ENSREG ACTION PLAN
FACT FINDING SITE VISITS

France's Report

September 2012

1 INTRODUCTION AND BRIEF DESCRIPTION OF PLANTS VISITED

As the stress tests peer review process is finished, the follow-up of the implementation of safety improvements is to be followed through an ENSREG action plan. The first step is to develop a limited number of fact-finding site visits. As it is well known France has a fleet of 58 operating PWR units located on 19 sites, which is the world's second largest, producing most of the electricity consumed in France. For all the reactors in service, the nuclear island was designed and built by Framatome (now Areva NP), with Electricité de France (EDF) acting as architect engineer. Today these reactors are all operated by EDF. All of the PWR plants in operation are one of three variations of the design, (series 900, 1300 and N4) and one more EPR power plant currently under construction. Four NPPs are situated by the sea, representing 14 reactors in service and 1 reactor under construction. One NPP with 4 reactors (Blayais) is situated on an estuary, which means it is subject to the influences of both sea and river. The other sites are situated beside waterways (mainly large rivers).

It was decided to visit three NPPs (Chooz, Cattenom and Fessenheim NPPs) representing each design series, during the week starting on September 10, 2012. In this case the review team has been selected from the one participating in the first peer review country visit. According the terms of reference developed by ENSREG for this activity, it is included in this report a summary description of the NPPs visited, a summary of observations and the appropriate conclusions to be considered in the ENSREG follow-up.

Main Characteristics of the visited plants

The French NPPs can be divided into six groups called "series", which differ from one another in certain respects.

The thirty-four 900 MWe reactors consisting of:

- the CP0 series, comprising the four reactors at Bugey (reactors 2 to 5) and the two reactors at Fessenheim
- the CPY reactors, comprising the twenty-eight remaining 900 MWe reactors, which can be subdivided into CP1 (eighteen reactors at Le Blayais, Dampierre-en-Burly, Gravelines and Tricastin) and CP2 (ten reactors at Chinon, Cruas-Meysse and Saint-Laurent-des-Eaux).

The twenty 1300 MWe reactors consisting of:

- the P4 reactors, comprising the eight reactors at Flamanville, Paluel and Saint-Alban;
- the P’4 reactors, comprising the twelve reactors at Belleville-sur-Loire, Cattenom, Golfech, Nogent-sur- Seine and Penly.

The N4 series comprise four 1450 MWe reactors, two at Chooz and two at Civaux.

Description of the main safety systems

Each reactor comprises a nuclear island, a conventional island, water intake and discharge infrastructures, and possibly a cooling tower. The nuclear island essentially consists of the nuclear steam supply system comprising the primary system and the systems designed for reactor operation and safety: the chemical and volumetric control (RCV or CVCS), the residual heat removal (RRA or RHRS), safety injection system (RIS or SIS), containment spray system (EAS or CSS), steam generator main feedwater system (ARE or MFMS), electrical, I&C and reactor protection systems.

Various support functions are also associated with the nuclear steam supply system: primary waste treatment (TEP or CSTS), boron recovery, feedwater, ventilation and air-conditioning, backup electrical power (diesel generating sets).

The fuel storage pit

Built adjacent to the reactor building, the BK building is used to store the fuel assemblies before and during the plant unit shutdowns and to cool the spent fuel (a third or a quarter of the fuel is replaced every 12 to 18 months depending on the fuel management strategy). The fuel is kept immersed in a pool filled with the water that acts as a radiological shield and contains about 2500 ppm of boric acid to continue to absorb the neutrons. Each fuel element is placed in a metal compartment whose design and separation distance from the other compartments prevent a critical mass being reached. The fuel pit is cooled by the reactor cavity and spent fuel pool cooling and treatment system (PTR or FPC(P)S).

The primary system and secondary systems

The primary system comprises cooling loops (three loops for a 900 MWe reactor, four loops for a 1,300 MWe, 1,450 MWe, or EPR reactor), the role of which is to extract the heat released in the core. Each loop, connected to the reactor vessel containing the core, comprises a primary pump, and a steam generator (SG). The primary water, heated to more tan 300 °C, is kept at a pressure of 155 bar by the pressuriser, to prevent it boiling. The entire primary system is located inside the containment.

The primary system water transfers the heat to the water in the secondary systems, via the steam generators. The steam produced in the steam generators is partly expanded in a high-pressure turbine and then passes through moisture separator-reheaters before final expansion in the low-pressure turbines, from which it is then routed to the condenser. The condensed water is then heated and sent back to the steam generators by the extraction pumps relayed by feed pumps through reheaters.

The reactor containment building

The PWR reactor containment building fulfils two functions:

- protection of the reactor against external hazards;
- containment, thereby protecting the public and the environment against radioactive products likely to be dispersed outside the primary system in the event of an accident.

The containments are therefore designed to withstand the pressures and temperatures that could be reached in an accident situation, and offer sufficient leaktightness in such conditions.

The main auxiliary and safeguard systems

In normal operation or during normal shutdown of the reactor, the role of the auxiliary systems is to provide basic safety functions: control of neutron reactivity, removal of heat from the primary system and fuel residual heat, containment of radioactive materials. This chiefly involves the chemical and volume control system (RCV or CVCS) and the residual heat removal system (RRA or RHRS).

The purpose of the safeguard systems is to control incidents and accidents and mitigate their consequences. This primarily concerns the safety injection system (RIS or SIS), the reactor building containment spray system (EAS or CSS) and the steam generator auxiliary feedwater system (ASG or EFWS). Each reactor has redundant conventional backup sources capable of supplying the electrical panels vital for correct operation of the safety equipment. The conventional backup sources for each reactor in service consist of two emergency diesel generator sets. In addition, one ultimate backup diesel-generator set (GUS) per site (not qualified against earthquake) exists on 900 MWe series; for the 1300 MWe and N4 series, one combustion turbine (TAC) per site (not qualified against earthquake).

Other systems important for safety

The other systems necessary for reactor operation and important for safety include:

- the component cooling system (RRI or CCWS), which cools equipment; this system operates in a closed loop between the auxiliary and safeguard systems , and the essential service water system (SEC or ESWS), which uses the heat sink to cool the RRI system;

- the reactor cavity and spent fuel pool cooling and treatment system (PTR or FPC(P)S), used notably to remove residual heat from irradiated fuel elements stored in the spent fuel pool;
- the ventilation systems, which play a vital role in containing radioactive materials by depressurising the environment and filtering all discharges;
- the fire-fighting water systems;
- the instrumentation & control system and the electrical systems.

In spite of the standardizing of the French nuclear reactor fleet, a number of technological innovations have been introduced as the design and construction of nuclear reactors have progressed. Compared with the CP0 series reactors of the Bugey and Fessenheim NPPs, the CPY series has a different building design, an intermediate cooling system between the system that sprays the containment in the event of an accident and that containing the water from the heat sink, and provides for greater management flexibility.

Significant changes with respect to the CPY series have been made in the design of the circuits and systems protecting the core of the 1300 MWe reactors (plant series P4 and P'4) and the design of the buildings accommodating the installation. The increased power has resulted in a primary system with four steam generators (SG). The reactor containment has a double concrete wall instead of a single concrete wall with a steel sealing liner as is the case with the 900 MWe reactors.

The P'4 series reactors display a few differences with respect to the P4, notably the fuel building and the design of certain systems.

The N4 series reactors differ from the preceding reactors more particularly in the design of the SGs which are more compact, the design of the primary pumps, and the control room computerisation.

For the spent fuel pools of the 900 MWe CP0 and CPY series reactors, the fuel assemblies are placed in storage rack compartments. These storage racks are made from a corrosion-resistant material not specifically designed to absorb neutrons, sub-criticality being guaranteed by the geometric arrangement of the assemblies. As from the 1300 MWe series reactors, the fuel pit storage racks have been manufactured in a neutron-absorbing material in order to guarantee sub-criticality in spite of a denser storage arrangement than for the preceding reactors.

The visited plants are:

- Chooz NPP having 2 units at the same site (1500 MWe and 4720 MW thermal) belonging to N4 series. Units were commissioned in 1996 and 1997.
- Cattenom NPP having 4 units at the same site (1300 MWe, 3817 MW thermal), belonging to P'4 series. Units were commissioned in 1986, 1987, 1990, and 1991.
- Fessenheim NPP having 2 units at the site (880 MWe, 2905 MW thermal), belonging to CP0 series. Both units were commissioned in 1977.

2 SUMMARY OF OBSERVATIONS

2.1 Description of measures already decided or considered

The ASN, after the assessment of the stress test reports presented by EDF, issued on 26th June 2012, 19 resolutions (one for each site, legally binding) with around 40 requirements each and a letter signed by ASN Director General with additional 41 requests to EDF. The implementation of the safety improvements must be as soon as possible, and the deadlines are short term mostly actions requiring studies and procedures changes, as well as modifications (from 2012 to 2015), medium term actions requiring extensive hard-ware implementations (from 2015 to 2019), and long term additional actions decided by the utility (from 2019 to 2025). ASN considers that the level of safety of the NPPs is sufficient to warrant no request for the immediate shutdown of any of them. At the same time, ASN considers that their continued operation requires increasing their robustness against extreme situations beyond the initial design basis, hence the foresaid resolutions & requirements imposing measures to

reinforce the safety of the installations. The calendar for implementation of all the measures has been submitted by EDF before the end of June 2012. The expert team had access to the mentioned instructions and in particular to the ones applicable to the NPPs visited (Chooz, Cattenom and Fessenheim).

A summary of the requirements are included below:

Hardened safety core

Following the stress tests, ASN considers that a hardened safety core must be implemented on nuclear facilities to increase their robustness against extreme situations beyond the initial design. Hardened safety core definition involves implementing a range of material and organisational measures on these facilities, with the aim of enabling them to withstand:

- natural phenomena of an exceptional scale, which can sometimes be combined and can exceed the phenomena used in the design or in the periodic safety review of the facilities;
- situations involving very long duration loss of electrical power supply or cooling sources, which could affect all the facilities on a given site.

The hardened safety core Structures, Systems, Components and Equipment (SSCE) should be qualified for Beyond Design Basis Accident (BDBA) conditions taken into account above mentioned objectives.

These measures will thus ensure that the facilities are protected, with the following three objectives:

- prevent an accident with fuel melt, or limit its progression,
- limit large-scale radioactive discharges,
- enable the licensee to perform its emergency management duties

The strengthened equipment includes e.g. :

- an additional ultimate back-up diesel generator set for each reactor ;
- ultimate water supply to spent fuel pool, emergency feed water tank and emergency core cooling system tank
- new emergency control centres including
    - communication tools
    - essential plant data supervision
    - intervention facilities (hot and cold dressing rooms, etc)
    - crisis tools storage
- technical and environmental instrumentation
- operational dosimetry.

The systems, structures and components (SSCs) making up these provisions must be kept functional in extreme situations, in particular those studied during the course of the stress tests. These SSCs shall in particular be protected against on-site and off-site hazards induced by these extreme situations, for example: falling loads, impacts from other components and structures, fires, explosions. Before end of June 2012 EDF submitted the proposal for the hardened safety core.

Conformity of facilities

The conformity of facilities with the applicable requirements is considered an essential component of their safety and their capability to confront the anticipated events. Thus conformity must be controlled on a long term basis relying on a systematic search of deviations. During the stress tests, some deviations were identified which do not compromise the safety of the facilities, but could constitute factors such as to weaken them. ASN considers that EDF must reinforce its processing of deviations and consequently introduced additional regulatory provisions.

Earthquakes

The stress tests showed that there were seismic margins on EDF´s nuclear reactors, and confirmed the benefits of the periodic reviews of the seismic risk on occasion of the ten year periodic safety review. ASN asked EDF to make a number of improvements related to the seismic robustness of the facilities. The implementation of these improvements on the above mentioned hardened safety core systems will help to reinforce the safety of the facilities in cases of extreme situations to withstand at least 1.5 times Safe Shutdown Earthquake (SSE), according to EDF's proposal currently under assessment by ASN and IRSN. ASN issued several requirements associated to the seismic area to be implemented as for example

- Prevention of safety relevant equipment against damage induced by nearby equipment (reinforcement of seismic interaction approach)
- Conformity/upgrading of seismic instrumentation
- Reinforcement of existing containment venting filtration system

Flooding

The results of the stress tests in this area showed that the consequences of the investigated reference flood augmentation scenarios (beyond DBF) are different for the sites. The nuclear island platforms of some sites would remain above water level. The consequences of augmented heavy rainfall scenarios are on the centimetre scale on the nuclear island platform for most of the sites (for some of them the volumes of water associated with each could be contained by the roadways). For sites 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 rupture of the cooling systems for the facilities connected to them. For sites with the lowest margins ASN requested improvements to complete protective works and measures. For all the sites, ASN requested the improvement of volumetric protection to increase the robustness of the facilities beyond the existing safety margins.

Specifically for Fessenheim NPP and embankment of Canal d'Alsace, ASN considers the approach by EDF (analysis of failure modes, realized reinforcement work, permanent monitoring, seismic alert measures) to be appropriate. ASN has required EDF to conduct a study on the robustness of the embankments. The study will include the level of seismic robustness of the embankments and the other structures protecting the facility against flooding.

Weather conditions

ASN requests EDF to conduct before the end of 2012 studies to take account of gusting winds, extreme hailstorm and lighting and heavy snow. Additional studies are also requested as part of the 3rd periodical safety review of the 1300 MWe series (tornadoes, extreme temperatures). Besides, extreme heavy rainfall scenarios have been studied during the stress tests as part of the BDB flooding scenarios.

Loss of power supply (SBO) and loss of cooling systems

As result of the analysis conducted by EDF for the stress tests, it is concluded that certain loss of heat sink and loss of electrical power supply scenarios could, in the most unfavourable situations and without adequate response, lead to core melt in just few hours. ASN considers necessary to increase the robustness o f the facilities to be able to deal with a long duration loss of power supply and loss of heat sink. This includes among other increasing the onsite fuel and oil stock for an autonomy of 15 days, safety demonstration for avoidance a severe accident following deterioration of reactor coolant pump seals, study the advantages and disadvantages of making possible to recharge the batteries in case of total loss of power supplies, examining the means to restore long term cooling of reactors and pools, and assessing the combination of the loss of main cooling systems and SBO. EDF is required to implement reinforced measures, integrated into the hardened safety core, comprising ultimate backup water and power supply to withstand these situations.

Management of severe accident

In the hardened safety core, EDF must include the essential elements for management of an emergency in particular with the extreme situations studied during the stress tests. ASN considers that additional measures must be taken concerning emergency management and training of the personnel involved. ASN also requested EDF to include the capability to manage the multi-facility situations considered and to take into account the possible effects one facility can induce on another.

After extensive analysis, and in compliance with ASN's requirement, the utility decided to build and implement the new emergency centres on-site. Until that is implemented, the existing emergency centres will be upgraded against external hazards and improved so far as possible.

EDF will implement mobile back-up means to open the pressurizer safety valves in case of total loss of electric power. Management of hydrogen risk, containment integrity, basemat protection and improvement of the filtered containment venting have also been considered. Severe accident management guidelines (SAMGs) will be further developed to cover also the shutdown state, accidents in the spent fuel pool and multi-unit events. ASN required reinforcements of the robustness of the NPPs against accidental drainage of the spent fuel pool (break pipes and siphon phenomena), transfer tube break, fuel assembly handling in case of SBO and protection against radiation. Risk of hydrogen in the annular space is also considered as a short term issue.

- Nuclear rapid respond force (FARN)

  In order to cope with accidents beyond 24 hours and to take into account the possibility that an accident occurs at the time the site's surroundings are devastated and the relief teams unavailable, the creation of a Nuclear Rapid Response Force (FARN) is ongoing. It will be composed by specialized crews and equipments. These crews will be made up of EDF 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 EDF national emergency organization.

  ASN has asked for a gradual creation of the FARN, requiring EDF to submit its specific organization, the system will be deployable at any site by the end of 2012, with identification of the necessary skills.

- Organisational and human factors and subcontracting

  The Fukushima Daiichi accident showed that the ability of the licensee and, as applicable, its contractors, to collaborate and organise their work in severe accident conditions is a key factor in controlling such situations. ASN reinforced the monitoring of the subcontractors carrying safety related activities: a new regulation was introduced in February 2012 stating that such monitoring must not be delegated.

  ASN also requested EDF to provide, by September 2013, specific training and preparation to emergency teams to enable them to respond to a particularly stressful accident situation and to define social and psychological care to be provided for them in such situations, taking account of the family environment.

Specific observations

The plant visit was focused on the observation of activities specifically implemented or in the implementation process.

Chooz NPP

Like for the rest of NPPs, ASN issued a resolution included 26 requirements to Chooz none of them being specifically requested for this NPP. The N4 fleet design gives a high level of robustness against natural hazards and many modifications have been implemented during first 10 years outage program.

During the plant visit the operator provided information on measures taken to improve the plant robustness against external hazards and accident management:

- Protection against water inlet into the nuclear auxiliaries buildings and water stop seals devices are in place since June 2012
- Protection against heavy winds are in place in locations like the aero refrigerators of the Diesel Generators or the pipes supplying steam to turbodriven auxiliary feed water pumps
- Protection measures taken for flooding of the platform. Preventing of water flooding of safety related rooms and areas is ensured by installation of watertight barrier in the entrances to the areas, thus barriers increase the margins to flooding by around 1m
- Satellite phone communications are also in place in each control room since June 2012 and available for the shift supervisor in case of emergency
- to ensure the availability of cooling water by preventing icing of the water inlet channel, necessary piping and connection points are prepared for feeding temperate water to the critical areas of the water intake systems
- reinforcements against earthquake

Cattenom NPP

Like for the rest of NPPs, ASN issued a resolution included 27 requirements to Cattenom none of them being specifically requested for this NPP. The robustness of the plant against natural hazards has been increased by implementation of many modifications. Nuclear island and SFP were designed within NRC level of earthquake (normalized to 0.15 g zero period). The cooling water intake from the Moselle river is 3 km away and the island platform is 20 m above the river water level.

During the plant visit the operator provide information on measures taken to improve the plant robustness against external hazards and accident management:

Due to the fact that unit 3 was in outage, the plant tour included also the visit of pressurizer safety valves control and PARs in the rector building. In the SFP, installation of the missing siphon breaker hole (detected during the stress test process) has been observed.

- the already available mobile equipment as diesel engine driven pumps, Equipment for H4 safety case (loss of safety systems in the long term phases of a LOCA) were collected and stored near the emergency centre. The related maintenance and operating procedures were modified taken into account the lessons learnt from Fukushima accident;
- Earthquake robustness upgrading of the emergency equipment storage building is ongoing;
- planning of new emergency centre is on-going, its implementation is foreseen in 2019.

In case of SBO and loss of batteries, the pressurizer safety valves can be operated only locally in the reactor building. Implemented and planned modifications at the 900 series to operate the valves from I&C cabinet using independent DC supply is considered as part of the next PSR.

The building “local point haut”, which is important with regard to LUHS prevention given that the diverse cooling water connections of the river, lake and plant systems are located in it, has been visited. It was reported that, as part of the stress tests, this building has been refurbished (painting, replacement of corroded equipment, implementation of fire detection, mobile materials satisfactory stowed, etc.).

Fessenheim NPP

After the 3rd PSR of reactor n°1, ASN stated on July 4th 2011 that the operation of this reactor can be maintained for 10 additional years, if 40 demands are respected according the defined schedule, 20 of them concern the daily operation and the other 20 represent specific modifications, which indicated an committed deadline.

A breach in the dyke of the Alsace channel could lead to an important amount of water on the NPP platform. Robustness of the dyke is already demonstrated by EDF for seismic levels far beyond SSE. Nonetheless, EDF considers that an earthquake could lead to various small leaks all along the dyke and to an overall flow of 7m3/s from the channel into the plain of Alsace. EDF therefore took into account conservatively a possible flow of 20m3/s to design the volumetric protections of Fessenheim. Those conservative analyses and results were discussed in France – Germany cross border working groups.

ASN requested EDF to submit a study stating the level of seismic robustness of the embankment and the other structures protecting the facilities against flooding including the consequences of a failure of these structures.

ASN issued 29 prescriptions on June 26 2012, 13 requiring studies, 6 related to organisation matters and 10 to modifications, of those 4 are implemented. The rest are to be implemented according required schedule.

During the plant visit the operator provided information on measures taken to improve the plant robustness against external hazards and accident management:

- the volumetric protection designed against almost 3 times of the maximum "leaks" from the channel including the mobile equipment (leak tight gates, pumps and diesel generators)
- construction of the alternate ultimate heat sink for reactor 1 using underground water to be in operation by end of 2012.
- reinforcements against earthquake

In the CP0 series (Fessenheim + Bugey) there is no seal separating the part of the SF building supporting the pool from the heavy loads handling zone, between the handling zone and fuel building spent fuel pool which would prevent a transmission of loads in the event of failing of spent fuel container. ASN has hence requested EDF to implement modification to prevent such loads drop and/or to mitigate its consequences (implemented as part of the 3rd ten yearly outage in Fessenheim) and to study more precisely the consequences of such drops.

2.2 Good practices, noteworthy successes and difficulties encountered

ASN has issued resolution on June 26 2012, for each NPP taking in consideration all the general and specific aspects in a systematic way.

The most significant prescriptions are related to the hardened safety core, FARN, volumetric protection enhancement, alternate ultimate heat sink, ultimate backup diesel generator and emergency management centre.

The outcome of the stress test performance lead in several cases to accelerate implementation of already decided safety improvements as for example the reinforcement of measures to prevent accidental draining of the spent fuel pool and ultimate backup diesel generator sets.

For Cattenom NPP and Fessenheim NPP the regulator established international cross border working group with the participation of German and Luxembourg authorities and the local communities for Cattenom NPP respective German and Switzerland for Fessenheim NPP to discuss the actions taken by the licensee and ASN. This includes also walk downs and inspections at the respective plants.

Findings were reported and corrective actions were requested by the regulator. The corrective actions were all implemented in the agreed time.

The main difficulties are the long time needed for the implementation of the measures to the complete NPP fleet, due to the heavy work load of the engineering departments and equipment suppliers.

3 CONCLUSIONS TO BE CONSIDERED IN THE ENSREG FOLLOW-UP

The National Action Plan to be elaborated by ASN to the end of this year shall include all ongoing measures related to the lessons learnt from Fukushima accident, including the measures that were identified in the PSR processes prior the accident (e.g. measures related to SAMGs and depressurisation of the primary circuit). The follow up shall review the proper implementation of the national action plan.