Post-Fukushima accident

France

Peer review country report

Stress tests performed on European nuclear power plants

ENSREG
European Nuclear Safety Regulators Group
Stress Test Peer Review Board

1 GENERAL QUALITY OF NATIONAL REPORT AND NATIONAL ASSESSMENTS

The accident at the Fukushima nuclear power plant in Japan on 11th March 2011 triggered the need for a coordinated action at EU level to identify potential further improvements of Nuclear Power Plant (NPP) safety. On 25th March 2011, the European Council concluded that the safety of all EU nuclear plants should be reviewed, on the basis of comprehensive and transparent risk and safety assessments - the stress tests. The stress tests consist in three main steps: a self-assessment by licensees, followed by an independent review by the national regulatory bodies, and by a third phase of international peer reviews. The international peer review phase consists of 3 steps: an initial desktop review, three topical reviews in parallel (covering external initiating events, loss of electrical supply and loss of ultimate heat sink (LUHS), and accident management), and seventeen individual country peer reviews. Country review reports are one of the specific deliverables of the EU stress tests peer review process. They provide information based on the present situation with respect to the topics covered by the stress tests. They contain specific recommendations to the participating Member States for their consideration or good practices that may have been identified, and to some extend information specific to each country and installation. Draft country review reports were initiated during the topical reviews based on discussions with the country involved in the three topics and on the generic discussions within each of the three topical reviews. Issues identified for each country during the topical reviews, due to only limited time available for each country, have required follow-up discussions in more detail, both between the topical reviews and the country reviews, and during the country reviews.
The current Country Report was finalized at the end of the Country Review, after final discussion with the reviewed country and visit of nuclear power plant. It is a part of the Final Report combining the results of the Topical Reviews and Country Reviews.

1.1 Compliance of the national reports with the topics defined in the ENSREG stress tests specifications

The Stress test reports for the 58 power reactors in operation and one reactor under construction have been submitted to ASN (Autorité de Sûreté Nucléaire) on 15 September 2011. The French national report (FR-NR) is also based on the opinion of the advisory committees, consisting of French and foreign experts, resulted from the technical assessment performed by IRSN (Institut de Radioprotection et de Sûreté Nucléaire, French technical support organization) of the licensees' reports. The FR-NR includes both the preliminary and the final report, as long as there was not a feedback from the ASN to licensees and a subsequent final ASN report based on the reviewed final licensees' reports, as the ENSREG (European Nuclear Safety Regulators Group) specifications require.

Generally, the French national report is in compliance with the ENSREG specifications. The report has a good quality and a clear evidence of the Regulator's review activities and position. However, the chapter numbering is different than proposed in the ENSREG content and format of national reports document and the report includes some other supplementary assessments, as the one related to "Conditions Concerning the Use of Outside Contractors" which is not in the scope of the European "Stress Tests".

1.2 Adequacy of the information supplied, consistency with the guidance provided by ENSREG

The French national report recalls that the approach used for hazards assessment is essentially deterministic; hence there is little information on probabilistic hazard assessments. Safety margins have been estimated based on available studies or by engineering or expert judgment. Tsunami hazard is not addressed explicitly in the report but explanations have been provided to the reviewers during the country visit. The assessment of extreme weather conditions is not as detailed as the other topics. The information to assess the response of the nuclear unit as well as the identification of safety margins is generally consistent with the ENSREG methodology. ASN provided comprehensive answers and clarifications to the written comments as well as to questions asked during the country presentation that completed the information provided in the national report.

The complementary safety assessments performed for the French NPPs are in general consistent with ENSREG specifications. However, in some instances, more detailed and comprehensive information in the national report would have been appropriate, but sufficient additional information has been provided during the topical review and the country visit.

1.3 Adequacy of the assessment of compliance of the plants with their current licensing/safety case basis for the events within the scope of the stress tests

The regulator ASN considers that the French NPPs are in compliance with the current licensing basis represented by the French national standards, rules and regulations on nuclear energy and radiation safety. ASN has implemented a process to search for deviations during normal operation, periodic testing, maintenance, conformity reviews and safety reassessments during Periodic Safety Review (PSR), and on the occasion of the routine inspections performed by ASN inspectors. ASN also pointed out that regulatory requirements related to detection and processing of deviations have been strengthened with the publication of a ministerial order in early February 2012.The particular regulations applicable to the topics of the Stress Tests, if existing, are given in the corresponding chapters of the national report.

The periodic safety reviews, conducted on a 10-year basis as required by Western European Nuclear Regulators' Association (WENRA), as well as regular inspections by ASN contribute to ensuring the compliance of the plants to the licensing basis. ASN inspectors accompanied by IRSN representatives performed a number of inspections to the NPPs in the framework of the stress test exercise. These inspections normally lasted several days, involving spot-checks on all topics in the scope of the required assessments. The assessment of compliance of the plants with their current licensing/safety case basis for the events within the scope of the stress tests seems to be adequate. Improvement measures are identified and will be required by ASN.

1.4 Adequacy of the assessments of the robustness of the plants: situations taken into account to evaluate margins

Comprehensive assessments of the current safety margins at the plants as well as improvement measures which can be envisaged to increase the robustness of the plants are documented for all events that are considered regarding the stress tests. The assessment of flooding risk entails a wide ranging set of hazards. Loss of electrical power supply and the LUHS as well as their combination were assessed for different operational modes by the licensee, according to ENSREG specification. The assessment covered whole site situations for reactors and spent fuel pools (SFPs). The impacts of beyond design hazards on the neighbouring activities liable to induce a risk for the NPP were taken into account. These assessments were carried out in addition to the permanently performed safety approach.

The correctness of licensee statements in the national report were assessed for design basis measures and checks were performed for additional measures in the beyond design basis area where possible. The assessments of the robustness of the plants and situations taken into account to evaluate safety margins are considered adequate, with some exceptions, highlighted by the regulatory body too. ASN proposes in the national report adequate measures to address these findings.

The national report also addresses all components, which are considered essential for the management of severe accidents and which are to a major extent already implemented in existing plants. These include organizational arrangements for accident management and emergency planning, hardware measures to address severe accident challenges (depressurization of primary circuit, containment overpressure, hydrogen management, corium stabilization, etc.), as well as procedural arrangements (symptom based Emergency Operating Procedures (EOP) and Severe Accident Management Guidelines (SAMG)).

1.5 Regulatory treatment applied to the actions and conclusions presented in the national report (review by experts groups, notification to utilities, additional requirements or follow-up actions by Regulators, openness,…)

Following the Fukushima Daiichi NPP accident, a complementary assessment of the safety of the French nuclear facilities, was initiated and performed. As a general strategy to improve the safety against extreme external events beyond the design basis the reviewers observed that the French licensee and ASN decided to implement new and robust systems rather than performing sophisticated analysis and evaluations. A large number of actions have been identified (e.g. the "hardened safety core" concept for all NPPs).

ASN has reviewed the licensee reports in terms of completeness, adequate application of the ENSREG methodology and correct categorization of the referenced documentation. In summary, the adequate application of the ENSREG methodology was confirmed. After the complementary safety assessments of the priority nuclear facilities, ASN considered that the facilities examined offer a sufficient level of safety requiring no immediate shutdown of facilities. At the same time, ASN considers that the continued operation of the facilities requires that their robustness to extreme situations needs to be improved as rapidly as possible.

As a conclusion of the national report ASN will impose a range of requirements on the licensees in the first quarter of 2012 and will tighten up the safety requirements concerning natural hazards (earthquake and flooding), the prevention of risks linked to other industrial activities, subcontractor monitoring and how deviations are to be dealt with. ASN plans to publish their decisions on the website. ASN declared that it will ensure that the licensees comply with the requirements issued and take into account the new safety requirements. In addition, ASN intend to take into consideration the conclusions of the peer reviews conducted at the European level.

ASN took note of the proposals by the licensees and required them to implement these proposals. In addition, ASN asked the licensee to develop a specific list of measures to be studied in the coming months to be included in the “hardened safety core” equipment and measures. In addition ASN requested to develop a number of more detailed studies and specific plans of implementation for the provisions associated with severe accident management.

2 PLANT(S) ASSESSMENT RELATIVE TO EARTHQUAKES, FLOODING AND OTHER EXTREME WEATHER CONDITIONS

2.1 Description of present situation of plants in country with respect to earthquake

2.1.1 Design Basis Earthquake (DBE)

2.1.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country,…)

ASN: Règle fondamentale de sûreté relative aux installations nucléaires de base

RFS 1.2.c (1981), revised in 2001: RFS 2001-01

During the country visit ASN informed that additionally to these guidelines the RFS 1.3.c (1984) is addressing the geotechnical hazards (e.g. soil liquefaction, soil stability, settlements) and the RFS 1.3.b is defining the requirements regarding the seismic instrumentation.

2.1.1.2 Derivation of DBE

The DBE is derived with a 3-step deterministic approach:

- Maximum Historically Probable Earthquake (MHPE)
    - Considers seismotectonic zones (homogeneous from a kinematic and a seismic point of view)

- Identify Historical Reference Earthquakes from SisFrance (Historical earthquakes listed over a period of about 1000 years), instrumental records since 1960s and paleo-earthquakes. The magnitude and depth of historical earthquake are derived from the entire set of intensity data points using an empirical regression.
- It is postulated that the historical reference earthquake(s) reoccur with the same characteristics, assuming as a conservative assumption, that they reoccur the position most unfavourable to the facility, while remaining compatible with the geological and seismic data (seismotectonic zones). From this, the MHPE is deduced and its characteristics are identified.

– Safe Shutdown Earthquake (SSE)

It is derived from the MHPE by adding one Intensity (MSK-scale) to the Intensity of the MPHE: I(SSE)= I(MHPE) + 1. The seismic motion at the site is described by acceleration response spectra associated with the MPHE, SSE and paleoevents, computed with assumptions for focal depth and distance.

– DBE, more stringent than SSE:

It has an enveloping design spectrum

- EDF-spectrum or NRC-spectrum (depending on the plant's age), normalized to site specific peak ground acceleration values, ranging from 0,1 g to 0,2 g for the existing 58 reactors;
- EUR spectrum, normalized to 0,25 g for EPR (European Pressurized water Reactor) -plant Flamanville-3

Because of the standardization of the seismic design for the nuclear island structures a site-specific differentiation for the DBE is introduced: for the nuclear island DBE – site structure DBE.

Site specific local geological characteristics are considered, as well as surface faulting, soil liquefaction and slope stability.

2.1.1.3 Main requirements applied to this specific area

A safe shutdown status has to be reached by the plants after a major earthquake (SSE). This means that the three main safety functions (safe shutdown, adequate cooling, confinement of radioactivity) have to be assured also in the case of SSE. Structures and equipment (SSC's) important for safety are listed and placed in safety classes. SSCs are seismically qualified by analysis or testing, according to their safety class. The requirements are defined in ASN guidelines (RFS-règles). ASN considers that the implementation of the baseline safety requirements by the licensee is satisfactory.

In addition to the design-basis earthquake resistance of the seismically classified equipment necessary in the event of an earthquake, the safety approach is supplemented by an approach called "event earthquake". The aim of it is to prevent damage to equipment necessary in the event of an earthquake by an item or structure not seismic-classified. During the course of their inspections, ASN observed the difficulty experienced by the licensee with ensuring an optimum integration of this requirement on certain sites in the day-to-day operation. ASN will require that on each site the licensee ensures the effective implementation of the "event earthquake" approach.

The plants are equipped with a seismic instrumentation system. The level of "½ Design Response Spectrum" is specified as decision basis for actions by the operators. In several site inspections ASN identified shortcomings in operating the seismic instrumentation. ASN will require personnel training programs. ASN will require that the licensee studies the advantages and drawbacks of implementing an automatic shutdown.

2.1.1.4 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

A deterministic approach is applied for the seismic hazard assessment and for the seismic qualification of SSCs. A Probabilistic Safety Assessment (PSA) has not been applied systematically so far for external events. Probabilistic Seismic Hazard Analysis (PSHA) studies were performed by the licensee for the St Alban, Flamanville and Civaux NPPs. The PSHA of the Saint-Alban site was developed in the frame of the 3rd PSR of the 1300 MWe series and the licensee's conclusion is that the PGA return period of the DBE obtained by the licensee is equal to about 10 000 years.

With regards to seismic safety operating experience feedback from the July 2007 earthquake in Japanese power plant at Kashiwasaki-Kariwa has been incorporated by the licensee (scope of seismic inspections, consequences of transformer fire).

For the new EPR at Flamanville a PSHA was performed, as input to the PSA.

2.1.1.5 Periodic safety reviews (regularly and/or recently reviewed)

PSRs are conducted by the licensee in a 10-yearly period for all nuclear power plants, instituted by act of 13 June 2006. Following a PSR, the changes decided for a plant series are implemented on each reactor, generally on the occasion of the reactor ten-yearly outage inspection. The French report by ASN provides good evidence that the PSRs are carried out regularly and diligently and have led to significant improvements in seismic safety.

2.1.1.6 Conclusions on adequacy of design basis

The DBE has been developed adequately according to the French regulation, based on a deterministic approach for seismic hazard assessment.
IAEA recommends conducting both deterministic and probabilistic approaches, as complementary strategies. It is recommended that ASN should consider introducing PSHA in France for the design basis of new reactors and for future revisions of the seismic design basis of existing reactors, in order to provide information on event probability (annual frequency of occurrence) and to establish a more robust basis for DBE specifications.
ASN indicated that, in the frame of the 3rd PSR of the 1300 MWe plants it requested the licensee to develop PSA for external events which are not in the scope of the PSA included in the safety report, that is seism, extreme weather conditions and external flooding, taking into account the specificities of the sites.
The DBE, as described in the report, addresses the issue of vibratory ground motion. The report does not inform about the investigation of further aspects of the seismic risk, such as surface faulting, soil liquefaction and earthquake induced landslides, which should be considered or ruled out based on assessments. During the country visit, ASN and IRSN have documented that these effects are taken into account.

2.1.1.7 Compliance of plant(s) with current requirements for design basis

Based on the PSR findings, ASN confirms the adequacy of the process for guarantying the conformity of the reactors with the design basis. The seismic retrofits conducted since the design of the units, based on reassessed hazards and changes to seismic justification methods were performed satisfactorily. These reinforcements led to significant improvements in seismic safety.
The seismic instrumentation which could be observed during the country visit appeared to offer the potential of improvement with respect to the number of accelerometers and to the evaluation procedure. An immediate evaluation of the recorded signals, allowing the comparison of response spectra with the design basis spectra and a direct access to this information from the control room is recommended in order to facilitate and to accelerate the measures to be initiated after a seismic event. ASN reported that following the dedicated inspections it requested the licensee to improve the situation related to the seismic instrumentation. It is also recommended to consider an upgrade of the corresponding safety rule RFS 1.3.b (1984).

2.1.2 Assessment of robustness of plants beyond the design basis

2.1.2.1 Approach used for safety margins assessment

An overall margin study was conducted by the licensee, considering 3 margin sources:

- Margins between MHPE and SSE and between SSE and DBE
- Margins due to the response of the structure
- Margins due to the design criteria for structures and equipment

A specific study was conducted for the Tricastin site (900MW), applying the SMA-method (Seismic Margin Assessment). In addition to the SMA approach, the licensee performed a seismic probabilistic safety assessment for the Saint Alban site (1300 MWe). For the next PSR of the 900 MW plants it is considered to perform a robustness analysis based on a seismic PSA or SMA.

2.1.2.2 Main results on safety margins and cliff edge effects

The licensee concludes that the seismic capacity of the containment and of the structures and equipment which, in the event of failure, would compromise the safety functions, is at least 1.5 times larger than the forces and stresses resulting from the Safe Shutdown Earthquake. The licensee considers that this level easily exceeds the seismic context of the sites, up to hazard values that are hardly plausible or implausible for these sites.

2.1.2.3 Strong safety features and areas for safety improvement identified in the process

ASN considers that the process to search for nonconformities during normal operation, maintenance, conformity reviews and safety reassessments, during the complementary investigations (event earthquake approach, specific seismic inspections, etc.), and on the occasion of the inspections performed following the Fukushima accident, is satisfactory.

ASN concludes that the complementary safety assessments demonstrated that the current seismic margins on the licensee nuclear reactors are sufficient to prevent cliff-edge effects from occurring in the event of a limited overshoot of the current baseline safety requirements. These assessments confirmed the benefits of examining the seismic risk on the occasion of each ten-yearly PSR. The seismic safety margins are the result both of the conservative values adopted for the DBE considered and the application of seismic standards.

As a substantial safety improvement, the licensee proposes to define a “hardened safety core” of reinforced equipment such as to minimise the potential for severe accidents and avoid significant radioactive releases into the environment, over and above the current safety requirements, for the deterministic situations studied in the complementary safety assessments. The licensee intends to draw up a list of the main hardened safety core items and the robustness requirements to be applied to them by 30th June 2012 for the power plants in operation as well as for the EPR reactor project

Specific requirements for the “hardened safety core” such as to allow control of the basic safety functions taking into account the most severe accident scenarios induced by earthquake or flooding have to be developed.

ASN considers that the approach proposed by the licensee is appropriate and has required that the licensee submits by June 2012 for approval the requirements associated with this hardened safety core, which shall include significant fixed margins with respect to the design-basis earthquake. The hardened safety core will be based mainly on new equipment diversified from the existing to prevent common cause failure.

Further important general measures to improve beyond design safety proposed in France include:

- Creation of a “Nuclear Rapid Response Force (FARN)”
- Reduce the risk of water loss in the SFPs
- Protection of ground water

A number of further actions, to be developed by the licensee, has been identified through PSR and targeted inspections after the Fukushima event. Areas concerned are the seismic instrumentation, the effective implementation of “event earthquake” approach, the training of operators to correctly react in case of an earthquake, the evaluation of a possible automatic shutdown and a better evaluation of the seismic margins.

2.1.2.4 Possible measures to increase robustness

ASN will ask the licensee to analyse the seismic robustness of the civil engineering structures participating in prevention of the loss of the heat sink or electrical power supplies. The appropriateness of further actions may emerge after a more detailed seismic margin assessment.

2.1.2.5 Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators

Forthcoming requirements by ASN (in addition to the "hardened safety core" concept):

- Increase seismic resistance of equipment used to manage LOOP, SBO and LUHS situation
- Secure the on-site stocks of fuel and oil
- Improve fire safety and seismic qualification of fire protection systems, reduce earthquake-induced fire risk
- Seismic qualification of hydrogen systems, reduce earthquake-induced explosion risk
- Strengthening of the detection and processing of nonconformities
- Effective implementation of "event earthquake" approach
- Definition and monitoring of an operations personnel training program to enhance the licensee 's preparation for a possible earthquake
- Study of the seismic robustness of embankments for Tricastin and Fessenheim sites
- Evaluate the possibility of automatically shutdown the plants based on trigger levels of the seismic instrumentation

ASN will request the licensee to conduct SMA studies in the forthcoming periodic reactor safety reviews for the 900MW fleet. Two pilots studies were already performed by the licensee: one SMA for Tricastin (900MWe reactors) and one PSA for Saint Alban (1300 MWe reactors).
The licensee has been requested by ASN to deepen the SMA, which was performed in a simplified way due to the short time available. The combination with earthquake induced flooding beyond design (dam failure, embankments failure) will also be considered.

2.1.3 Peer review conclusions and recommendations specific to this area

The DBE has been adequately developed according to the French regulation, based on a deterministic approach for seismic hazard assessment. The review team recommends ASN to continue considering the implementation of probabilistic methods (PSHA) as a further improvement and justification for the DBE of operating and new reactors.
There is satisfactory evidence provided that the French licensees are compliant with the design basis requirements and that a PSR process is being applied effectively and led to significant seismic reinforcements.
Many safety improvement measures have been identified, which shall be implemented by the licensee and reviewed by ASN. The most ambitious improvement measure is the intended definition and deployment of a "hardened safety core" at each plant. This measure will provide a significant increase of overall robustness, not only for seismic events.
The seismic instrumentation could be improved to a state of the art concept. It is also recommended to consider an upgrade of the corresponding safety rule RFS 1.3.b (1984).

The safety margins for seismic events above the DBE have been roughly estimated by the licensee. It is appreciated that a more systematic evaluation will be required by ASN either by performing PSA or SMA.

2.2 Description of present situation of plants in country with respect to flood

2.2.1 Design Basis Flood (DBF)

2.2.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country…)

Original design basis for flood protection: basic safety rule RFS I.2.e of 12th April 1984 ("Consideration of the off-site flood risk").
The flooding risk was reassessed following the Blayais flooding in 1999.

2.2.1.2 Derivation of DBF

According to the basic safety rule RFS I.2.e, the definition of the flood safety margin level (CMS) differentiates according to the site location:

1. For coastal sites, the CMS corresponds to the combination of the maximum calculated tide (tide coefficient 120) and the 1'000-year storm surge.
2. For river sites, the CMS is the highest of the following two levels:
   a) Level reached by a river whose discharge is obtained by increasing the 1'000-year flood level by 15%;
   b) Level reached by a combination of the highest known flood waves, or the 100-year flood level if higher, and collapse of the most prejudicial retaining structure.
3. For estuary sites, the CMS is the highest of the following three levels:
   a) Level reached by a combination of the 1'000-year river flood level and the tide of coefficient 120;
   b) Level reached by the combination defined in 2.b and a tide of coefficient 70;
   c) Level reached by the combination of the 1'000-year marine surge and the tide of coefficient 120.

Following the partial flooding of the Le Blayais nuclear power plant in December 1999, the licensee updated its CMS evaluation of all the sites and systematically took account of other hazards liable to cause flooding.

- For all sites:
  - o Water retaining structures (other than dams) deterioration
  - o The intumescences (swelling due to operation on valves or pumps)
  - o High intensity rainfall
  - o Regular and continuous rainfall
  - o Groundwater rising
  - o Failure of a circuit or equipment
- For river sites:
  - o Influence of the wind on the river or the chop
- For coastal sites:
  - o Wave swell

The licensee also took into account certain combinations of hazards.
The tsunami hazard at coastal sites is not addressed in the national report. During the country visit, ASN and IRSN indicated that, following the partial flooding at Le Blayais, the licensee conducted a study in order to assess the flooding risk by a tsunami.
The licensee identified two kinds of tsunami which could impact the coasts of Atlantic, la Manche and the North Sea:

- Seismic tsunamis: The licensee considers that seismic tsunami risk could be eliminated because of the low seismicity of areas close to French coast and because of the low probability of the concomitance of a tsunami and a high tide for further sources.
- Tsunami induced by landslide: The licensee considers that their effects are significant only close to the source and that the amplitude of plausible tsunamis is lower than the combination of the maximum calculated tide (coefficient 120) and the thousand year storm surge.

ASN considered that this analysis is adequate and that the tsunami risk is a priori covered by reference marine level and waves.
It is understood that this hazard is covered by the tide and storm surge scenarios, as it was explained in the Topical Review presentation.

2.2.1.3 Main requirements applied to this specific area

Different design values apply to the different sites:
- Maximum 1'000-years flood + 15% (CMM) to the river sites of Belleville, Cattenom, Chooz, Dampierre, Fessenheim, Golfech, Saint Laurent and Tricastin.
- Dam burst/collapse (REB) plus 100 years flood to the river sites of Bugey, Civaux, Cruas, Nogent and Saint Alban
- A combination of CMM and failure of a dike due to water rise (Val d'Authion dike) for the river site of Chinon
- 1'000 year storm surge + tide 120 for the costal sites of Flamanville, Gravelines, Paluel and Penly and the estuary site of Blayais.

The three main safety functions (reactor shut down, heat removal, confinement of radioactivity) have to be assured in the case of a flooding at the CMS level. As a consequence of the Le Blayais event, an increased flooding level has been defined for each site. In the report the current CMS level is compared with the height of nuclear island platform for each plant.
ASN and IRSN also launched a revision of RFS I.2.e concerning the inclusion of the flooding risk, taking account of all the work done since the flood at the Le Blayais nuclear power plant. The new guide for protection against the flooding risk will concern the choice of hazards liable to lead to flooding of the site and the methods for characterising them all. This draft guide was the subject of a consultation in June 2010, broadened to include the public. After consideration of the remarks collected, the guide will be submitted to the advisory committees for their opinion which will meet in May 2012. ASN aims to distribute this new guide in 2012.

2.2.1.4 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

Operational experience feedback has been a main source of the present approach to flooding issues, aimed to get an increased level of protection against this type of risk. The Blayais-incident in 1999 resulted in a reassessment of all plants with additional safety requirements. A PSA has not been carried out so far for external events. The next PSA, conducted for the following PSR should include, among other topics, external events (extreme weather conditions, external flooding, earthquake, environment and human activity of the vicinity of the power plant).

2.2.1.5 Periodic safety reviews (regularly and/or recently reviewed)

The plants are reassessed on the occasion of the PSR (10-year-period) instituted by article 29 of the act of 13 June 2006 or further to certain exceptional events, such as the partial flooding of the Le Blayais nuclear power plant during the storm on 27th December 1999.
In its safety assessment reports, the licensee states that the flood protection conformity of its facilities is based on:
- periodic surveillance through periodic tests or inspections as part of the preventive maintenance programmes on equipment contributing to protection, identified in the design studies;
- monitoring and management of the volumetric protection (VP).

2.2.1.6 Conclusions on adequacy of design basis

ASN explained that the design basis flood is defined considering statistical extrapolations limited to 10^{-3}/y supplemented by a margin or a conventional combination. ASN and IRSN stated that the current state of the art in flood level calculations doesn't allow calculating, with a sufficient confidence, 10^{-4}/y levels, except in some specific conditions such as "small catchments areas - up to some 1000 km^2".

It is recommended to perform a comparative evaluation with the methodologies used in other European countries.

2.2.1.7 Compliance of plant(s) with current requirements for design basis

During the targeted inspections conducted in June and October 2011, ASN observed numerous anomalies regarding the monitoring, maintenance and perimeter of the volumetric protection. Examples are given in the report.
Following the submission of the Stress Test reports, the licensee has made the commitment that the VP conformity remediation work will be completed on all the NPPs before the end of 2011. The licensee proposes several measures, which in general ASN considers as satisfactory.
After analysis of the Stress Test results, ASN deems that the requirements resulting from the complete reassessment of the consideration of this risk on the nuclear power plants, completed in 2007, give the installations a high level of protection against the risk of flooding. However, ASN observes that the steps such as to meet these requirements have not yet all been taken. In order to ensure that this high level of protection is actually reached, ASN will require that the licensee completes the NPP protective measures within the time allotted following the "flood" reassessment of 2007, and no later than 2014.

2.2.2 Assessment of robustness of plants beyond the design basis

2.2.2.1 Approach used for safety margins assessment

A margin assessment has been performed site by site, in a deterministic way, considering severe scenarios beyond the design basis.
The licensee analysed three types of cliff-edge effects that could be triggered by a flood:

- Flood causing the loss of site heat-sink (situation H1)
- Flood causing a LOOP situation
- Flood causing total loss of the electricity sources (H3 situation) associated with the possible loss of the reactor backup systems.

In order to evaluate the robustness of the facility to cliff-edge effects the licensee:

- identified the cliff-edge effects caused by off-site flooding and calculated the corresponding water levels;
- conducted "beyond design-basis" vulnerability analyses, by increasing certain current design scenarios by a fixed amount;
- compared the water levels reached for each of the increased scenarios with the water levels leading to cliff-edge effects;
- proposed studies to confirm the existence of the cliff-edge effect or the steps to be taken to reinforce the robustness to such a cliff-edge effect.

2.2.2.2 Main results on safety margins and cliff edge effects

The analysis performed by IRSN during the stress test review revealed cliff-edge effects close to review flood levels. The results are different for the sites. They are not reported in a quantitative sense in the French national report, but are documented in the licensee stress tests reports (which are publicly available). ASN requested improvements to increase the margins.
The consequences of the investigated reference flood augmentation scenarios (beyond DBF) vary widely. The nuclear island platforms of some sites would remain above water level. For other sites the flooding could reach levels above the nuclear island platforms. For a certain number of riverside sites, the licensee considers that the water height estimates, based on extrapolations from existing studies or models, need to be consolidated.
With regard to the flood scenarios induced by an earthquake beyond design-basis, the licensee estimates that, depending on the sites, either the risk of flooding can be ruled out, or the associated water volumes are contained by the roadways, or the associated water volumes are liable to create a layer of water a few centimetres high on the nuclear island platform. Though, further studies are required to issue a final statement.

ASN will request the licensee to reinforce the protection of the facilities against the risk of flooding beyond the current design basis, to prevent the occurrence of total loss of heat sink or electrical power supply situations for the maximum rainfall and flooding induced by an earthquake beyond design-basis scenarios.
The licensee justifies the ability of the embankments of the Tricastin and the Fessenheim sites to withstand 1.5 times the SSE.

2.2.2.3 Strong safety features and areas for safety improvement identified in the process

The flooding safety is being increased, based on the results of a wide range of beyond original design basis scenarios which have been studied systematically for all the sites, as a consequence of Blayais (1999) and Fukushima (2011).
The "hardened safety core concept" (see 2.1.3) shall also improve the flooding safety, as it will guaranty the possibility to manage SBO or LUHS after beyond design flooding.
The systematic evaluation of safety margins and cliff edge effects, which was presented during the country visit, is considered to be a strong safety feature, although these values are not documented in the FR-NR. A number of actions has been identified and requested by ASN. Areas concerned are the safety of dikes and the volumetric protection against flooding, e.g.:

- Increase the protection of the facilities against the risk of flooding in excess of the current baseline safety requirements, for example by raising the level of the volumetric protection.
- Further investigations / safety verifications of the embankment dams of Fessenheim and Tricastin, with strengthening measures if required.

2.2.2.4 Possible measures to increase robustness

The licensee proposes further site specific studies, depending on the fact that the cliff edge effect is linked to a LUHS or a loss of power situation.
The licensee also proposes other measures to reinforce the robustness of the facility:

- a study of the consequences:
    - of a rise in the groundwater level on the structural resistance of the buildings of units 1 and 2 on the Penly site;
    - of a karst flood on the lack of buoyancy of the buildings on the Paluel site;
- studies to confirm the ability of the protective embankments to withstand a CMS+1m under the effect of wave swell;
- studies on the seismic behaviour of the protections in the event of an earthquake initiating dam failure and studies concerning multiple dam failures;
- study on the seismic resistance and electrical backup of the sewer lifting pumps

For three sites (Tricastin, Fessenheim and Bugey), on which the heat sink is at a higher elevation than the site platform, there is a risk of a major leak in the event of a rupture of the cooling systems (CRF) for the facilities connected to them. The licensee stated that isolation valves can isolate the system from the heat sink in all circumstances, but initiated a study programme to improve the robustness of these isolation valves up to a level beyond design-basis, yet to be defined.
ASN considers that improvement of the volumetric protection would, in most cases, be able to prevent H1/H3 cliff-edge effects for the maximum rainfall and flooding induced by an earthquake beyond design-basis scenarios.
Regarding the identified hazard for Tricastin site, ASN considers that:

- The licensee will need to identify the local singularities in the embankment and eliminate the risk of internal erosion in these sectors;
- The licensee will have to conduct a geotechnical survey of its component materials and monitor its piezometry;
- The licensee must check with the CNR (Compagnie Nationale du Rhône) that the monitoring and up keeping of these embankments guarantees the long-term effectiveness of their drainage, along with the absence of any disorders. The licensee shall in particular ensure that this monitoring is able to confirm the effectiveness of the piezometric device.

2.2.2.5 Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators

In 2006, the licensee and the CNR defined a strategy to protect the Tricastin site, consisting of a combination of several material and operational countermeasures, scheduled for completion by late 2014. Pending the performance of this work, ASN considers that protection of the Tricastin NPP cannot be guaranteed in the event of a 1'000-year flood + 15%.
Fessenheim NPP and embankment of Canal d'Alsace:
ASN considers that further studies are needed. ASN will require that the licensee conducts a study on the seismic resistance of the embankment beyond design basis and to evaluate the consequences in case of embankment failure.

2.2.3 Peer review conclusions and recommendations specific to this area

The Design Basis Flooding has been adequately developed according to the French regulation.
ASN detected deviations regarding the monitoring, maintenance and perimeter of the volumetric protection. Numerous actions have been identified by ASN in order to verify the compliance of the plants with the current design basis and to improve the flooding safety. A program is being established and will be controlled by ASN.
The peer review team recommends to perform a comparative evaluation between the level of DBF defined according to ASN requirements with the methodologies used in other European countries.

2.3 Description of present situation of plants in country with respect to extreme weather

2.3.1 Design Basis Extreme Weather

2.3.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country,…)

The regulatory basis is provided by the national standards.
Structures are designed on the basis of the rules existing at the time of design. The effects of wind (direct or indirect), lightning and snow are considered. Hail is not considered in the design of the units, however, the licensee claims it is covered by other hazards such as indirect effects of the winds or heavy rainfall.
Wind and projectiles: "Snow and Wind 65 Rules", projectiles with up to 200 km/h speed considered
Lightning: Ministry Order, January 2008, revised July 2011; Standard NF EN 62305-2 (2006): "Lightning protection risk evaluation"
During the country visit ASN informed that the following hazards are taken into account in the licensee's current safety cases:

- Very hot weather
- Very cold weather
- Frazil
- Wind
- Snow
- Missiles in case of extreme wind
- Lightening
- Very low water level.

2.3.1.2 Derivation of extreme weather loads

The national report provides only limited information on this topic. During the country visit it was explained that the loads are derived from statistical data, past experience and national standards for the design of civil structures.

2.3.1.3 *Main requirements applied to this specific area*

Wind: Buildings shall be able to withstand winds with characteristics conforming to the updated "Snow and Wind Rules"; recently the licensee defined a baseline for safety requirements concerning the protection against projectiles generated by extreme winds.
Lightning: Protection is provided by a mesh cage

2.3.1.4 *Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)*

The technical background is provided by national standards and safety assessments as well as meteorological data and the past experience about extreme natural phenomena (operational experience feedback).

2.3.1.5 *Periodic safety reviews (regularly and/or recently reviewed)*

PSR is mentioned for the issue of wind resistance.
There has been no systematic PSR-evaluation of extreme meteorological conditions outlined in the report. ASN mentioned that, in the beginning of each PSR, the issues to be reassessed in depth are determined by ASN based on the licensee's proposal and a technical assessment by IRSN. For instance, for the 3rd PSR of the 1300 MWe plants, the following extreme weather conditions hazards are being reassessed: very hot weather, frazil, very low water level, extreme winds, and tornados.

2.3.1.6 *Conclusions on adequacy of design basis*

The combination of extreme weather condition has not been addressed systematically in the design basis so far.
ASN will require updates and supplements.

2.3.1.7 *Compliance of plant(s) with current requirements for design basis*

As far as the design basis is defined (see above) the licensee confirms compliance of their plants.

2.3.2 Assessment of robustness of plants beyond the design basis

2.3.2.1 *Approach used for safety margins assessment*

Safety margins are estimated in a simplified way by expert judgment. For certain buildings, the licensee made a comparison of extreme weather impacts with design loads from "off-site explosion". For lightning the operating experience feedback confirms robustness up to high levels.

2.3.2.2 *Main results on safety margins and cliff edge effects*

The licensee provides no quantitative values for safety margins. Their main results concern the effects of wind and lightning on nuclear island buildings. They do not envisage the possibility of specific cliff edge effects, except for rainfall which is already considered in relation with flooding. ASN will require further investigations (see 2.3.1.6), considering more severe loadings.

2.3.2.3 *Strong safety features and areas for safety improvement identified in the process*

ASN identified the need to study in some cases more severe loads; the need for related improvements could be originated from these studies.
Lightning: A preventive maintenance program for the "Hot non-IPS structures" (IPS: Buildings important to safety) and a maintenance program for the turbine hall are currently being drafted.

2.3.2.4 *Possible measures to increase robustness*

With regard to the EPR, the licensee states that in order to prevent any cliff-edge effects beyond the baseline safety standards, the additional equipment that could be deployed following the stress test will be designed for or protected against extreme climatic conditions.

2.3.2.5 *Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators*

Further studies have been requested, concerning wind (direct and indirect effects), lightning and hail. Extreme meteorological conditions have to be considered in the required definition of the "hardened safety core".

2.3.3 Peer review conclusions and recommendations specific to this area

The peer reviewers confirm the conclusion drawn by ASN that further studies need to be conducted in order to provide a complete and systematic design basis and safety margin assessment with respect to extreme weather conditions.

ASN states in the report that it asked the licensee to conduct the analyses for those climatic phenomena which are related to flooding. It is recommended to include also tornadoes, heavy rainfall, extreme temperatures and the relevant combinations of extreme weather conditions in these complementary studies. The review team recommends to consider extreme meteorological conditions in the required definition of the "hardened safety core".

3 PLANT(S) ASSESSMENT RELATIVE TO LOSS OF ELECTRICAL POWER AND LOSS OF ULTIMATE HEAT SINK

3.1 Description of present situation of plants in country

3.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country…)

French nuclear safety regulations include all the general legal texts setting down nuclear safety rules, whether binding (Act voted by Parliament, decrees and ministerial orders and ASN regulatory decisions) or non-binding (ASN basic safety rules and guides).
The regulation of nuclear safety and radiation protection in France is based on two main Acts:

– Act 2006-686 of 13th June 2006 on transparency and security in the nuclear field (TSN Act);
– Planning Act 2006-739 of 28th June 2006 concerning the sustainable management of radioactive materials and waste.

The French regulations applicable to civil basic nuclear installations are in conformity with various conventions, international standards and European legislation: IAEA "Basic safety standards"; Convention on Nuclear Safety for civil nuclear power generating reactors; Joint convention on the safety of spent fuel management and the safety of radioactive waste management; Euratom treaty; Euratom directive of 25th June 2009 establishing a community framework for the nuclear safety of nuclear installations.
The following main decrees and ministerial or inter-ministerial orders in force govern the nuclear safety at French NPP:

– Decree 2007-1557 of 2nd November 2007 on basic nuclear installations and the control,
– The order of 10th August 1984 on the quality of the design, construction and operation of basic nuclear installations, known as the "quality" order,
– The order of 31st December 1999 amended by the order of 31st January 2006 stipulates the general technical regulations, except for water intakes and effluent discharges, designed to prevent and mitigate off-site detrimental effects and hazards resulting from the operation of nuclear facilities.

– The order of 26th November 1999 sets the general technical requirements concerning the limits and procedures for water intakes and effluent discharges subject to authorisation in nuclear facilities.
– Pressure vessels specifically designed for nuclear facilities are subject to particular requirements that are regulated and monitored by ASN. They are defined in the decree of 13th December 1999 and in specific orders.

3.1.2 Main requirements applied to this specific area

ASN has in the past drawn up basic safety rules (RFS). These are recommendations which clarify the safety objectives and describe practices that ASN considers to be satisfactory. As part of the current overhaul of the general technical regulations, the RFS are being gradually replaced by "ASN guides". There are at present about forty RFS and other technical rules from ASN (which can be consulted on its website). ASN explained that main means of preventing and mitigating the consequences of accidents is "defence in depth". This involves a series of consecutive, independent levels of protection. If one level of protection, or barrier, were to fail, the next level would take over.
An important aspect in the independence of the levels of defence is the use of technologies of different natures ("diversified" systems). The design of a nuclear facility is based on a defence in depth approach.
During the country visits, ASN provided to the reviewers more details related to specific requirements on the assessment of the loss of electrical power and loss of heat sink events.
These events have been assessed as part of the licensing process of the operating plants. This assessment has been performed in conformance with the general requirements in force (single failure criterion, defense-in-depth, redundancy, diversity). ASN issued in 2000 a document called “Technical guidelines for the design and construction of the next generation of Nuclear Power Plants with pressurized water reactors” which includes also requirements related to loss of power and loss of heat sink. These requirements have been applied for EPR licensing.
ASN reported that, since the publication of the TSN Law of 2006, implementation of an integrated comprehensive, coherent and structured regulation is in progress. WENRA reference levels and requirements related to the loss of power and the loss of heat sink will be taken into account.

3.1.3 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

ASN informs that they, with the technical support of IRSN and its advisory committees, devote particular attention to rigorous regulation of safety. The regulations require the implementation of a "defence in depth" arrangement, which consists of a set of redundant, diversified measures (automation, systems or procedures) able to prevent accidents, manage them if they are not preventable or, failing which, mitigate the consequences.
ASN informs also that operating experience feedback (OEF) includes those events occurring in France and abroad with pertinence for enhancing nuclear safety or radiation protection.
No details regarding all safety analyses performed by the licensees or required by ASN are provided in the national report. Information received from the ASN and IRSN representatives, during the review meeting in Luxembourg, confirmed that the Safety Analysis Report, required for licensing purposes, covers loss of the off-site electrical power supplies and the conventional backup supplies (SBO) for one reactor on a site only, as well as loss of UHS calculated for one reactor and for the entire site, too. Also, the lines of defence provided by design are assumed to be lost in a deterministic manner.

3.1.4 Periodic safety reviews (regularly and/or recently reviewed)

A PSR in France is a standard safety assessment tool and is carried out with periodicity of 10 years, in accordance with part III of article 29 of the TSN, 13th June 2006 Act. The "defence in depth" arrangements are regular checks and systematic reviews on the occasion of the PSRs. During the PSR, a detailed inspection of the conformity of the facility with its own nuclear safety requirements is also performed and identified corrective measures as well as the measures with the aim to increase the

nuclear safety are implemented gradually. The safety improvements that have to be achieved must be defined with respect to the safety objectives of the most recent facilities.
The PSR process was explained using the 900 MW series (34 units); the third series of the PSR for the 900 MW series commenced in 2003. Besides the standard PSR topics, ASN usually requires the licensee to address generic topics as well as to demonstrate evolution of the nuclear safety. Based on a review of the comprehensive PSR report, ASN may grant operation for another 10 years. Typically, continued operation beyond 30 years can be associated with specific license conditions.

3.1.5 Compliance of plants with current requirements

The compliance of the plants with current requirements is assessed usually during the PSR. In addition, the compliance of the plant with current requirements is ensured by routine inspections performed by ASN and IRSN. For example, there are about 20 routine inspections performed at each site every year, covering 40-50 standard issues. These inspections are by means of spot-checks and by analysis of the proof of regulatory compliance provided by the licensee. Regular inspections of the LOOP/SBO design features are also performed by ASN to check compliance with current requirements. Specific inspection carried out by ASN and IRSN covered issues like risk of flooding, fuel for emergency diesel generator, etc. Routine inspections regarding the LOOP/SBO design features are also performed by the licensee.
After the Fukushima accident, all NPPs as well as 19 other nuclear facilities (reprocessing, research reactors, and fuel fabrication facilities) were inspected. Specific inspections were performed on Fukushima related topics during 2-3 days per NPP. Regular inspections were also performed but they focused mainly on those systems and features with important contribution in case of loss of electrical power or LUHS, mainly due to an external hazard, as earthquake, flooding or other extreme conditions. The licensee also performs routine inspections, including the electrical power supply facilities and systems that ensure the cooling chains, both for reactors and SFPs.
ASN deems not necessary to carry out supplementary inspections on systems and features with important contribution in case of loss of electrical power or LUHS, by the licensee or by ASN, since they are part of the regular scheme.
The inspections performed by ASN revealed that corrective actions were necessary to ensure compliance of the plants with the current safety requirements. ASN pointed out that regulatory requirements related to detection and processing of deviations have been strengthened with the publication of a ministerial order in early February 2012.

3.2 Assessment of robustness of plants

3.2.1 Approach used for safety margins assessment

In assessing the safety margins with respect to the loss of the off-site electrical power supplies and the conventional backup supplies (SBO) and LUHS the deterministic approach with conservative assumptions was used. All situations, which were required by the Stress Tests specifications were analyzed for reactor units (one reactor as well as all the units) and for SFPs.
The coping times for LOOP, SBO and LUHS without any external support, have been calculated analytically in terms of time periods to fuel damage, for different operation modes of the reactors; the threshold values were calculated for SFPs.
The national report describes in detail the design provisions of electrical systems for each NPP design operating in France and shows capabilities to cope with the LOOP and LUHS.
A deterministic approach was used for the assessments performed for the scenarios regarding the loss of safety functions. Safety analyses have been performed for LOOP and standby diesel generators for one reactor on a site only, as well as loss of UHS, calculated for one reactor and for the entire site (for Safety Analysis Report, required for licensing purpose). For the other scenarios required by ENSREG, most part of the analyses were performed by calculation, but also engineering judgment was used, especially for the cases beyond the design basis and experience feedback was considered.
All calculations performed were reviewed by the Technical Support Organisation IRSN, who checked the safety cases, methodology and results.

A brief description of the NPPs provisions to cope with the loss of power and LUHS is presented below:

- **Loss of the off-site electrical power supplies and the conventional backup supplies (SBO) of one reactor**

ASN informs that the LOOP supplies of a reactor is a situation analysed in the safety analysis; it corresponds to the loss of the main and auxiliary lines and failure of house load operation.

In general, each reactor is connected to the electricity transmission system via the "main line"; the step-down transformers supply the normal and safety buses. If the main line fails, the reactor can isolate itself from the electricity transmission system and, via the step-down transformer, continue supplying the electrical buses in "house load operation" mode. This operation mode is not credited in case of LOOP in SAR (Instrument compressed air distribution system).

The backup power sources for each reactor in service typically consist of two Emergency Diesel Generators, seismically qualified, while the EPR reactor has four emergency generators, also seismically qualified. In case of a loss of offsite electrical power supplies and backup supplies, these diesel generators are considered to be not available.

Each NPP also has an additional on-site emergency power source, whose technology differs according to the plant series involved:

- in each operating reactor, one ultimate electrical power source provided by a back-up turbine generator (LLS, seismically qualified) driven by steam from the steam generators (SG), if available. However, the licensee needs to verify the resistance of the ASG system turbine-driven pumps and the backup turbine generator (LLS) to the temperature rise in the buildings beyond 24 hours (time specified in the safety case);
- for the 900 MWe series, one ultimate backup diesel-generator set (GUS) per site (not qualified against earthquake);
- for the 1300 MWe and N4 series, one combustion turbine (TAC) per site (not qualified against earthquake);
- for the EPR reactor, two ultimate backup diesel-generator sets (SBO) per reactor (qualified at DBE) .

The station batteries provide power autonomy of one hour for the reactors in service and two hours for the EPR reactor. For the EPR, if the off-site electrical sources and the on-site backup sources fail, two batteries are dedicated to SA mitigation (called "12-hour" batteries).

In order to increase the autonomy of the plant, a robustness study for the NPPs considers a situation where the off-site electrical power supplies for the entire site are lost for two weeks. The licensee has been required by ASN to implement the corresponding procurement measures to ensure autonomy of fuel, oil, cooling water reserves, and compressed air reserves for this period.

In case of a loss of the off-site electrical power supplies and the conventional backup supplies a design solution for in-service reactors is the ultimate backup diesel-generator set (GUS) for the 900 MWe series or the combustion turbine (TAC) for the 1300 MWe and N4 series, and two ultimate SBO backup diesel-generator sets for the EPR. The "2-hour" and "12-hour" batteries are charged automatically by the SBO generator when it is in operation.

For the reactors in service, the analysis of a coping time in the event of a loss of the offsite electrical power supplies and conventional backup supplies of one reactor without external intervention is as follows:

- when the primary system is closed, the fuel will become exposed a few days after the start of the accident;
- when the primary system is partly open (i.e. the primary vents are open and the reactor closure head is still in place) and the primary system vents are closed again,, as the residual power is lower, it takes longer for the fuel to become exposed than when the primary system is initially closed;
- when the primary system is fully open (i.e. the primary vents are open and the reactor closure head is lifted), a gravity make-up of a limited fraction of the SFP water can be provided to compensate for the vaporisation caused by the loss of the primary cooling system at shutdown. This is followed by a make-up from the PTR (reactor cavity and SFP cooling) system tank:

- on the 900 MWe series, by the charging pumps of the chemical and volumetric control system (CVCS) of the neighbouring reactor; if no additional measures are taken, the fuel assemblies will become uncovered more than a day after the start of the accident;
- on the 1300 MWe and N4 series, by the mobile motor-driven cooling pump; if no additional measures are taken, the fuel assemblies will become uncovered several days after the beginning of the accident;

– for the SFP, permanent make-up by the fire-fighting water distribution or production system (JPD or JPP) pumps of the neighbouring reactor prevents the fuel from becoming uncovered.

For the EPR, a coping time in the event of a loss of the offsite electrical power supplies and conventional backup supplies for a reactor without external intervention, is as follows:

– the reactor presents no risk of core meltdown or radioactive release for at least the 24 hours of operation of the SBO generator sets;

– if cooling is ensured by the SG, the auxiliary feed water system tanks run dry after about two days, but they can be refilled, giving a total water autonomy of seven days, and the fuel would start suffering damage only after about 9 days (with replenishment of on-site fuel and oil SBO tanks);

– The SFP inventory can be maintained by one fire-fighting pump to compensate for the evaporation and avoid uncovering of the fuel assemblies for the 24 hours of autonomy of the SBO generator set; the fuel would become uncovered about 5 days after the initiating event (the core is still in the reactor vessel and the residual power in the SFP is low);

– with the reactor in a cold shutdown state with the reactor cavity filled, cooling of the SFP is ensured for twenty-four hours; the fuel would become uncovered after more than 2 days (the fuel assemblies have been moved to the SFP).

One reactor as well as all units at one site have been considered in the analysis.

• **Loss of the off-site electrical power supplies and the conventional backup supplies (SBO) and any other on-site backup electrical power source for the entire site**

This situation corresponds to the loss of the off-site electrical power supplies combined with the loss of diesel generator sets, LLS and GUS or TAC. In this SBO situation, the battery capacity of the reactors in service is about 1 hour; however their capacity can be prolonged setting the batteries in "battery saving mode" (by manual action of operators based on specific procedures), enabling high-priority consumers to be powered for longer periods of time by load-shedding of lower-priority consumers.

For the EPR reactor the four "2-hour" batteries can supply the I&C, the man-machine interfaces and the containment internal isolation valves, and two "12-hour" batteries can supply I&C dedicated to severe accidents, the severe accidents console, the iodine filtration of the inter-containment space, the containment external isolation valves and the emergency lighting of the control room, of the crisis technical room and of the fallback station.

This situation is not analyzed for the design safety case; the coping time for reactors in service is as follows:

– when the primary system is closed, the core would become uncovered more than 24 hours after the start of the accident;
– when the primary system has just been opened and if the primary system vents fail to close, the fuel would become uncovered after about 10 hours;
– when the primary system is fully open and the reactor cavity not full:
  - o for the 900 MWe series the fuel would become uncovered a few hours after the start of the accident;
  - o for the 1300 MWe and N4 series, not using the mobile motor-driven cooling pump; the fuel would become exposed several days after the start of the accident;
– for the SFP, as all the pumps of the fire-fighting water production or distribution system are not available, the fuel would become uncovered within 1.5 days.

For the EPR reactor, the SBO situation was not analyzed for the SFP; with this regard, ASN considers that licensee has to explain the missing assessment.

It is one of the results of the stress tests that the licensee needs to increase the battery autonomy.

- **SBO combined with loss of any other on-site backup electrical power source and loss of turbine driven auxiliary feed-water pumps for the entire site**

In the worst cases analysed, in this combination of events, the time until the fuel uncovery is just a few hours with the primary system closed for the EPR and with the primary system fully open for 900 MWe series.
For the SFPs, in the situations mentioned above, in the worst case analyzed, the fuel will become uncovered within 1.5 days.

- **Loss of ultimate heat sink**

Water is essential to maintain the UHS for the French plants, which is taken directly from the natural environment - the sea for coastal NPP sites, or a waterway for NPP situated on the banks of a river. The water intake structures and the pumping station pump and filter the raw water which, once collected and filtered, is used to cool the systems via heat exchangers. The pumping station is connected directly to the intake-outfall structure. For the operating reactors, each site usually has one pumping station for two plant units. Each pumping station has two redundant and geographically separated channels. The water intake structure varies from one site to another.
There are specific procedures in place developed for the NPPs for situations with very low river water levels or high intake temperatures to shutdown the plant units and ensure heat removal.
ASN informs that reactors in service are designed to have autonomy of at least 100 hours after a heat sink loss. If the heat sink loss affects all a site's reactors simultaneously, the targeted autonomy announced by licensee is 24 hours for seashore NPPs and 60 hours for riverside NPPs in the case of an unpredictable hazard (e.g. sudden influx of clogging material), and 72 hours in case of a predictable hazard (e.g. a climatic event such as extreme cold + frazil ice) in which case the tanks can be filled to maximum level as a preventive measure.
ASN informs that in France, no nuclear power reactor except the EPR has an alternative heat sink (lake, water table or atmosphere). On the other hand, some NPPs have a larger water reserve through their design. The risk of UHS loss by clogging, freezing, etc. is not addressed equally for all sites. The recent events have shown that the means currently in place have been sufficient to cope with the hazards, though sometimes with difficulty. The licensee has therefore started to reinforce the robustness of the heat sinks against the risk of a "massive influx of clogging material."
The situation of a total loss of the heat sink called "H1". This situation can affect either a single reactor or all the reactors on a site, and in the latter case it is referred to as a "whole-site H1".
For the evaluation of the impact of an H1 situation on the reactors (affecting first one, then all the reactors of a site), the licensee has identified 4 possible configurations:

- Primary system closed and residual heat removal system (RRA) not connected
- Primary system closed and RRA connected
- Primary system partly opened
- Primary system fully open

The equipment present on the site enables the following functions to be ensured for the time necessary to restore the heat sink:

- cooling of the primary pump seals;
- use of the thermal inertia of the primary system borated water reserve (PTR tank) as a backup heat sink;
- refill the auxiliary feed water system reserve tank to allow removal of residual power by the steam generators (when they are available) in the longer term.

The EPR has an alternate heat sink, which comprises two independent systems (Reactor building ultimate heat removal system and Alternate heat sink (SRU)) which themselves are made up of two redundant channels. The SRU system can draw in raw water from the main pumping station ("normal" mode) or from the outfall structure in the sea ("diversification" mode).
Because the EPR has an alternate heat sink, the licensee has not studied the consequences of a loss of the alternate heat sink on the safety of the EPR reactor, which is not in line with the ENSREG specification. For the operating NPPs, ASN observes that the licensee's calculations and reasoning imply hazard robustness of the equipment used to manage a whole-site LUHS situation.

Loss of SFP cooling depends on the residual power in the pool, the autonomy is estimated to be at least one month. In all the configurations studied by the licensee, for both the reactor and SFP, the estimated time before the nuclear fuel uncovery occurs is longer than the required time estimated to restore a correct operation of the heat sink.

- **Loss of ultimate heat sink with SBO for the entire site**

In case of LUHS combined with SBO and with the loss of the LLS, TPS ASG and TAC/GUS, the time until fuel uncovery is just a few hours with the primary system closed. In states with the primary system fully open - reactor cavity not full - the available time is a few hours for the 900 MWe series (due to the current absence of independent means for water injection to the primary system for the 900 MWe series), and about 10 hours with the primary system partly open (all plant units).
In the primary system open states on the 1300 MWe and 1450 MWe series, and in the primary system open states and reactor cavity full (all series), the available time in an LUHS + SBO situation (excluding summed effects) is longer (several days).

3.2.2 Main results on safety margins and cliff edge effects

- **Loss of the off-site electrical power supplies (LOOP)**

ASN concludes that for LOOP event, the supply management methods are capable of guaranteeing 3 days autonomy for the generator sets of the reactors in service and 4 days for the EPR reactors. ASN however requires that the site should be autonomous for two weeks under all circumstances, and notably after an earthquake or a flood leading to an isolation of the site.

- **Loss of the off-site electrical power supplies and the conventional backup supplies (SBO)**

The SBO for a NPP site in full operation represent the worst case scenario, except for 900 MWe series. Particularly the 900 MWe series is also very sensitive in shut down mode, when the primary system is open and the CVCS charging pumps are no longer available. If no complementary measures are taken, the fuel will become uncovered a few hours after the start of the accident. When the primary system is closed, the core will become uncovered more than 24 hours after the start of the accident.
The licensee proposes - for primary system just-opened situations - to modify the pressure build-up management so as to remove the residual power via the steam generators. ASN considers that the licensee must prove that the proposed change in the management of the primary system partly-open situation will effectively result in a sufficient delay before the fuel becomes uncovered and to implement external means for the medium and long-term management of a situation of loss of the off-site and on-site electrical power supplies on a site.
ASN also requested that the hardened safety core comprises electricity generating set and an emergency cooldown water supply for each reactor. These reinforcements are needed to prevent short term cliff edge effects for SBO situation. A related action plan is scheduled to be agreed upon by June 2012.
The battery discharge time has been identified as the cliff edge effect for all reactors in operation (loss of information in the control room and of the instrumentation and control).
For reactors in service, ASN requires the licensee to significantly increase the autonomy of the batteries used in the event of a loss of the offsite and on-site electrical power supplies.

- **Loss of UHS**

The cliff-edge effect in a situation of total heat sink loss ("H1") is associated with the exhaustion of the feedwater reserves. On the basis of the water volumes required by the operating technical specifications, the autonomy is several days (100 hours) if only one reactor is affected.
The cliff edge effect for a total loss of UHS at the EPR has not been indentified; an extension of the LUHS incident to the entire site, given that operation of the Flamanville 3 EPR does not require equipment common to plant units 1 and 2, a damage to the fuel of the Flamanville 3 EPR will start about 9 days after loss of the heat sink.
The cliff-edge effects associated with the environmental qualification (resistance to ambient temperature) of the equipment required in H1 situations have not been investigated. Besides that in the current design safety case (baseline safety standard in national report) has not defined systematic requirements relative to earthquake resistance and flood protection of the equipment used in H1 situations.

ASN considers the demonstration of the licensee's capacity to manage a whole-site H1 situation is insufficient in the long term. Certain weaknesses in the capacity of the facilities to withstand a whole-site H1 situation induced by an earthquake, including the current design safety case earthquake, or by flooding beyond the design safety case. In those cases, the core could become uncovered in just a few hours in an H1 situation (for all plant states).
The EPR's alternate heat sink is not guaranteed in the event of a design-basis earthquake, but the licensee committed to verify its resistance to earthquake.

- **Loss of UHS with SBO**

Short-term cliff-edge effects were identified in the combination of SBO and LUHS (H3) situation, which is characterized by a shorter time before core uncovery than the time planned for the implementation of the remedial measures.
ASN considers that the licensee must back up its conclusions regarding the capability of the NPPs to manage a degraded situation (LUHS or SBO) on several plant units simultaneously, including when a plant unit suffers a severe accident. If necessary, the licensee will define additional provisions for the management of this situation.

3.2.3 Strong safety features and areas for safety improvement identified in the process

The licensees analyzed the loss of heat sink and loss of electrical power supply situations for the reactors, which go beyond the situations studied in the current design safety case, in particular considering that the postulated situations are assumed, on the one hand, to affect all the reactors on a site, on a long-term basis and, on the other, to be possibly the result of an off-site earthquake or flooding, including a level higher than that considered in the current design safety case requirements. Analyses showed that certain heat sink and electrical power supply loss scenarios can, if nothing is done, lead to core melt in just a few hours in the most unfavourable circumstances (SBO on a whole site, 900 MW, primary system fully open and reactor pool not full). The licensee identified numerous measures that can prevent the cliff edge effects by increasing the time lapse before the fuel becomes exposed.
The SBO generator sets at EPR already have robustness features. ASN will request the licensee to integrate these generators in the “hardened safety core”.
For reactors in service, ASN will ask the licensee to integrate an electricity generating set and an emergency cool down water supply for each reactor in the "hardened safety core" of the material and organizational measures, which will be subject to more stringent requirements, particularly with respect to the earthquake and flooding risks. These measures will have to allow control of the basic safety functions in exceptional situations. They will thus ensure an ultimate protection of the facilities, with the following three objectives: prevent a severe accident or limit its progression, limit large-scale releases in the event of an accident which it was not possible to control, enable the licensee to perform its emergency management duties. ASN requested the licensee to propose corresponding specifications and procedures by 30th June 2012, which shall include significant fixed margins with respect to the design-basis requirements. The hardened safety core will be based mainly on new equipment diversified form the existing one to prevent common cause failure.
The vulnerability of the UHS at operating NPPs as highlighted by recent events of clogging and partial loss of the heat sink at Cruas and at Fessenheim in December 2009, has led the licensee to initiate a plan of action to reinforce the robustness of all NPP heat sinks.

3.2.4 Possible measures to increase robustness

ASN informs that a number of measures were identified to be implemented in short and long term safety improvement programs, in order to increase the robustness of the operating NPPs and to increase the safety margins. These measures are already in place, planned or are being planned and they resulted from the assessments performed by the licensee as well as from the inspections and walk downs at the NPPs.
In addition to the hardened safety core, ASN identified about 40 different requirements that contain short-term and mid-term safety measures. These measures involve in general a seismic qualification of SSC that are currently not qualified, but are considered in the chain of preventive or mitigative measures in the course of accident, safety improvement of the existing design features (e.g. battery

capacity), as well as the installation of new equipment, e.g. diesel driven make up pumps for primary and secondary circuits.
The short-term measures are to be implemented by March and June 2012 (ASN requirements) and long-term measures by the year 2018 (as for example one ultimate backup diesel generator for each reactor as part of the hardened safety core, etc.). Temporary measures are also envisaged before the long term measures are implemented; e.g. to deploy one mobile diesel generator per unit before 2013.

3.2.5 Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators

Based on examination of the licensee reports by IRSN a number of issues requiring the licensee's attention were identified to increase the safety margins. A list with the measures proposed to be implemented was presented, as well as the schedule for their implementation.
For the 900MW series, the licensee proposed measures to improve the performance of the RCP seals under SBO conditions when the reactor is initially in power operation. In this condition, there is only one make-up pump to seal injection for two reactors. These measures comprise studies to determine the appropriateness of the flow that supplies the primary pump seals of each of the two reactors of the 900MWe series, robustness tests on state of the art high-temperature seals, operation with accelerated cooling and an examination of the devices existing or under development. A first licensee position is expected at the end of the first half of 2012 on a design modification allowing simultaneous injection at the seals on the two neighbouring reactors of the 900 MWe series.
For the 900 MWe series, the licensee will install a diesel motor-driven pump that ensures adequate make-up of the primary system, when it is open; and installation of the "ultimate backup diesel generator" which will supply power to a means of make up the primary system.
For the EPR reactor, the licensee will present an analysis of the situation with generalized electrical power failure by the end of 2012, and decide whether additional provisions are necessary.
Furthermore, ASN will require that the licensee sets up a "hardened safety core" of material and organisational measures to guarantee the operational nature of the structures and equipment, such as to be able to manage the basic safety functions in these exceptional situations. It has been clarified that the hardening measures will be applied not only to major equipment, such as the ultimate diesel generator or ultimate make-up means, but also to all the pertinent electrical distribution systems.
Specifications for this hardened safety core are to be proposed by the licensee with a level of robustness to be significantly beyond design. They will be reviewed by ASN by the end of 2012.
Also, a FARN shall be established that will be able to provide equipment and personnel trained to cope with site emergencies and severe accidents, aimed to be fully operational on-site within 24 hours, in continuity and replacement of the operating teams that will have up to then fulfilled the emergency measures for the site, taking into account that site access infrastructures may be partially destroyed. This requirement is based on lessons learned from Fukushima event. The four groups of the FARN shall be implemented by 2014. About 400 personnel need to be trained and specialized equipment, designed with large safety margins. However, detailed criteria are not yet defined. The four groups are considered to cover all sites.
Some other measures were already implemented in order to improve the plant response at the loss of power/ loss of UHS scenarios, including those resulting from external hazards. One of the measures, identified by the licensee before Fukushima, is related to the prevention of pressure meltdown sequences for reactors in operation. This is based on opening of the pressuriser SEBIM valve tandems, which causes a rapid de-pressurisation of the primary system. To fulfil this "primary system depressurisation" function, the current design of the remote control of the pressuriser SEBIM valves requires permanent energising of their solenoids. In case of discharged batteries or unavailability of power cables, depressurization cannot be achieved. The modification proposed by the licensee aims - in a situation of total loss of electric power sources and exhaustion of the batteries - to control the valve solenoids directly from the relaying rooms from a new stand-alone Mobile Backup Means (MMS). ASN considers that the proposed improvements, which meet the CSA specifications, must be implemented,, which is planned to take place in the framework of next 10-yearly inspection of each reactor. This is possibly a topic of potential general interest for exchanging information on solutions,

in terms of configuration and requirements assigned to the system devoted to such a depressurization function, as implemented in each MS on PWR units.

3.3 Peer review conclusions and recommendations specific to this area

The assessments performed and presented in the French national report related to the loss of electrical power and LUHS or their combinations are in general in line with the ENSREG specification. For the cases which have not been analyzed for the stress test (e.g. loss of the primary and alternate heat sinks for EPR, SBO for the SFP at EPR etc.) ASN required the licensee to complete the remaining assessments by the end of 2012. The peer review team observed that there is redundancy and diversity in the electric and cooling capabilities to ensure safety functions.
Besides that there are plans to increase system robustness to cope with SBO and loss of UHS.
Several issues were identified in particular for the 900MWe series plants as possible cliff edge effects, but also for the other operating NPP designs. The peer reviewers noted that the measures proposed to remedy these findings and that short- and long term safety improvement measures have been identified.
Even if specific safety improvements have not been implemented yet, ASN presented during the country visit the draft requirement that will be issued to the licensee by April 2012, after formal consultation of the licensee as the French regulation requires. This document contains prescriptions for implementation of the measures mentioned in Section 3.2.4 and 3.2.5 above.
The draft schedule for implementation of these measures is between 2012-2018.
The peer review team noted that ASN already requested the licensee to increase seismic resistance of equipment used to manage LOOP, SBO and LUHS situations. The seismic qualification will continue at several SSCs that are considered as measures to prevent or mitigate the core damage risks (SBO, LUHS). The battery autonomy is currently an issue that needs to be addressed at all operating NPP designs.
Batteries have an important role in case of a SBO because they ensure the minimum operability of some consumers important to safety, the monitoring of the plant parameters and emergency lighting. The reviewers observed that the battery discharge time by design is in the range of 1 hour and it is expected to increase the autonomy by well-prepared load shedding and staggering strategies
ASN has asked the licensee to ensure the availability of power supply for the I&C for the main control room and other fundamental functions to be included in the hardened safety core. The reviewers recommend ASN to also consider the benefits of recharging the batteries before their complete depletion in case of a total SBO in addition to the foreseen battery capacity increase.

4 PLANT(S) ASSESSMENT RELATIVE TO SEVERE ACCIDENT MANAGEMENT

4.1 Description of present situation of plants in Country

France has a fleet of 58 operating PWR units, which is the world's second largest, producing most of the electricity consumed in France. These plants were all developed by Framatome from the initial Westinghouse design. All of the PWR plants are one of three variations of the design, having output powers of 900 MWe, 1300 MWe, and 1450 MWe. One more EPR power plant is currently under construction.

4.1.1 Regulatory basis for safety assessment and regulatory oversight (national requirements, international standards, licensing basis already used by another country…)

Preventing the hazards and detrimental effects of all types that nuclear facilities are liable to create, such as nuclear or non-nuclear accidents, radioactive pollutions and others are covered by the TSN Act from 2006.

4.1.2 Main requirements applied to this specific area

In France, there are no direct requirements for the licensees to be taken into consideration concerning severe accidents. However, the establishing of EOPs and SAMGs are assessed by the national regulator (ASN), before taken into operation. The ASN has the role to define standards for nuclear safety in France and to ensure their application and plans to include all WENRA reference levels into national legislation by the end of 2013.

4.1.3 Technical background for requirement, safety assessment and regulatory oversight (Deterministic approach, PSA, Operational Experience Feedback)

The demonstration of the safety of the French NPP is based firstly on a deterministic approach, by which the licensee guarantees the resistance of the installation to reference accidents. This approach is supplemented by probabilistic safety assessments (PSA) based on a systematic examination of the accident scenarios to assess the probability of arriving at unacceptable consequences. They help to determine whether the measures adopted by the licensee are satisfactory or not.
For the existing reactors, the PSAs are carried out and updated during the 10-year reviews. For the future reactors, the PSAs are developed at the same time as the design becomes clearer so as to highlight situations involving multiple failures for which measures must be taken to reduce their frequency or limit the consequences. In France level 1 and level 2 PSA are used, although for some reactors several external events are currently only covered by PSA level 1.
The next PSA, conducted for the following PSR should include internal hazards (fire, flooding, explosion), external events (extreme weather conditions, external flooding, earthquake, environment and human activity of the vicinity of the power plant), and the SFPs.
ASN also examines the operating experience gathered in the nuclear facilities. It ensures that the licensee has made a pertinent analysis of the event, has taken appropriate steps to correct the deficient situations and prevent a reoccurrence, and has sent out OEF. ASN and IRSN also conduct an overall examination of experience feedback about events. This feedback can result in requests to improve the condition of the facilities and the organisation adopted by the licensee, but also in changes to the technical regulations.
The French reactors are all governed by a defence in depth philosophy, where provisions are divided into 5 different levels, for which levels 4 and 5 are dedicated to the management of severe accidents.

4.1.4 Periodic safety reviews (regularly and/or recently reviewed)

In addition to continuous monitoring, the licensees are required – under ASN oversight – to periodically review (every ten years) the safety of their facilities. The level 1 and level 2 PSAs are used in the PSRs to evaluate the frequency of core meltdown or release and, for PSA1, how it has evolved with respect to the evaluation made at the end of the preceding review. The identification of the main factors contributing to the total probability of core meltdown or the probabilities of releases reveals any weak points for which changes to the installation or its operation are considered advisable or indeed necessary.
The ten-yearly PSRs depend on the different reactor series, and are adapted for every 10 year period. The licensees have to take into account modifications before the given inspection. The PSR is also an opportunity for a detailed inspection of the conformity of the facility with its own nuclear safety requirements. Its aim is also to make changes to the facility in order to improve its level of safety and as far as possible comply with the requirements applicable to the most recent facilities. The safety review enables ASN to assess the possibility of continuing with operation of the facility up until the next ten-yearly PSR.

4.1.5 Compliance of plants with current requirements (national requirements, WENRA Reference Levels)

The compliance of the NPP to the current national requirements is ensured via the PSRs, conducted every 10 years (see preceding section). These reviews are the reference for the application of updates to the requirements. Furthermore the ASN conducts over 500 inspections per year to confirm the application of the latest safety standards. For urgent requirements (as for some improvements resulting

from the Fukushima experience feedback) a shorter delay might be required for reinforced measurements to be taken into account.
The French NPPs generally follow the WENRA reference levels for severe accident management. Provisions to mitigate cliff edge effects, such as high pressure core melt scenarios, containment degradation by molten fuel or slow pressurization, hydrogen management, etc. are taken into account. The report mentions the existence of the necessary procedures and guidelines to manage severe accidents. Furthermore France takes part in international exchanges and co-operation examining the safety standards in their NPPs.

4.2 Assessment of robustness of plants

4.2.1 Adequacy of present organizations, operational and design provisions

4.2.1.1 Organization and arrangements of the licensee to manage accidents

From a legislative point of view, the licensee is required to provide human resources to deal with severe accident conditions up to 24 hours. The On-Site Emergency Plan (PUI) defines the functions necessary for managing the emergency and the conditions of shift relief. The internal PUI exercises held by the licensee cover all the domains, design accidents, fuel building incidents and severe accidents.
After that time, nation-wide teams are foreseen to help. Currently, the “GIE Intra” intervenes in case of nuclear crisis and the inter site assistance (AMT-C) is able to provide assistance. It is made up of EDF (Électricité de France, licensee of the French NPPs) centralized departments, which are used to go to NPPs for maintenance operations. They have a nuclear background, but they are not trained to SA situations, as they don't do any exercise of that kind. Their intervention on site would be supervised by the site emergency team.
In the future, the creation of FARN is planned with material and crews. This team is required to be operational on site within 24 hours.

4.2.1.2 Procedures and guidelines for accident management (Full power states, Low power and shutdown states)

The licensee’s site emergency organisation is described in the site PUI, which is required by the regulations and devised to cover situations presenting a significant risk for the safety of the facilities, and which can lead to the release of radioactive, chemical or toxic substances into the environment. The PUI covers the management of SAs. It also describes the measures designed to aid and protect the people present on site, preserve or restore the safety of the facilities and limit the consequences of accidents for the public and the environment.
The procedures implemented in the management of SAs, the training and exercise drills are part of the SAMG (also called GIAG in French) and the sites' PUI baseline.
SAMGs exist for all reactors series. The main strategy of management of a SA is the same for all the existing plants (the priority is to maintain the containment). Operational documents are different for each type of reactors series (900 MWe, 1300 MWe, 1450 MWe): they are adapted to the differences in the design. Loss of instrumentation is taken into account (for instance opening of the venting system “U5” based on with pre-calculated curves, if the measurement of the pressure in the containment is not available).
The French SAMGs however, do not cover accidents in the SFP, and do not include multi-unit events. Shutdown states are currently only implemented for the 900 MWe series, their implementation for the other series of the French reactor fleet is foreseen. ASN will request improvements regarding these points.

4.2.1.3 Hardware provisions for severe accident management

Risk due to the production of hydrogen:

Since the end of 2007, all the reactors in service are equipped with passive autocatalytic re-combiners (PAR). PARs designed for design based accidents (DBA) are seismically qualified but those for severe accidents do not have seismic qualification.
The Flamanville 3 EPR will have PARs and devices for monitoring the concentration and distribution of hydrogen in the containment by interconnecting the two parts of the containment and favouring mixing by convection.
Risk of slow pressurisation of the containment:
On the reactor fleet in service, this risk is dealt with by the containment spray system to cool down the containment and wash out fission products. If this is not available, there is a filtered venting system "U5" and an associated operating procedure allowing decompression and filtration of the reactor containment in order to maintain its long-term integrity. Filtration is divided between an inside containment pre-filter and a sand bed filter common to two reactors for the 900 MWe series. The opening of this system, which is an ultimate reactor containment protection measure, takes place after at least 24 hours as from a minimum pressure equal to the containment design pressure (about 5 bars absolute for all the plant series).
For the EPR the licensee plans to add a mobile and independent water makeup system in the reactor building via the containment spray system, which would be deployed within 48 hours of the beginning of the accident. In addition, ASN is asking the licensee to identify the existing or additional systems to be included in the hardened safety core, to ensure management of pressure in the containment in a SA.
Elimination of the risk of high-pressure fuel damage or core meltdown:
In order to avoid a high pressure fuel meltdown, the primary system needs to be depressurized.
To fulfil this primary system depressurisation function, the current design of the remote control of the pressuriser SEBIM valves requires permanent energising of their solenoids, and therefore the availability of the electrical power source and power cables. A modification to improve SEBIM valve opening reliability, decided before the Fukushima accident and already been applied on certain reactors, is planned for the next 10-yearly inspection of each reactor.
The modification proposed by the licensee also aims - in a situation of total loss of electric power sources and exhaustion of the batteries - to control the valve solenoids directly from the relaying rooms from a new stand-alone Mobile Backup Means (MMS).
For the Flamanville 3 EPR, the licensee indicates that the EPR is designed with two redundant primary system discharge lines enabling the primary system to be depressurised and avoid the risk of reactor vessel rupture at high pressure.
Hydrogen deflagration in the annular space:
the licensee undertook to study the hydrogen risk in the other peripheral buildings of the reactor containment. The study of the hydrogen risk in the inter-containment space on the 1300 MWe reactors is in progress as part of the PSR associated with their third 10-yearly inspection.
Basemat melt-through and ex-vessel corium flooding:
On the operating reactor the risk of basemat melt-through is limited or delayed by re-flooding the corium in the vessel or injecting water into the reactor pit via the vessel and the containment spray system to keep the corium flooded. So-called "ultimate" alignments can be implemented by the emergency teams to flood the corium. Complementary corium-concrete interaction tests (tests CCI-7) are planned for 2012 to confirm the possible stabilisation of a corium pool by means of flooding from above.
Flooding of the cavity introduces a risk of ex-vessel sudden steam production (steam explosion). the licensee has informed that an international research program is in progress to characterise the conditions of occurrence and intensity of such phenomena. According to the licensee the available studies show the containment to be well able to withstand the loads resulting from a steam explosion.
For the Flamanville EPR, a corium catcher situated in a special compartment on the edge of the reactor pit, is designed to collect, cool and stabilise the corium.
Possibility of using existing equipment:
For the use of existing equipment, the licensee (EDF) indicates in its reports that the equipment used is generally SA specific equipment and, if conditions permit and its use is compatible with the containment control objective, non-SA-specific equipment. There is a limited number of equipment items specific to the SA domain on the the licensee sites.

For operating NPPs, currently the baseline safety standard however contains no hazard-resistance requirements for the SA-specific equipment and instrumentation. Consequently their availability cannot be guaranteed in extreme situations. Therefore the ASN will require the licensees to integrate the equipment necessary for emergency management, including the SA equipment, into the "hardened safety core", which is a group of important equipment and instrumentation that need to be qualified to resist well beyond the current design basis.
Provisions for using mobile devices:
There is a local mobile device dedicated specifically for SA situations: a processing unit for the plant unit radiation monitoring system (KRT) for spectrometric measurements during containment venting. Other mobile devices not specific to severe accident management can also be used, if they have been set up before entry into the SA condition and if their operation is not contrary to the severe accident management objectives.
ASN observed that the equipment necessary for emergency management, and in particular the MMS (mobile safety equipment), the PUI equipment and the MDC (complementary domain equipment), was not managed satisfactorily by the sites and that the storage conditions did not guarantee permanent availability, particularly in the event of external hazards. For ASN, the equipment necessary for emergency management must be included in the "hardened safety core" of tightened material and organisational provisions. The devices, their storage places and deployment procedures must be identified in the site PUIs. They must be tested regularly, and training in their deployment must be provided during exercises. ASN will issue a requirement on this subject.
The French national report presents an extensive analysis of cliff edge effects in the domain of severe accident management. These include design features to prevent fuel damage in the core and SFP, depressurize the reactor coolant system, mitigate hydrogen, prevent containment overpressure and prevent basemat melt through. Most of these were implemented due to experience feed-back since the Three Miles Island accident, further details are given in section 4.2.3.
Re-criticality is excluded when the corium is not fragmented in water. When flooded, and before reactor pressure vessel (RPV) failure, the use of borated water is mandatory.

4.2.1.4 Accident management for events in the spent fuel pools

Hydrogen management:
The licensee studied the following elements concerning the hydrogen management:

- The phenomena capable of generating hydrogen (radiolysis, zirconium/steam reactions)
- The possible build-up of hydrogen;
- The means implemented to prevent hydrogen explosion or detonation.

The presence of fuel assemblies in the SFP can lead to the production of hydrogen by radiolysis of the water. An additional analysis is being initiated to assess the possible risk in the absence of ventilation.
The licensee also states that oxidisation of the cladding by steam, would lead to the production of hydrogen in sufficiently large quantities to exceed the flammability threshold, but that bearing in mind the means used to prevent uncovering of the fuel assemblies, the risk of hydrogen production by oxidisation of the zirconium cladding is ruled out.
The licensee therefore proposes completing its thermo hydraulic studies of the fuel storage pool before the end of 2012, taking account of the different behaviour of the various areas of the SFP. In accordance with the hydrogen risk studies, particular steps may need to be taken depending on the result of these studies, such as the installation of passive autocatalytic re-combiners in the fuel building. These studies cover both the NPP fleet in service and the future reactors.
Mitigation of releases after fuel melt:
In the case of an accident involving loss of pool cooling, this would lead to boiling of the water in the pool. Dynamic containment would then no longer be effective, as the filtration is ineffective in the presence of the steam given off by SFP boiling. Furthermore, the fuel building consists of a metal cladding roof and a thin concrete wall (about 30 cm), for the entire fleet in operation. The fuel building is not therefore designed to ensure containment in the event of a pressure rise following a release of steam owing to boiling of the SFP.
Instrumentation necessary for accident management:

The licensee analysed the adequacy and availability of the required instrumentation for monitoring the parameters of the SFP in the event of a severe accident.

For the NPPs in operation and the EPR (European pressurized reactor under construction in Flamanville), the licensee proposes studying the steps to be taken to reinforce the robustness of the instrumentation in the SFP (water temperature, water level, dose rate in the hall) to ensure management of the situation and in particular management of makeup. This means further qualification to SA environmental conditions and against external hazards; and ensuring electrical power supply (SFP instrumentation will be included into the hardened safety core).

Other issues:

The licensee did not study the possible consequences of a loss of the integrity of the pools or cavities in the fuel building or reactor building, as well as the systems connected to them. Indeed, 1.5 m of water is enough for radioprotection. In case of core uncover, skyshine dose rate 20 m away from the SFP is 1 mSv/h. ASN will require the licensee to further analyse this issue. Furthermore, ASN considers that the natural hazards to be considered as part of the stress tests can induce risks other than the loss of electrical power sources or heat sinks, such as deformation of the storage racks, falling loads, shaking of the civil engineering structures supporting the SFP, a breach of a pipe or leak tight barrier connected to the pool and loss of integrity of a door or sluice.

Furthermore, ASN considers that changes to hardware or to operating conditions to prevent uncovering of an assembly during handling in the event of a transfer tube break must be examined.

The studies performed on possible accident mitigation in the SFPs revealed some vulnerabilities on the present instrumentation. The proposed studies are a first step in order to improve safety in case of a severe accident. It is however very difficult to control the mitigation of releases after fuel melt, as the building where the spent fuel is stored is not part of the containment. Therefore strong precautions must be taken to avoid accidents in the fuel pools.

4.2.1.5 Evaluation of factors that may impede accident management and capability to severe accident management in multiple units case

Extensive destruction of infrastructures around the facility:

In the event of major damage to roads and civil engineering structures, the licensee calls upon the public authorities who, in addition to the PPIs specific to the emergency situation, implement the provisions of the "ORSEC" national emergency response plan. The aim of these provisions is to facilitate site access for the duty teams. The FARN is proposed by the licensee in order to cope with this issue.

Disruption of work efficiency caused by high local dose rates, radioactive contamination and destruction of certain facilities on the site:

The licensee presents the impact of this type of situation on the accessibility and habitability of the control rooms. In a severe accident situation, if the pressure in the reactor building rises, it may be necessary to de-pressurise the containment to maintain its integrity by using a venting-filter. The licensee states that in the light of the current preliminary studies on the habitability of the control room after opening the venting-filter, temporary evacuation of the control room may be needed following opening of the filter. ASN has asked the licensee to undergo further studies on this subject and to improve this situation.

Feasibility of measures to manage accidents in case of external hazards (earthquake, flooding):

Application of the procedures by the operators in the control room is not affected by an external hazard (earthquake, flooding), as the control room is robust to the design-basis hazards. The communication means used in normal operation could be rendered inoperative by the external hazard. ASN considers that failure of the means of communication in an emergency situation is unacceptable, therefore it is vital to reinforce them, also with respect to robustness concerning the loss of electrical power. ASN will therefore require the licensees to integrate the communication means in the "hardened safety core" of reinforced material and organisational provisions.

Loss of electrical power supply:

Total loss of electrical power supplies (loss of the off-site sources and the on-site diesel generators) is a situation taken into account in the severe accident management guide (GIAG). This situation could moreover lead to loss of the telecommunication means used in normal operation. The dynamic

containment achieved by the ventilation systems would be lost, and particularly the main control room ventilation function and the filtration of that ventilation via the iodine trap. The licensee has planned to reinforce the electrical backup of control room ventilation and filtration through the Ultimate Backup Diesel Generator (DUS).
Potential failure of the instrumentation:
The instrumentation helps optimise management so as to delay or prevent entry into a severe accident situation if possible. In its reports, the licensee indicates that the situation diagnosis and prognosis are established by the emergency teams on the basis of the measurement of certain identified parameters. In case of loss of the electrical power supplies for the operating NPPs, the instrumentation that detects entry into the SA situation is no longer available in the control room. The licensee has undertaken to ensure the electrical backup of this instrumentation by adding an Ultimate Backup Diesel Generator (DUS). However, for the operating NPPs in the event of an earthquake, the availability of the instrumentation useful in SA situations is not guaranteed because it is not earthquake classified. These should therefore also be integrated into the hardened safety core.
Impact of other neighbouring facilities on the site:
The hazardous phenomena associated with the hazard sources (explosive, thermal, toxic, etc.) of the industrial facilities presented in the hazard studies have been taken into account in the design of the NPPs and are reassessed periodically. ASN nevertheless considers that licensees must examine these hazardous phenomena in the extreme situations analysed in the Fukushima aftermath and draw its conclusions as to the complementary measures required.
Capability to severe accident management in multiple units' case:
The licensee indicates that it has analysed the sizing of the operating teams for application of the current severe accident management procedures, particularly for events affecting several reactors. It indicates that in this context it has postulated the situation where it is impossible for the on-call teams to reach the site for the first 24 hours following an unpredictable large-scale hazard affecting the entire site. The licensee concludes from these analyses that the sizing of the operating teams, in conformity with the current baseline, does not always allow application of the SPE (permanent surveillance document).
ASN considers that the operating and emergency teams must be of adequate size to ensure all their duties on all the site's installations. ASN will therefore require the licensee to supplement its organisation to take into account accident situations affecting all or part of the facilities of a given site simultaneously.
The studies below show lacks in the availability of instrumentation and communication means as well as in the habitability of the control rooms. The proposed improvements are very important, as a malfunction of any of these components has to be avoided as far as achievable.

4.2.2 Margins, cliff edge effects and areas for improvements

4.2.2.1 Strong points, good practices

Generally speaking the French reactors have been updated continuously since their construction, and France has an extensive programme in order to improve nuclear safety of their plant by regularly implementing new safety relevant features. A more detailed list of such features is given in section 4.2.1 and 4.2.3 with a dedicated paragraph concerning the upgrading of the plants since the original design.
Furthermore, in its national report, the French nuclear safety authority provided a detailed study on very precise scenarios (such as falling containers in SFP, possible accidents due to breaking of the transfer tubes, possibilities for on-call teams to access the site in severe accident scenarios, etc.). The mitigation of cliff edges is mainly reinforced by the introduction of a “hardened safety core”, i.e. a set of elements required to manage severe accidents which should be resistant to beyond DBA. Moreover, the creation of a FARN, is foreseen. More details on these improvements are given in section 4.2.3.
Several measures to prevent fuel dewatering in the SFP are also requested.

4.2.2.2 *Weak points, deficiencies (areas for improvements)*

The French safety provisions originally did not take into account the fact that severe accidents can be caused by natural hazards. For the operating reactors some equipment needed for the management of severe accidents is not qualified for beyond DBA. These include the venting filters, but also mobile equipment. They have been pointed out by the licensee and the ASN required general improvement of such equipment.

Another issue is the habitability of the control rooms in the event of a severe accident and mainly after opening the venting system. ASN has asked the licensee to undergo further studies on this subject and to improve this situation. These include improvements in the provisions for multiple unit events. These issues should be treated by the instauration of the means proposed by the licensee and ASN and are of upmost importance.

4.2.3 Possible measures to increase robustness

4.2.3.1 *Upgrading of the plants since the original design*

Improvements have been made to the reactors in operation and are designed into the EPR reactor, owing to the work achieved since the Three Mile Island accident. ASN is also making efforts to ensure that limiting radioactive releases into the environment in the event of any accident is a major objective of the continuous process to improve the safety of the installations. This process in France is in particular organised around the ten-yearly PSRs, which aim to enhance the baseline safety requirements applicable to the installations. In this way, the filtered venting system as well as the re-combiners were not included in the reactors since their design, but were part of the upgrading programs.

4.2.3.2 *Ongoing upgrading programs in the area of accident management*

Ongoing upgrading programs include studies of the hydrogen risk in peripheral buildings of the reactor containment. The study of the hydrogen risk in the inter-containment space on the 1300 MWe reactors is in progress as part of the PSR associated with their third 10-yearly inspection.

Moreover, for the reactor fleet, examination of the potential contamination of the groundwater by liquid radioactive releases, is in progress. As part of the complementary safety assessments subsequent to the Fukushima accident, the licensee decided to speed up the studies in response to the ASN requests. Furthermore, the possibility of implementing countermeasures to basemat melt-through and soil pollution are among the topics being examined as part of the more general ten-yearly safety reviews framework. In this context, ASN will be asking the licensee to send a feasibility study on the implementation of technical arrangements to prevent the transfer of radioactive contamination to the groundwater in the event of a severe accident leading to melt-through of the basemat by the corium.

4.2.4 New initiatives from operators and others, and requirements or follow up actions (including further studies) from Regulatory Authorities: modifications, further studies, decisions regarding operation of plants

4.2.4.1 *Upgrading programmes initiated/accelerated after Fukushima*

FARN:

In order to cope with accidents beyond 24 hours, the creation of a FARN is foreseen. It will be composed by specialized crews and equipments. These crews will be made up of the licensee's employees based on 4 NPPs distributed in France. Near to these 4 NPPs, the FARN equipments will be stored in regional basis.

The FARN must be capable of intervening on accident sites in less than 24 hours to relieve the shift teams and deploy the emergency means of resupplying power, with operations on a site starting within 12 hours after the start of mobilisation. The FARN teams must be dimensioned to intervene on a 6 reactors-site, including a site where a massive release has taken place, and have appropriate instrumentation that can be deployed on the sites on arrival.

In case of emergency at multiple sites the FARN intervention could be adapted according to priorities defined by the the licensee national emergency organisation.

Hardened safety core (“Noyau dur”):

To ensure an ultimate protection of the facilities and in order to cope with severe beyond design basis accidents (BDBA), the ASN requested the licensee to define a certain “hardened safety core” of material and organizational measures, which will have to allow control of the basic safety functions in exceptional situations, with the following three objectives: prevent a severe accident or limit its progression, limit large-scale releases in the event of an accident which it was not possible to control, enable the licensee to perform its emergency management duties. ASN requested the licensee to propose corresponding specifications and procedures by 30th June 2012, which shall include significant fixed margins with respect to the design-basis requirements. The hardened safety core will be based mainly on new equipment diversified form the existing one to prevent common cause failure. This hardened safety core shall be defined by June 2012 and must include:

– the emergency management rooms and equipment (they must display high resistance to hazards and allow the management of a long-duration emergency)
– the mobile devices vital for emergency management;
– the active dosimetry equipment, the measuring instruments for radiation protection and the personal and collective protection equipment, which must be permanently available in sufficient quantity on the sites;
– the technical and environmental instrumentation for diagnosing the state of the facility and assessing and predicting the radiological impact on the workers and populations,
– the communication means vital for emergency management are included in the hardened safety core provisions. They more particularly comprise the means of informing the public authorities and alerting the populations if the off-site emergency plan (PPI) is triggered in the reflex response phase;
– strengthened equipment including, for NPPs, an electricity generating set and an emergency cooldown water supply for each reactor.

Furthermore, qualification against external hazards of the hydrogen recombiners and the venting filters in use on the reactor fleet will be requested.

With regard to the Flamanville EPR reactor, it will have to integrate such hardened safety core measures. ASN deems that the design of this reactor already offers improved protection against severe accidents which should make it easier to create its hardened safety core. the licensee will identify the existing or additional systems to be included in the "hard-core", in particular to control the pressure in the containment in the event of a severe accident.

Further issues:

The licensee proposes several improvements or studies to reinforce the management of accident or severe accident situations on its sites.

These improvements target more particularly:

– the appropriateness of the human and material resources for the activities associated with deployment of the "hardened safety core" equipment and the additional equipment proposed earlier,
– the reinforcement of the material resources and communication means,
– the conducting of a study to improve the resistance and habitability of the safety building;
– the design of a Local Emergency Centre, integrating stringent habitability requirements and allowing more effective management of the emergency. The design requirements taken into account shall be consistent with those of the hardened safety core,
– the reinforcement of the means of measurement and of technical and environmental information transmission, including meteorological information, necessary for emergency management;
– the complementary measures to reduce the risk of loss of water inventory in the SFPs;
– the management of subcontractors and skills of the licensee’s workforces.

These include improvements in the provisions for multiple unit events.

4.2.4.2 *Further studies envisaged*

Optimisation of venting filter:
Besides the requirement to make the U5 filter earthquake resistant, the filtration efficiency if used on two reactors simultaneously (in the case of the 900 MWe series) as well as the improvement in the filtration of the fission products, especially iodine isotopes will be studied. During the country visit additional information was provided about the alkalization of the sumps by introducing Sodiumtetraborate baskets, which are already implemented at some plants, to retain organic iodine in the sump and minimize releases during venting.
Also the impact of the oxygen already present in the filter pipe resulting in the risk of hydrogen deflagration and its possible consequences at the system outlet will be studied.
Habitability of control rooms:
ASN will require the licensee to carry out a detailed study of the radiological consequences of opening, notably on accessibility of the site, of the emergency management rooms and of the control room. They shall be accessible and habitable during long-duration emergencies and designed to accommodate the crews necessary for long-term site management. According to the licensee, preliminary results presented during the country visit, show that the site accessibility and habitability of the main control rooms and local emergency rooms in case of filtered venting actuation is not compromised.
ASN will require the licensee to ensure, from the control rooms, the emergency shutdown panels or the emergency management rooms, the control and monitoring of all the reactors of a site in the event of hazardous substance releases or opening of the venting-filtration system.
Furthermore feasibility studies of technical measures to protect ground water and surface water in the event of a severe accident are foreseen.

4.2.4.3 *Decisions regarding future operation of plants*

ASN considers that the facilities examined offer a sufficient safety level to require no immediate shutdown of any of them. At the same time, ASN considers that their continued operation requires an increase in their robustness to extreme situations beyond their existing safety margins, as soon as possible. These include the upgrading programs mentioned in 4.2.4, i.e. mainly the implementation of a hardened safety core as well as the creation of the FARN, described earlier in more detail
A first set of requirements regarding the Fukushima experience feedback will be issued by April 2012. The definition of the hard-core equipment has to be proposed by the licensee (EDF) by the end of June 2012, and the final implementation of the last components should be achieved by 2018. In the meantime temporary provisions shall be taken, such as the use of a supplementary diesel generator.
Moreover, the Fukushima accident proved that an off-site hazard could affect several facilities on the same site at the same time. ASN will ask the licensee to complete its emergency response organisation so that it is able to manage a "multi-facility" event. For multi-licensee sites, it is also important that the licensees coordinate the management of an emergency and limit the impact on the neighbouring facilities.
ASN also considers that to date, the means of limiting releases in the event of a core melt are insufficiently robust to the hazard levels adopted in the stress tests. In the same way as for the preventive measures, ASN will be requiring that the licensee define a range of measures able to limit the releases in the event of a severe accident involving hazards in excess of those adopted in the current baseline safety requirements. The licensee will in particular propose improvements to the filtered venting system to improve its robustness and its effectiveness. The licensee will also complete its feasibility studies with a view to implementing technical measures such as a geotechnical containment or system with equivalent effect, designed to protect groundwater and surface waters in the event of a severe accident with core melt.
More particularly with respect to the spent fuel storage pools, the licensee examined the consequences of a natural hazard, assuming that the integrity of the pools equipment remains undamaged. In these situations, the licensee concludes that with regard to the residual heat removal from the fuel, long-term topping-up of the water in the pool must be guaranteed, in order to compensate for the boiling induced by the loss of cooling. This will be the subject of an ASN requirement.

4.3 Peer review conclusions and recommendations specific to this area

The licensee follows an approach based on the WENRA reference levels for severe accident management. Safety reviews ensure that the nuclear safety of the plants is evolving and that experience feedback is taken into account when improving the regulations.

The national report presents a detailed study on the possible improvements with an ambitious program of implementations to be made.

Before the Fukushima accident the French safety philosophy did not consider that a severe accident can be caused by an extreme external event. For this reason, many SAM related provisions were not seismically qualified.

The main improvements to be made in order to cope with severe accidents, possibly affecting multiple units and caused by natural hazards have been pointed out by ASN. One recommendation of the peer review process is to guarantee their implementation. The reviewers consider the identified actions to be adequate for a further improvement of the safety features. The consideration and implementation of these issues is important to be realised as soon as possible, apart from the PSRs, which are usually the reference for introducing new safety standards in France. Better resistance of the defence in depth levels 4 and 5 dedicated to severe accident management has to be achieved in order to cope with severe accidents caused by beyond design basis events and taking into account multi-unit accidents.

List of acronyms

ASG	Steam generator auxiliary feedwater system
ASN	Autorité de Sûreté Nucléaire
CMM	Maximum thousand year flood
CMS	Flood safety margin level
CNR	Compagnie Nationale du Rhône
CVCS	The chemical and volumetric control system
DBE	Design Basis Earthquake
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DUS	Ultimate Backup Diesel Generator
EDF	Électricité de France, licensee of the French NPPs
ENSREG	European Nuclear Safety Regulators Group
EOP	Emergency Operating Procedures
EPR	European Pressurized water Reactor
FARN	Nuclear Rapid Response Force
FR-NR	The French national report
GUS	Ultimate backup diesel-generator set
IAEA	International Atomic Energy Agency
IRSN	Institut de Radioprotection et de Sûreté Nucléaire
KRT	Plant radiation monitoring system
LLS	back-up turbine generator
LOOP	Loss of off-site power
LUHS	loss of electrical supply and loss of ultimate heat sink
MHPE	Maximum Historically Probable Earthquake
MMS	Mobile Backup Means
NPP	Nuclear Power Plant
OEF	Operating experience feedback
PAR	Passive autocatalytic re-combiners
PSA	Probabilistic Safety Assessment
PSHA	Probabilistic Seismic Hazard Analysis
PSR	Periodic Safety Review
REB	Dam burst or collapse
RFS	Fundamental safety rule
RRA	Residual heat removal system
SAMG	Severe Accident Management Guidelines
SAMG	Severe Accident Management Guidelines (GIAG in French)
SBO	Station Black Out (total loss of electrical power supplies)
SEBIM	Pressuriser valves
SFPs	Spent fuel pools
SMA	Seismic Margin Assessment
SRU	Alternate heat sink
SSC	Structure, System and Component
SSE	Safe Shutdown Earthquake
TAC	Combustion turbine
U5	Containment venting-filtration procedure and system
VP	Volumetric protection
WENRA	Western European Nuclear Regulators' Association