF INSTALLATIONS

Verification of the continued compliance of facilities is based on the following four inspection or study provisions.

Examination of unit compliance (ECOT)

IRSN's examination of the compliance inspection programme submitted by EDF focused on the scope and nature of the inspections designed to check the compliance of systems, structures, components and organisations with the standards in force. These checks, which are systematically carried out on each reactor or site, are intended to verify that the actual state of the installations complies with the reference state considered for conducting the studies. This programme of examinations, completed by EDF during the appraisal, is satisfactory.

Ten-yearly tests

EDF presented a methodology for identifying the specific tests to be carried out during the third ten-yearly outage programmes (known as "ten-yearly tests"). These tests and the analyses that lead to their definition help to demonstrate that the safety level is maintained by checking that, after 30 years of operation, following the integration of material and intellectual modifications and the performance of numerous maintenance activities, the reactors remain compliant with the applicable safety standards. With the exception of a few additional analyses to be carried out by EDF, IRSN considered in 2010 that the methodology implemented by EDF provided a satisfactory basis for its work. EDF indicated that the list and justification of the ten-yearly tests planned for VD3 1300 would be submitted in December 2014.

Complementary investigation programme (PIC)

As part of defence-in-depth, EDF has defined, as a continuation of the exercise carried out during the VD2 1300 review, a PIC aimed at confirming the assumptions made regarding the absence of degradations occurring during operation in areas not covered by maintenance programmes. The VD3 1300 PIC will therefore cover ten reactors, and the checks will concern the main primary circuit (CPP), the main secondary circuit (CSP), mechanical circuits and equipment other than the CPP and CSP, electrical equipment and instrumentation and control, and civil engineering. These inspections are carried out on the oldest reactors or those considered to be the most sensitive to the risk of deterioration. These inspections, carried out on a sample basis, did not call for any comment.

Dossiers d'aptitude à la poursuite d'exploitation (DAPE) (Continued operation suitability files)

EDF's demonstration of control of ageing of equipment and structures in 1300 MWe reactors up to their fourth ten-yearly outage programmes under satisfactory safety conditions, through the Ageing Analysis Files (FAV) and the resulting generic DAPEs drawn up using the same methodology as that implemented during the VD3 900 review, is satisfactory. However, some ageing mechanisms should lead to the opening of new FAVs, while some FAVs should be reclassified as "sensitive" or be better characterised, and that some maintenance checks and procedures should be completed.

3.1.3 MODERNISATION OF THE CONTROL ROOM - SOCIO-ORGANISATIONAL AND HUMAN ASPECTS

EDF has implemented an approach relating to the socio-organisational and human aspects (SOH) right from the start of the design project for the modifications associated with the renovation of the 1300 MWe control rooms, which is satisfactory from the methodological point of view.

On the other hand, the modification validation phase, as carried out by EDF during tests on a mock-up, remained partial for several reasons: limited number of modifications tested, lack of representativeness of the mock-up and scenarios. As a result, it does not constitute a real overall validation of the ability of the control teams to carry out their control actions in the best conditions for safety. Consequently, IRSN recommended that this partial validation should be supplemented by the implementation of feedback on the Paluel and Cattenom reactors at the head of the series during start-up tests and validation of the system as a whole, and over a significant period of operation before the refurbishment is extended to all the reactors in the series.

3.1.4 MATERIAL AND INTELLECTUAL MODIFICATIONS

IRSN's analysis focused on the material changes and changes to the General Operating Rules (GOR) declared by EDF for the P4 train in the 1300 MWe class, and in particular those resulting from the conclusions of this review.

Material modifications

Generally speaking, the material modifications declared by EDF (known as "batch A") do not call for any comment from IRSN in terms of their design, implementation and operating principles in terms of the risks of regression induced on safety, with the exception of the modification mentioned below. However, the demonstration of the absence of regression associated with certain modifications remains to be examined, in particular with regard to the numerous modifications associated with the renovation of the instrumentation and control system, which are highly interdependent, including at the interface with the business associated with the renovation of the control room. In this context, a particularly issue is the adequacy of requalification tests once they have been defined by EDF. Examination of the modification aimed at reducing the risks of containment bypass associated with direct releases of activity into the environment when the safety injection circuits (RIS) or containment spray circuits (EAS) operate in recirculation on the containment sumps led IRSN to make three recommendations.

In addition, IRSN recommended that the modification aimed at improving verification of the position of certain valves subject to administrative orders whose position is difficult to identify should be extended to other valves.

EDF's position on the need for modifications in the safety demonstration does not call for any comment on the part of IRSN, with the exception of modifications aimed at reducing the risks associated with severe accidents and for fuel stored in the deactivation pool.

Changes to Chapter III of the EGR - Technical Operating Specifications (TOS)

The changes to the ETS declared by EDF take into account the intellectual changes resulting from the safety review studies and the VD3 1300 "batch A" material changes declared by EDF.

Following its analysis, IRSN considered that the changes proposed by EDF, supplemented by the commitments made by EDF during the appraisal, are satisfactory. However, the IRSN's analysis highlighted the need for additional points to be added before the STEs for train P4 are applied in the VD3 1300 state. These points, which concern the countermeasures used in the PSAs and not adopted as additional provisions, the inclusion in the ETSs of severe accidents, the "very hot" reference for ventilation/air conditioning systems, the hazards leading to the loss of the cold source and the VD3 1300 modification "Limitation of releases from the PTR tank vent", are the subject of recommendations by IRSN.

Changes to Chapter VI of the EMO - Incidental/accidental rules of conduct

The changes to Chapter VI of the EMO declared by EDF, mainly resulting from consideration of the conclusions of the safety review studies, are acceptable.

Changes to Chapter IX of the EMO - Periodic tests

The changes to Chapter IX of the EGR declared by EDF take into account the intellectual changes resulting from the safety review studies and the VD3 1300 "batch A" material modifications declared by EDF.

Following its analysis, IRSN considers that the changes proposed by EDF, supplemented by the commitments made by EDF during the appraisal, are satisfactory. However, IRSN's analysis highlighted the need for additional information before Chapter IX of the EMOs for train P4 is applied to state VD3 1300. These additions, which are the subject of recommendations, relate in particular to the classification of periodic test criteria, ventilation and air-conditioning systems, the safety of fuel stored or handled in the BK, aggressive equipment and provisions (AED) in connection with the application of the "very hot" standard, external flooding and the VD3 1300 modification aimed at improving the reliability of pressuriser valve opening.

Changes to Chapter X of the RGE - Core physical tests

There were no comments on the changes to chapter X of the EGR, resulting from the material modifications "Renovation of the reactor protection system (RPR)" and "Renovation of the nuclear power measurement system (RPN)".

3.2 PSR4 of 900 MWe reactors

3.2.1 Safety objectives

The lifetime extension of French reactors has been subject, in a context where the evolution of the role of nuclear power in electric supply was politically challenged, the standardized nature of the reactors fleet allows for considering this lifetime extension as a global programme, and rules about participative democracy require that such a programme is discussed as long as it bears environmental impacts, to a series of voluntary or compulsory consultations, from stakeholder technical dialogue to broader public debate, for almost a decade.

This process showed some deficiencies regarding its scope, timing and outcome[13]. In particular, the strategy defined through energy planning introduced decisions on nuclear supply over time that implicitly required a lifetime extension of some reactors before the corresponding technical and safety require-

13. Marignac, Y., Besnard, M., *Processus de 4ème réexamen périodique de sûreté des réacteurs de 900 MWe d'EDF - État des lieux et principaux enjeux*. WISE-Paris (France), 31 March 2019. See http://bit.ly/penf0021

ments were even set. Also, the lifetime extension programme was never submitted, as such, to a compulsory public concertation that would address both its opportunity and terms of implementation. Moreover, while a 2015 law introduced the sound principle of a public enquiry on the proposals filed by the operator for the PSR4 of each reactor prior to ASN decision on its continued operation[14], this only takes place in practice once the PSR is completed and modifications and controls implemented, which deprives the procedure of its substance. The whole process has nevertheless allowed for a continuous discussion, over ten years, on the objectives and conditions of the life extension that felt legitimate and brought some changes.

One major outcome is that the process has confirmed the principle of raising requirements to come closer to the safety requirements applied to new reactors, in the context of coinciding or planned construction. This is what led EDF, in the global response to proposed objectives that it filed in 2018 to feed the informal consultation on the generic part of the lifetime extension process, to state that its "general approach was to aim for the nuclear safety objectives set for 3rd generation reactors, of which the EDF reference reactor is the EPR-Flamanville 3"[15].

The licensing basis of Flamanville-3, as stated in its April 2007 licensing decree, introduces some very specific requirements: the reactor "must be designed, built and operated in such a way as to prevent the occurrence of (...) core meltdown accidents that could lead to significant early radioactive discharges", and so that "in the event of a low-pressure core meltdown accident, only very limited measures to protect the population in terms of scope and duration would be needed"[16].

The decree also states, regarding the reactor building, that "any leakage from the inner wall of the containment is collected and filtered before release into the environment" (the EPR design includes a double concrete containment wall) and the containment must be "designed and built in such a way as to ensure that it is leaktight: - without requiring the short-term evacuation of residual power from the containment, even after a core meltdown accident; - in the event of an overall deflagration of the maximum quantity of hydrogen that could be contained in the containment during a low-pressure core meltdown accident". Finally, regarding the fuel building, it must have: "- ventilation systems to ensure dynamic containment under normal operating conditions and in the event of an accident involving the handling of a fuel assembly; - a device to de-

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14. Loi n° 2015-992 du 17 août 2015 relative à la transition énergétique pour la croissance verte, *Journal officiel*, 18 août 2015. See http://bit.ly/penf0092

15. EDF, *4e réexamen périodique des centrales 900 MWe - Synthèse de la note de réponse aux objectifs*, October 2018 – translation by Institut négaWatt. See http://bit.ly/penf0126

16. Décret n° 2007-534 du 10 avril 2007 autorisant la création de l'installation nucléaire de base dénommée Flamanville 3,comportant un réacteur nucléaire de type EPR, sur le site de Flamanville (Manche), *Journal officiel*, 11 April 2007 – translation by Institut négaWatt. See http://bit.ly/penf0127

tect leaks resulting from a possible loss of watertightness of the rack pool casing. This building is also designed to collect any leaks from the rack pool and the pipes connected to the pool".

These requirements, among others, are more demanding, and in a much more precise way, than those in place for the existing 900 MWe reactors, as introduced in their licensing decrees in the years 1972 to 1982[17]. Although the regulatory process would not go so far as to modify these initial decrees to reflect changes – which was criticized as a clear juridical weakness[18] –, the principle of "aiming for" the EPR requirements was taken into account through an explicit reinforcement of the objectives set for the reactors over their lifetime extension.

This leads to an explicit revaluation of some detailed safety objectives, as follows:

- regarding reactor accidents without core meltdown, the objectives are, obviously, to comply with the safety criteria for accident studies in the safety report, but also to aim for levels of radiological consequences that do not require the implementation of measures to protect the population (under French regulation, this corresponds to thresholds of an effective dose of 10 mSv for sheltering and 50 mSv for evacuation, and an equivalent dose to thyroid of 50 mSv for the administration of stable iodine);
- regarding the protection of the reactor against external aggressions, the objectives are to ensure that the facilities are robust enough to withstand the levels of stress as reassessed during the periodic review, and to aim for a core meltdown risk related to aggressions of a few 10^{-5} at most per year of reactor operation for all initiators;
- furthermore, the objectives applying to core meltdown accidents are to make the risk of early and large radioactive releases extremely unlikely, and to avoid lasting effects in the environment;
- finally, regarding the fuel pool, the objective is to make the uncovering of fuel assemblies during accidental draining and loss of cooling extremely unlikely.

The modifications involved in the PSR4, as implemented or planned by EDF, are both inspired by this revaluation and used to assess the expected progress. For instance, even though the scope of internal and external events has been both broadened and hardened in the review process, EDF claims that "probabilistic safety studies, including hazards, have concluded that [concerned] reactors are robust, with an acceptable core meltdown risk of between 4 and 6 10^{-5}/reactor-

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17. See for instance Décret n° 76-594 du 2 juillet 1976 autorisant la création par Électricité de France de quatre tranches de la centrale nucléaire du Tricastin dans le département de la Drôme, *Journal officiel*, 4 July 1976. See http://bit.ly/penf0128
18. Marignac, Y., Besnard, M., 31 March 2019, *op. cit.*

year", in line with the objective above[19]. Moreover, regarding severe core meltdown accidents of the reactor, EDF's deterministic calculations conclude that, for populations, effective doses over 7 days are divided by 20 and doses to thyroid over 7 days are divided by 30 to 50, while lifetime effective doses are divided by 3 to 4. According to EDF, this shows that "there is no need to impose countermeasures beyond 5 km for evacuation and 10 km for the intake of stable iodine".

3.2.2 Safety improvements

The safety improvements valued in the PSR4 of the French 900 MWe reactors cover a large range of reinforced and new safety features, which mostly relate to two areas of concern: (i) a series of rather minor modifications arising from the reassessment of internal and external hazards considered in the design basis, (ii) the so-called "hardened safety core", which mainly consists, through reinforcing the power supply and the cold source against extreme aggressions, and introducing complementary features to mitigate the most severe accident conditions, to enhance the robustness in well beyond design basis situations.

The first set of significant modifications covers a series of issues related to aggressions within design basis, the scope and level of which have been extended, while the robustness requirements of the defense against have been reinforced. The scope of aggressions includes internal hazards (fire, explosion, flooding, failure of pressurized equipment, collisions and falling loads, electromagnetic interference, emissions of hazardous substances) and external ones (earthquake, extreme weather conditions, electromagnetic interference, large fire, accidental plane crash and nearby industrial hazards). The analysis particularly focused on the prevention and control of internal fires, of floodings, and the reassessment of extreme weather conditions in the face of projected climate change.

EDF extended the status of so-called "equipment important for safety", or EIPS (équipements importants pour la sûreté), which are subject to stronger monitoring requirements against failure, to the equipment necessary to the protection against aggressions. It also run sensitivity studies, including the introduction of aggravating events, and changes in the criteria of maximum delay before the intervention of operators. The studies led to modifications that mostly relate e.g. to reinforcing protections against internal and external flooding, seismic protection of fire doors, and improving the ventilation of electrical rooms.

The second, much more significant area of material improvements lies in the concept of noyau dur (ND), or hardened safety core that emerged as a result of post-Fukushima complementary safety assessments. It consists in a series of

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[19]. EDF, *Note de réponse aux objectifs du quatrième réexamen périodique du palier 900 MWe*, Note d'étude, distributed 5 September 2018 – translation by Institut négaWatt. See http://bit.ly/penf0129

material and organisational safety features meant to withstand hazards of a level significantly higher than that considered in the design basis.

These ND features primarily target the reinforcement of the cooling system through:

- a reinforced emergency feedwater circuit for steam generators (ASG-ND);
- a reinforced, or ultimate cooling system to evacuate residual heat from the reactor building without opening the filtered containment vent (EAS-U), including a dedicated pump and completed by a mobile ultimate cold source (SF-U).
- This secondary cooling system is completed by some features which aim at preventing any possible bypass of the containment of the reactor building:
- an extension of the 3rd containment barrier through dedicated provisions to isolate the reactor building and monitor possible leaks of the EAS-U system;
- the prevention of the risk to lose integrity of the containment wall due to an hydrogen explosion in a core meltdown accident, thanks to passive autocatalytic recombiners in the reactor building;
- a so-called "corium stabiliser", which consists in a system that would, in the case of a meltdown leading to a corium leak from the pressure vessel, allow for the corium to spread before it is cooled through passive reflooding, so as to prevent an abrasive drilling through the concrete slab of the building.

This corium stabiliser is an important innovation that derives from the core catcher concept that was introduced in the design of the EPR reactor. However, the concept had to be adapted to existing reactors, as it relies on a dedicated area below the vessel, covered with a layer of a material more resistant to corium abrasion than the slab concrete, and equipped with a specific cooling system – all of which could not be directly implemented in 900 MWe reactors. The concept of the corium stabiliser therefore lies in the implementation of "fuses" at the bottom of the vessel pit: first, a less robust plug in the concrete will, when touched by the corium, let open a way through to an adjacent, dry room where it could spread; then, a trigger would let the water accumulated at the bottom of the building flood onto the spread corium and cool it. This adaptation means that instead of preventing any abrasion of the slab, as the EPR core catcher is aiming for, the role of the corium stabiliser is to reduce the corium concrete interaction down to a level which prevents the corium to drill through the slab.

Altogether, this innovation comes with a lot of uncertainties regarding the behaviour of the corium, the timeline of events in the case of a real accident compared to the projected steps (with a specific concern for the conditions of water and corium interaction), and the pace and depth of the remaining abrasion. While modelling capacities can shed some light on those issues, a lot of aspects are still discussed, including the role of concrete composition in the speed and depth of abrasion, which leads to considering the possible need to thicken the spreading zone of the slabs based on the most siliceous concretes with a silicocalcareous concrete less prone to this abrasion[20]. It is nevertheless considered a very significant contributor to bringing the safety objectives of 900 MWe reactors beyond the PSR4 close to that of evolutionary reactors such as the EPR.

The concept of noyau dur also applies to the reinforcement against the risk of accident arising from the dewatering of the fuel, both in the deactivation pool and during loading and unloading of the core in the reactor building. It is by comparison much less pushed than the mitigation of core meltdown accidents, and mostly consists in the following:

- an ultimate water supply to the deactivation pool and its steam outlet, that is connected to the discharge line of the fuel pool cooling circuit (PTR circuit). The deactivation pool provides in turn an ultimate water supply to the reactor's building pool in reloading situations, by gravity feed through the transfer tube kept open;
- the implementation of a robust level instrumentation of both pools, allowing to adjust the water feed, and of a mobile borication unit to counter the risk of a return to criticality;
- reinforced measures to prevent a breach in the transfer tube as well as draining via circuits connected to the pools (automatic isolation of some lines, siphon breaks, etc.).

This set of modifications, although it is considered by EDF, IRSN and ASN likely to "practically eliminate" the risk of a large-scale dewatering of the fuel in pools, is still falling short from providing the same level of defence in depth that the EPR in Flamanville is supposed to bring – with its more redundant and robust water supply system and its large, commercial airplane proof containment wall of the fuel building.

To be consistent with the objective of providing key safety functions against severe accidents conditions in extreme situations, the concept of noyau dur also comes with hardened equipment to guarantee power and water supply:

- the so-called Diesel d'ultime secours (DUS), or ultimate diesel-powered generator, a 3 MWe generator set in a new, reinforced building and equipped to deliver power supply to the equipments of the reactor that need it in ND conditions, with a fuel autonomy of 3 days at full load;
- a dedicated electric transmission and distribution system, which is able to supply both the new ND equipment and the existing SSC equipment that are needed in ND conditions;
- a specific control and command system, articulated with the existing one but designed to operate the ND equipment in ND conditions;
- an ultimate water source, meant to supply both the ASG-ND and the spent fuel deactivation pool in ND conditions, comprising of a source of water either from a groundwater catchment or from a storage, possibly equipped

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[20]. See for instance a critical review of that discussion in Laponche, B. *Quatrième visite décennale des réacteurs de 900 MW – Le récupérateur de corium*, Global Chance, 8 September 2019. See http://bit.ly/penf0131

with a pumping device, and a power supply and filtration system if needed (with power supplied via the DUS), with a complete autonomy of 3 days;
- robust water piping and electric grid systems to carry electrical power supply and water to the ND equipments.

The last of specific ND new features is the implementation of a local crisis centre (LCC), meant to enable the plant operator to manage a major crisis over the long term (up to 15 days), ensuring sufficient accessibility, autonomy and habitability, resistance to external hazards of the ND level, and protection against radioactive and chemical risks (including contamination and irradiation that could result from a total core meltdown accident in one unit).

Finally, all the above equipment and SSC, as part of the ND system, are required to be designed to withstand so-called "extreme" external events that go well beyond those considered in the basic design. This includes extreme earthquake, flooding or tornado situations, in particular:
- regarding earthquakes, the seismic spectrum response considered must be 50% higher than the highest one considered for basic design (which itself includes a margin compared to the maximum historically plausible), and higher than the maximum probable site specific one in 20 000 years;
- regarding external flooding, protections are enhanced to cover for a fixed increase in assumed flooding levels, such as a 30% increase compared to millennial maximums, or a consequence of the breach of dikes or dams that could result from a ND level earthquake.

3.2.3 Security issues

There is a lot of discussion and controversy about possible security failures. A report coordinated by Greenpeace and filed to authorities under confidentiality[21], apart from a public summary, shows that reactors, and especially spent fuel pool buildings, are vulnerable to terrestrial or aerial attacks that could likely not be prevented and would likely lead to failure of safety features.

3.2.4 Conformity and uncertainties

There was some heavy maintenance included, such as the replacement of SGs (that was mostly included by the PSR3), but other diffuse conformity and maintenance issues not very well dealt with. A lot of issues arose about the conformity of heavy equipment (forging of components such as SGs), and the quality of conformity through surveys and maintenance of cables, anchors, electric equipment.

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21. Becker, O., Besnard, M., Boilley, D., Lyman, E., MacKerron, G., Marignac, Y., Zerbib, J.-C., *La sécurité des réacteurs nucléaires et des piscines d'entreposage du combustible en France et en Belgique, et les mesures de renforcement associées* – Résumé du rapport. Coord. WISE-Paris (France) 2017 - https://bit.ly/penf0132

Experience shows that evolution of equipment, through aging, and an increasing challenge with conformity lead to an increasing risk of undetected failures of equipment and systems, or at least discrepancies with conditions considered in safety assessment (cf. the example of stress corrosion, that remained undetected for many years – although it's not about 900 MWe reactors). Safety margins decrease and uncertainties increase.

3.2.5 Implementation gaps and delays

The completion of reinforcements and controls and related maintenance within the projected and agreed schedule might increasingly be challenged. Experience shows that this could really become an issue. We've witnessed growing delays and a non-respect by EDF by the deadlines it had committed too[22]. Recently, EDF said the workload of the PSR4 is for each 900 MWe unit about 5 times bigger than that of the PSR3.

At some point, EDF filed a request about the work planned at each reactor to implement conformity and reinforcement that is required for PSR4, asking ASN to agree for part of the work to be postponed by a few years – it eventually turn into a breaking in two or even three parts, with some work planned 4 and 5 years after the PSR. ASN agreed to this, arguing first that it was regulatory possible since it was not explicitly ruled out, and that this was about being pragmatic regarding the realistic capacity of EDF to implement the work. This is absolutely contrary to the key principle that "the operator is the first responsible of safety", of which derives that it must at any time show and justify technical, industrial and financial capacities that match safety requirements – and not that safety requirements should adjust in any way to these capacities… One consequence is that it will take up to 2035 before the reinforcements that were decided as an outcome of post-Fukushima studies are completely implemented, when it was foreseen that this would take a decade at most and promised that this would be part of the post-40 years life extension[23].

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22. Marignac, Y., Besnard, M. *Respect des prescriptions et des exigences de sûreté par EDF : retour d'expérience sur les risques de dérive et de dérogation*. WISE-Paris (France) 2019 - http://bit.ly/penf0020

23. Marignac, Y., Besnard, M. *Les mesures de renforcement du parc nucléaire français, dix ans après Fukushima*. Institut négaWatt (France) 2021 - https://bit.ly/penf0055

4 MAIN ISSUES RELATED TO PSR4 FOR 1300 MWE REACTORS

In 2016, EDF began the generic phase of the PSR4 of its twenty 1300 MWe nuclear reactors, and in July 2017 sent the ASN its "periodic review orientation file".

In accordance with article L. 593-18 of the Environment Code, the periodic review must enable the compliance of a facility with the rules applicable to it to be verified and the risks and drawbacks it presents for the interests mentioned in article L. 593-1 of the same code, i.e. public safety, health and hygiene and the protection of nature and the environment, taking into account in particular the state of the facility, experience acquired during operation, developments in knowledge and the rules applicable to similar facilities.

Pursuant to Article L. 593-19 of the Environment Code, EDF must submit a report to the ASN and the Minister responsible for nuclear safety, presenting the conclusions of the periodic review for each of its 1300 MWe reactors. In particular, this report will include the measures it plans to take to remedy any anomalies identified or to improve the protection of interests. For reactor no. 1 at Cattenom nuclear power plant and reactors nos. 1 and 2 at Paluel nuclear power plant, which will be the first to be subject to this PSR4 requirement, the report must be submitted by 26 October 2027 at the latest.

As with previous periodic reviews, in order to take advantage of the standardised nature of its reactors, EDF plans to carry out this periodic review in two stages:

- a so-called "generic" periodic review phase, covering subjects common to all 1300 MWe reactors. This generic approach makes it possible to pool studies on the control of ageing, obsolescence and compliance of the installation, as well as studies on the reassessment and design of any modifications to the installations;
- a "specific" periodic review phase, covering each reactor individually, between 2027 and 2035. This phase enables the specific characteristics of the facility and its environment to be taken into account, such as the level of natural hazards to be considered and the condition of the facility.

The so-called "generic" periodic review phase begins with the definition of the objectives assigned to this periodic review. To this end, EDF has submitted a "periodic review orientation file", which sets out its objectives and is the subject of this report.

This first orientation stage provides a framework for the work of the generic phase of the periodic review, during which EDF will define the installation inspections to be carried out, the measures to be taken to remedy the anomalies found, and those to improve the protection of the interests mentioned in Article L. 593-1 of the Environment Code. At the end of this generic phase, the ASN will take a position on whether the objectives of the periodic review have been achieved and may ask for the planned provisions to be supplemented.

The periodic review obligation will be deemed to have been met for each reactor, in accordance with article R. 593-62 of the Environment Code, when EDF has submitted the report concluding its specific periodic review. After the public enquiry provided for in article L. 593-19 of the Environment Code and analysis of the report concluding the periodic review of each reactor, the ASN will, if necessary, impose the additional technical requirements it considers necessary to govern the continued operation of this reactor.

Specific context of the PSR4 of 1300 MWe reactors

The PSR4 of 1300 MWe reactors are taking place in a special context:

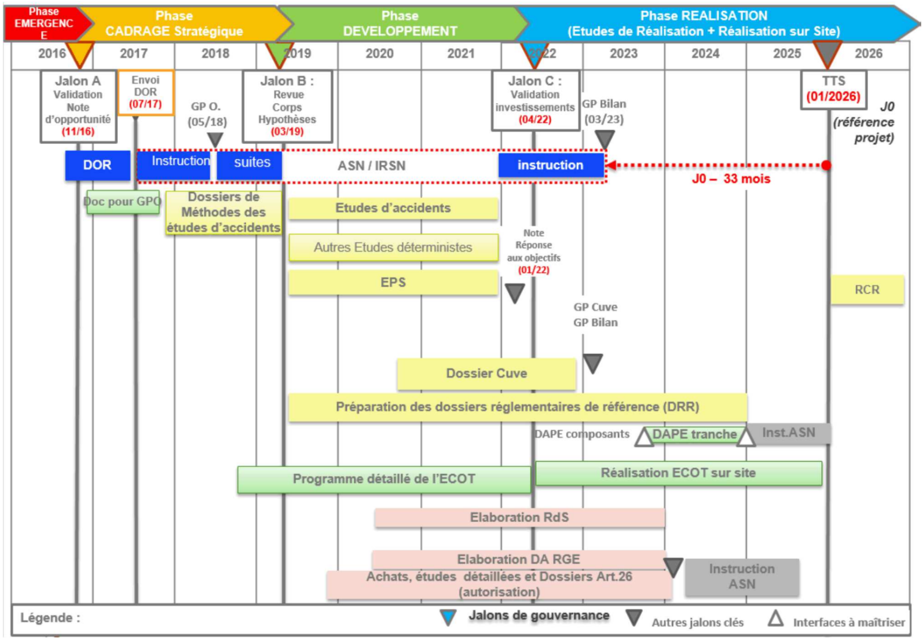
- the initial assumption taken into account for the design of certain reactor equipment was for forty years of operation. Extending operation beyond this period requires design studies to be updated or equipment to be replaced;
- the PSR4 is an opportunity to complete the integration of modifications resulting from ASN requirements issued following the additional safety studies carried out following the accident at the Fukushima Daiichi nuclear power plant;
- in 2009, EDF stated that it wished to "extend the operating life significantly beyond forty years and keep open the option of a 60-year operating life for all reactors". In this scenario, the 1300 MWe reactors could coexist in the long term with third-generation reactors, of the EPR type or equivalent, whose design meets significantly enhanced safety requirements. Their safety must therefore be reassessed in the light of these new safety requirements, the state of the art in nuclear technologies and the operating life targeted by EDF. The safety objectives to be adopted for the PSR4 of 1300 MWe reactors must therefore be defined in the light of the objectives applicable to new generation reactors. The ASN specified its requests and expectations in this respect in its letter of 28 June 2013. This approach is considered to be consistent with Council Directive 2014/87/Euratom of 8 July 2014. Similarly, the objectives to be assigned to this fourth review must take into account those adopted for the PSR4 of 900 MWe reactors.

In terms of the general context, EDF also plans to be able to use assemblies based on enriched natural uranium or enriched reprocessed uranium. In addition, although this is not explicitly mentioned in its orientation file, EDF has told ASN that it is studying the possibility of introducing so-called "MOX" fuels based on mixed uranium and plutonium oxide.

EDF plans to carry out its review in three phases:

- an orientation phase, which began at the end of 2016;
- a phase for carrying out the studies and inspections for the review, which runs from March 2019 to March 2023;
- a summary and conclusion phase, corresponding to the submission of each review conclusion report.

Timeline of preparatory works for the VD4 of the 1300 MW fleet



Source: *EdF: DOSSIER D'ORIENTATION DU RÉEXAMEN PÉRIODIQUE VD4 1300 page 9/68*

umweltbundesamt

4.1 General objectives of the PSR4

The general objectives of the periodic review concern: (a) compliance of installations; (b) reassessment of the safety of the installations; (c) reassessment of the inconveniences generated by the installations; (d) control of operating activities in terms of organisational and human factors. The present analysis focuses on the two first issues.

Compliance of installations

In its guidance document, EDF states that "in accordance with the regulations, the primary objective of the review is to verify that the installations comply with the safety requirements applicable at the start of the review". The inspections described in the guidance document correspond to those usually carried out by EDF as part of previous reviews. EDF thus plans to carry out checks in various contexts, such as unit compliance examinations, ageing control, additional investigation programmes, design reviews and qualification maintenance.

EDF also states that, as regards the scope of the unit conformity examination (ECOT), it "will also incorporate the feedback from the investigation of the VD2 N4 and VD4 900 ECOTs, with checks being extended to all EIPs and the analysis of compliance deviations being taken into account as input data".

These checks are likely to lead to the identification of discrepancies. In its guidance document, EDF provides for the following management of compliance deviations:

- compliance deviations known at the time of transmission of the guidance document in July 2017 "will be dealt with before the deadline for the [fourth ten-yearly inspection]";
- reports will be submitted annually [to enable] follow-up of any new deviations that may be detected and should be dealt with as part of the fourth safety review [of 1300 MWe reactors]";
- compliance deviations detected during the unit compliance review process will be "corrected at best before restart following the ten-yearly outage and at the latest within the time limit assessed according to the harmfulness of the deviation".

With regard to anomalies, EDF states that "at present, only one anomaly is scheduled to be rectified in the PSR4 of the 1300 series (absence of reactivity monitoring in certain transients in the complementary area)".

ASN considered that checking that installations comply with the rules applicable to them is a fundamental requirement for guaranteeing the safety of installations and enabling them to continue operating. This verification of compliance must be carried out on a permanent basis at the installations. It also benefits from an in-depth examination (review of maintenance programmes, programme of additional investigations, design reviews, specific tests, etc.) carried out by EDF during periodic reviews.

The ASN has told EDF, in general terms for continued operation beyond the PSR4 and specifically for the PSR4 of 900 MWe reactors that it "expects [EDF] to make significantly enhanced proposals regarding the scope of the compliance review of each reactor in operation. The checks that [EDF will propose], in particular [in situ] inspections, should cover all the requirements defined for items important for protection (EIP)". In this regard, the ASN has issued requests for design reviews, overall tests and additional in situ checks for the PSR4 of 900 MWe reactors.

Feedback from the operation of EDF's reactors confirms that the checks carried out during the previous periodic reviews were not sufficient to identify certain deviations likely to jeopardise the protection of the interests referred to in Article L. 593-1 of the Environment Code. Deviations, some of which are very serious and have existed for several years or even since the reactors were built, are regularly detected.

Generally speaking, the compliance of facilities is an essential prerequisite for a safety reassessment. ASN therefore considers that the conformity of installations should be the primary objective of periodic reviews and that, in this respect, EDF's proposal is inadequate.

According to ASN, the compliance verification programme submitted by EDF should be supplemented for 1300 MWe reactors, in order to achieve the objective that had been assigned to EDF for 900 MWe reactors. With regard to the control of ageing and obsolescence, ASN considers that EDF will have to incorporate into this review the ASN requests that will be made following the meetings of the Standing Groups held in 2018 on these subjects.

Moreover, deviations that have an impact on the protection of the interests mentioned in L. 593-1 of the Environment Code and that have been identified before the start of each ten-yearly inspection should be corrected as soon as possible and no later than the fourth ten-yearly inspection of each 1300 MWe reactor. Deviations detected during the said ten-yearly outage must be corrected as soon as possible, taking into account their importance for the protection of the interests mentioned in L. 593-1 of the Environment Code.

Finally, ASN considered that a more ambitious scope for rectifying deviations than just the so-called "compliance" deviations defined in ASN guide no. 21 should be adopted, and that this scope should cover all deviations within the meaning of the order in reference.

Finally, ASN considered that any anomalies in the safety demonstration studies likely to lead to non-compliance with the safety criteria should be rectified as soon as possible and before the submission of the report concluding the periodic review of each reactor. This corrective action will take into account the design rules and safety demonstration criteria corresponding to the situations under consideration. In the event of late detection of such anomalies, which cannot be rectified before the submission of the review conclusion report, ASN considers that the operator should identify in this report the measures it has taken or plans to take to ensure compliance with the safety criteria with application of the study rules for the situation concerned.

Reassessment of the safety of the installations

In its guidance document, EDF states that "As part of the process of continuous improvement of the safety from which the nuclear fleet has benefited since its commissioning, EDF has chosen as the general safety guideline [for the fourth review of the 1300 [MWe] reactors] to move towards the safety objectives set for 3rd generation reactors, of which the EDF reference reactor is the EPR-Flamanville-3". This ambition is reflected in the following safety objectives:

- for "design basis" accidents, [...] radiological consequences below the threshold for implementing measures to protect the population (iodine tablets, sheltering, evacuation)";
- for internal and external hazards to be taken into account in the design basis: to bring the reactor back to a safe state and maintain it there for hazard levels reassessed during the review and to include hazards in the overall core meltdown risk assessment (target tending towards that of new reactors)"; "for core meltdown accidents to be taken into account in the design basis: to bring the reactor back to a safe state and maintain it there for hazard levels reassessed during the review and to include hazards in the overall core meltdown risk assessment (target tending towards that of new reactors)";

- for core meltdown accidents: to aim for population protection measures limited in space and time. This objective is reflected in the reduction of significant releases that would lead to lasting effects in the environment, including following natural hazards, in particular by avoiding depressurisation of the containment towards the atmosphere and, in the event of a vessel breakthrough, by stabilising the corium on the reactor building floor;
- for accident situations associated with the spent fuel storage pool: make the risk of uncovering the assemblies stored in the pool residual".

During this periodic review, EDF also plans to finalise the integration of all the hardened core provisions prescribed by the ASN.

In addition, EDF states that the definition of the guidelines "is conducted in a manner consistent with the guidelines of the PSR4 900 (taking into account the results of the GP Orientations)", and that, in general, for each of the review topics, the results of the review investigation will be incorporated.

Lastly, EDF states that "the selection of the modifications envisaged will be informed by an approach that enables the safety issues to be weighed, using a codified approach to prioritise them".

ASN noted that EDF is planning to change the nature of the fuel assemblies admitted to its 1300 MWe reactors (enriched reprocessed uranium, or even MOX-type assemblies), and that these changes could have an impact on the safety of its installations.

First of all, it therefore pointed out that the safety objectives applicable to periodic reviews must be independent of the nature of the assemblies introduced into the reactor.

The objectives adopted by EDF are the same as those adopted for the PSR4 of 900 MWe reactors. Generally speaking, in view of the fact that, since the guidelines for the PSR4 of 900 MWe reactors, there have been no notable events leading to changes in risk assessment, nor any major changes in knowledge, ASN considers that EDF's objectives are acceptable in principle. However, it considers that they need to be supplemented.

According to ASN, the requests made in its letter on the continued operation of reactors and its letter on the guidelines for the PSR4 of 900 MWe reactors should apply to the PSR4 of 1300 MWe reactors. In particular, ASN points out to the need:

- to look for measures to limit the radiological consequences of all design basis accidents, accidents in the complementary field and accidents related to hazards";
- to seek high-impact measures in terms of preventing severe accidents and limiting their consequences", with particular emphasis on managing severe accidents without opening the containment decompression and filtration system;

- to seek new technical solutions to improve the safety of on-site spent fuel storage in deactivation pools".

Prevention of incidents and accidents

Generally speaking, ASN considers that, with regard to defence in depth, EDF should explicitly include in its objectives the search for measures to improve the prevention of incidents and accidents, in particular by reassessing the control of its operating activities and by looking for measures with a high impact in terms of preventing serious accidents.

In response to this position, EDF proposed instead to "seek the necessary provisions to achieve the objectives of the periodic review, covering the relevant defence in depth levels, including the prevention level". ASN considers that this proposal by EDF does not meet the expectations expressed above and therefore maintains its initial wording.

Limiting the radiological consequences of accidents

In addition, in line with the requests made as part of the investigation completed in 2013 on the continued operation of the reactors, ASN considered that EDF should supplement its objectives to include an objective relating to the limitation, as far as reasonably possible, of the radiological consequences in the short, medium and long term, for all the accidents studied in the safety report. Therefore, ASN considers it necessary to examine the measures that can be implemented to limit the consequences in the short, medium and long term, by including an objective of reducing the radiological consequences for all operating conditions (design basis and complementary scope, including those resulting from internal or external hazards).

In response to this position, EDF proposed to restrict the provisions to be examined in this context to those that could be implemented under economically acceptable conditions, with reference to an order, that states that "the operator shall ensure that the provisions adopted [...] make it possible to achieve, taking into account the state of knowledge, practices and vulnerability of the environment, a level of risks and inconveniences mentioned in Article L. 593-1 of the Environmental Code that is as low as possible under economically acceptable conditions". ASN points out that a reference to "an objective relating to the limitation of radiological consequences as far as reasonably possible" has been included.

Provisions planned with regard to hazards

With regard to hazards, EDF plans to verify its ability to "restore and maintain the reactor in a safe state for reassessed hazard levels". In general terms, EDF proposes to "compare sensitivity studies to the 2014 WENRA international reference levels according to EDF's positioning with regard to the WENRA 'reference levels' for existing reactors" and plans to justify "the performance of its facilities with regard to the hazard level corresponding to the occurrence of 10^{-4}/year/reactor, for natural external hazards for which the data required for this assessment are available and meaningful".

In accordance with the "T4" and "T6" reference levels of WENRA, ASN considers that, as part of the deterministic demonstration expected with regard to natural hazards, the following should be included as an objective of the periodic review verification of the absence of cliff effect for natural hazards corresponding to a target value of annual frequency of exceedance of less than 10^{-4}/year, or, where it is not possible to calculate the probabilities associated with hazards of natural origin with an acceptable degree of confidence, for events selected and justified with an equivalent objective.

EDF has objected to this objective. In response, ASN stresses the generic and structuring nature of this requirement for all climatic hazards, and therefore maintains his position.

With regard to the performance of probabilistic safety studies associated with hazards, ASN considers that this represents a step forward in terms of safety, insofar as such studies provide additional information to the deterministic approach adopted hitherto. However, ASN does not consider it appropriate to "include hazards in the assessment of the overall risk of core meltdown (a target tending towards that of new reactors)". In fact, a direct comparison of the probability of core meltdown or of fuel assemblies being uncovered in the pool associated, on the one hand, with hazards and, on the other hand, with equipment malfunctions (usually referred to as "internal events"), seems unfounded insofar as the methods used to calculate these probabilities do not take comparable phenomena into account (equipment failure probabilities based on experience feedback, assessment of the severity of certain hazards based on observations followed by modelling to define more severe hazards, modelling of certain physical phenomena associated with the effects of a fire, etc.).

On the other hand, the probabilistic assessments associated with a given type of event are useful for defining possible improvements to the installation, enabling the risks relating to this event to be reduced. ASN therefore considers it necessary to identify, on the basis of probabilistic studies associated with hazards and where relevant, provisions aimed at reducing the risk of core meltdown or of fuel assemblies being uncovered in the deactivation pool.

Provisions for the safety of fuel pool storage

With regard to the fuel assembly storage pool, the safety objective adopted by EDF in its accident studies is the absence of fuel assembly uncovering. EDF does not associate this objective with a requirement for the pool not to boil. For example, in the event of a loss of cooling, the safe state (no uncovering of assemblies) is achieved by injecting water to compensate for evaporation due to boiling. In such situations, the environmental conditions in the building make intervention difficult. However, as part of the PSR4 of 1300 MWe reactors, EDF plans to deploy a system (known as "PTR bis"), based in part on mobile equipment, which will eventually ensure cooling of the pool and therefore a boil-free situation. Consequently, ASN considers that, in accident situations, including those caused by hazards, the objective of not uncovering the fuel assemblies handled or stored should be supplemented by the objective of eventually returning the installation to a safe state and maintaining it there for the long term, corresponding to a situation where the water in the pool does not boil.

In response to this position, EDF has proposed that "the possibility of putting in place provisions to ensure that the fuel deactivation pool does not boil over in the long term" be studied. ASN considers that this point deserves to be an objective and maintains its wording.

Provisions planned for major release situations

In the same way as for 900 MWe reactors, the periodic review must make it possible to check that the planned provisions meet the requirements of Article 3.9 of the Order for scenarios leading to major releases whose kinetics do not allow the necessary actions to protect the population to be implemented in time. ASN considers that, as part of this periodic review, EDF should specify the situations that fall within the scope of this article and the measures implemented to deal with them. In this respect, it is particularly important to describe the measures planned for situations involving the discovery of irradiated fuel assemblies stored under water or being handled.

Accidents leading to significant but delayed releases are likely to have significant consequences for the environment and people. ASN considers that, for these situations, the operator must give priority to a defence in depth approach and that measures must therefore be sought by the operator to limit their consequences, in addition to measures to prevent them.

As part of the PSR4 of 900 MWe reactors, the ASN made targeted requests to EDF along these lines (examination of the value of geotechnical enclosures in the event of a breakthrough in the raft and improvements to the so-called "U5" filter). ASN considers that this search for provisions should be extended to all situations likely to lead to significant deferred releases and that the objectives of the review should be supplemented so that they explicitly include an objective aimed at making significant deferred release situations extremely unlikely and also identify provisions to limit the consequences of such accidents.

In response to this position, EDF proposed that the objective should be "to make situations leading to massive but delayed releases with lasting effects in the environment as unlikely as reasonably possible". This proposal does not reflect the search for measures to limit the consequences of such situations when the kinetics of the event would allow it. ASN therefore maintained his proposal.

Weighing up the issues

The "weighing up the issues" approach will enable EDF to objectively determine, using an advanced cost-benefit approach, which modifications to its facilities should be retained and which are not relevant.

ASN considers that the use of the "weighing of issues" approach should not be such as to limit discussions during the technical appraisals. With this in mind, ASN considers that EDF should ensure that the ASN is systematically presented with all the modifications that have been considered, even those that have not been retained.

Control of operating activities

EDF plans to "implement a systematic approach to taking account of organisational and human factors in safety reviews". To this end, EDF aims to:

- "identify, from the operator's point of view, both from the point of view of the equipment and systems operating baseline, the recurring operating difficulties: risks of error, overly complex baseline; situations that are not very "forgiving", which may in particular lead to errors and significant events";
- review the unitary and cumulative effects of the planned modifications and their potential socio-organisational and human (SOH) impacts".

Finally, as part of the review, EDF plans to submit a presentation of the organisation of the project relating to the PSR4 of 1300 MWe reactors in terms of organisational and human factors, as well as the conclusions of the review of the unitary and cumulative effects of the planned modifications and their potential socio-organisational and human impacts.

ASN considers that the studies planned by EDF are not sufficient to provide a satisfactory response to the objectives it has set itself. In particular, it considers that EDF should draw up a detailed work programme, which should include elements to justify that the complex socio-technical systems constituted by EDF's nuclear installations are capable of coping with the diversity of real operating situations. This analysis should also include a study of the operating activities involved in ensuring the conformity of the installations.

In response to this position, EDF has proposed that the reference to "operating activities contributing to the control of the conformity of installations" be deleted. Also, ASN considers that this reference is consistent with the importance to be attached, during this review, to ensuring that reactors comply with their standards, and therefore maintains its initial wording.

ASN also notes that the subject of organisations was already the subject of numerous questions from the public during the consultation that took place from September 2018 to March 2019 on the note responding to EDF's objectives for the fourth periodic reviews of 900 MWe reactors.

5 GENERAL RECOMMENDATIONS

5.1 Safety system's level P4/P'4 and EPR

Relates to EDF NRO (2023a) chapter I.2.1.2.1.1

Motivation/Observation:

The guidelines for PSR4 of 1300 MWe reactors are based on general objectives which come close to, but do not fully meet, the objectives set for the safety requirements of the EPR reactor. However, this increase is not to be reflected in their existing licences, which remain unchanged. Moreover, the enhanced level of safety is mostly aimed for through ways of new means (such as the core catcher) that are of a very different nature, in terms of defense in depth, from those used in new designs, therefore not bridging differences in the initial design.

Recommendation:

The proposed change in safety requirements for 1300 MWe reactors through the PSR4 is substantial and should therefore be reflected in the regulatory provisions laid down in their authorization decrees (DAC).

As the means introduced to achieve general objectives as close as possible to those of the EPR rely, by design and nature, on a very different defense in depth strategy, this difference should be explained and its implications elucidated.

In practice, the implementation of the general requirements results in numerous deviations (in design, rules, studies and compliance criteria). All these deviations and their implications must be explained.

5.2 Evaluation of safety margins

Relates to EDF NRO (2023a) chapter I.2.1.2.1.1

Motivation/Observation:

The margins available to a reactor with regard to safety requirements, taking into account a degree of uncertainty, form an important component of its safety level. Phenomena such as ageing and wear, which can only be partially offset by maintenance and replacement, materially consume these margins. Changes in design rules, and any increase in requirements that is not accompanied by a reinforcement designed to restore margins, consume them. The state of the margins and their evolution must be constantly clarified and made explicit, including defining in advance, where relevant, the thresholds beyond which the reactor must be shut down.

Recommendation:

The main margins from which reactors benefit in relation to the requirements applicable should be systematically identified, quantified where possible, and their use in the context of the PSR4 should be explained.

The margins that 1300 MWe reactors aim to achieve after extension in relation to the previously defined safety requirements must be compared with the margins that a newly built EPR-type reactor achieves in relation to comparable requirements.

When the margins relating to important parameters are consumed by identifiable or foreseeable phenomena, temporary or definitive shutdown criteria must be set in relation to a predefined threshold.

5.3 Experience feedback

Motivation/observation:

Recent experience feedback alerts us : questions relating to the quality of the work carried out in a context of loss of quality, the accumulation of non-conformities relating to the resistance of major components to damage, and the potential existence of non-conformities relating to non-inspectable components all combine to raise serious questions about the degree of compliance of the installations, and to prompt the strengthening of the examination procedures provided for in this area.

Recommendation:

The extent and variety of the causes of non-compliance call for open and traceable processes to be put in place to monitor all the actions taken to examine compliance.

In view of the shortcomings revealed by the random examination approach, a (much more) exhaustive, controlled verification of all the items important to safety that are accessible to physical inspection should be considered as part of the PSR4.

The risk of non-compliance must be covered more comprehensively in the studies, by examining the consequences of the accumulation of non-compliances observed on the one hand, and by developing a "stress test" method with regard to the risk of non-compliance on important elements not accessible to physical verification on the other.

Temporary or definitive shutdown criteria must be defined in advance in order to manage the detection of significant non-conformities, in a way that is proportionate to their consequences.

5.4 Implementation of Post-Fukushima action plan

Motivation/Observation:

In view of the difficulties encountered in recent years by EDF in meeting deadlines for studies and work, and even in complying with regulations, as well as those encountered by the ASN in ensuring that the operator complies with these various commitments, there is a high risk that the implementation of the safety improvements planned as part of the PSR4 will drift over time. A 4 to 5 years delay has already been granted by ASN for some of the works planned in the PSR4 of 900 MWe reactors, including the completion of the last post-Fukushima reinforcements. This risk is reinforced by concerns about EDF's technical and financial capacity to cope with this work, in a context when ASN said in 2022 that the industry needs a “Marshall Plan” to meet its objectives.

Recommendation:

In view of the continuous slippage in the deadlines for carrying out studies and work, it is necessary to provide the review with a more precise and stricter framework of timetable obligations.

To ensure that all stakeholders and the public are properly informed, this framework must be accompanied by the introduction of a public scoreboard of the commitments made by the operator, which should, wherever possible, be the subject of instructions, and by monitoring of their implementation.

In order to avoid fait accompli situations where deadlines are not met, stricter technical criteria for information from the operator and justification of deadlines should be defined.

Temporary or permanent shutdown criteria could then be developed to deal with situations where there is an unjustified slippage in relation to these criteria for assessing the technical difficulties of meeting deadlines.

6 REFERENCES

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7 GLOSSARY

ASG .... Steam Generator Emergency Feedwater System

ASN .... French Nuclear Safety Authority

BAS/BL .... Backup Auxiliary Buildings and the Electrical Buildings

BK .... Fuel building

CHFR.................................. Critical Heat Flux Ratio

CSA .... Complementary Safety Assessment

DAPE .... Dossiers d'aptitude à la poursuite d'exploitation

EAS .... Containment spray system

ECOT.................................. Examination of unit compliance

ECS .... Additional Safety Studies

EDF .... Électricité de France, NPP operator

EIPS.................................... Équipements importants pour la sûreté, in English equipment important for safety

EPR .... European Pressurised Reactors

FAV .... Ageing Analysis Files

FSR..................................... Fundamental Safety Rules

GW..................................... Giga Watt hour

HCTISN.............................. French High Committee for Transparency and Information on Nuclear Safety

HHSV .... Maximum historically likely earthquakes

HSC.................................... Hardened Safety Core

HSE .... Safety earthquake

IAEA .... International Atomic Energy Agency

IPS-NC .... Important for safety - not classified

IRSN .... Institut de Radioprotection et de Sûreté Nucléaire

LOCA .... Loss of Coolant Accident

LPI...................................... Linear Power Index

LTE..................................... Life-time Extension

LTO .... Long-term operation

MDTE	External voltage failure situation
MMC	Minimum Means of Control
MCC	Common Cabling Modes
MW	MegaWatt
MWe	MegaWatt electric
ND	Noyau Dur, in English HSC
NPP	Nuclear Power Plant
NRO	Note de Response, answer of ASN to EDF (EDF 2023a)
PCI	Pellet-Cladding Interaction
PIC	Complementary Investigation Programme
PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Review
PSR3	Third Periodic Safety Review
PSR4	Fourth Periodic Safety Review
PTR	Reactor cavity and spent fuel pool cooling and treatment system (FPC(P)S
RFS	Basic safety rules
RPR	Renovation of the reactor protection system
RPN	Renovation of the nuclear power measurement system
RRA	Refroidissement du réacteur à l'arrêt, in English residual heat removal system
RTGV	Rupture de tube de générateur de vapeur, in English SGTR
SGTR	Steam generator tube ruptures, in French: RTGV
SPIN	Reactor's digital integrated protection system
SSC	Structure, Systems, Components
TOS	Technical Operating Specifications
UDG	Ultimate Diesel Generators
VD3	Third Visite Decennial, PSR is connected to decennial outage

VD4 .... Fourth Visite Decennial, PSR is connected to decennial outage

WENRA .... Western European Nuclear Regulators´ Association

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