Critical Review of the National Action Plans (NAcP)

of the EU Stress Tests

on Nuclear Power Plants

Study commissioned by Greenpeace

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Content

1 Introduction

The March 2011 accident at the Fukushima Dai-ichi nuclear power plant proved that it was not justified to exclude highly unlikely accidents from happening. In a prompt reaction to this catastrophic accident, the European Council concluded in March 2011 that the safety of all EU nuclear plants should be reviewed on the basis of a comprehensive and transparent risk and safety assessment ("stress tests"). The EU Nuclear Safety Regulators Group ENSREG took over this task.

However two month later the scope of the EU stress tests was reduced: The EU stress tests were defined as a targeted reassessment of the safety margins of nuclear power plants developed by ENSREG, with contributions from the European Commission. The EU stress tests comprise three topics:

(1) The response of a nuclear power plant when facing different extreme situations (earthquakes, floods and extreme weather events, and the combination of events),

(2) capabilities to cope with consequences of loss of power (Station Black-out – SBO) and loss of heat removal via Ultimate Heat Sink (UHS);

(3) capabilities to prevent major radioactive emissions in case of a severe accident: the Severe Accident Management (SAM).

All EU Member States operating nuclear power plants – plus Lithuania – and the neighbouring countries Switzerland and Ukraine, take part in the stress tests process.

By the end of 2012, the national regulators had provided national action plans (NAcP) to remedy the identified shortcomings during the EU stress tests.

This report presents a critical review of 10 of these 17 NAcPs. To understand the larger framework of the stress tests, firstly a short overview over the set-up of the EU stress tests is presented in the following:

The *first phase* of the EU stress tests started in June 2011 – the *operators* of the NPPs prepared a *self-evaluation* of their plants. Licensees had to provide a final report by 31 October, 2011.

In the *second phase,* the national regulator *reviewed* final reports submitted by the operators. All final national stress tests reports were handed over to the EU Commission by 31 December 31, 2011.

Then the *third phase* started: the peer review, which was conducted by experts nominated by the national states to review the national reports. The peer review teams reviewed the national reports in a desktop research. Each country was visited by one expert team. The peer review was completed with a main report that includes final conclusions and recommendations at European level regarding the three topical parts and 17 country reports including country-specific conclusions and recommendations. The report was endorsed and published by ENSREG on April 26, 2012.

The European Commission presented the ENSREG report in June 2012 to the European Council. The EU Commission did not see the Council mandate for stress tests fulfilled and demanded further testing; six additional so-called fact-finding visits were undertaken, those follow-up reports were published in late October 2012.

To implement the stress tests findings, an *ENSREG action plan* (published 1 August 2012) has been developed to track implementation of the recommendations. In line with this action plan, each national regulator had generated a *national action plan (NAcP)* and published it by the end of 2012.

In October 2012 ENSREG published a compilation of recommendations to assist the preparation as well as the review of national action plans (NAcP) [ENSREG 2012b].

The ENSREG action plan specified the need to peer review these national action plans via a common discussion at a dedicated ENSREG-workshop to share lessons learned on the implementation of post-Fukushima safety improvements. This ENSREG-workshop to discuss the NAcP will take place in

Brussels on 22 – 26 April 2013. Stakeholders had the opportunity to submit questions and file comments regarding the peer review of national action plans from 25 February to 20 March 2013 via the ENSREG website. The outcomes of the workshop will be presented to the public in the next ENSREG conference.

The European Commission and ENSREG will review the status of the implementation of the recommendations by June 2014.

A key issue which is still open is how comprehensively the peer review of the national action plan will be conducted. This might be seen as an opportunity to force the nuclear regulators to formulate mandatory requirements which need to be fulfilled in a rather stringent time schedule; in contrast to the years or even decades currently planned in many countries. This could make operators decide to shut down old and unsafe nuclear power plants NPP instead of investing into extensive modernisation measures.

It is important to understand that the EU stress tests could not take into account all key safety issues such as the capability to prevent accidents – the scope of these tests was not designed to deliver a comprehensive risk assessment. Too many factors were not taken into account – most importantly ageing, safety culture and design. Thus it is important to underline that the EU stress tests cannot be understood as a comprehensive safety check of the NPP in Europe.

The public and independent experts were pointing out that the stress tests were mainly set up to improve the confidence in the safety of European NPPs. Nevertheless the stress tests revealed a number of shortcomings regarding the plants´ capability to withstand several external hazards and the lack of possibilities to cope with the consequences. However, the outcomes of the stress tests consist only of recommendations for "further improvements".

Commissioned by Greenpeace, a critical review of the national actions plans (NAcP) was performed by Oda Becker and Patricia Lorenz in March/April 2013. It is the follow-up of "*Critical Review of the EU Stress Test performed on Nuclear Power Plants*" published in May 2012 [WENISCH 2012]. The report of 2012 discussed the main weaknesses as identified by operators, national regulator and peer review team during the stress tests process and pointed out those issues and important shortcomings of individual NPPs not mentioned in the stress tests. The report points out some of those design weaknesses (e.g. wall thicknesses, location of spent fuel pool outside the containment). It reviewed not all but 13 NPPs (34 units) in 10 countries (see table next page). To illustrate the risk of potential impacts of severe accidents, scenarios for selected reactors were presented. The results of the Austrian project flexRISK (Flexible Tools for Assessment of Nuclear Risk in Europe) were used to provide the necessary input data.

One year later, this report called "**Critical Review of the National Actions Plans (NAcP)**" evaluates the result of the stress test exercise and filters out the real action under all the safety talk and kilometres of reports produced since May 2011. It was not the aim to make a systematic review of all points which are to be addressed; this report rather investigated whether the actions/activities set out in the individual country NAcP are the foundation to remedy the main weaknesses the stress tests revealed. To show a more complete picture of the safety respectively risk of the NPPs, some important safety issues not included in the stress tests are explained. These evaluations do not claim to be exhaustive, but the findings contribute to a more comprehensive understanding of the risk of nuclear power plants in Europe.

The overall aim is to assess whether an accident comparable to the Fukushima accident could happen in Europe even after the stress tests or to put it in a nutshell: lessons learnt from Fukushima?

Unit	Reactor Type	Net Capacity [MWe]	Commercial Operation	Country
Doel 1	PWR, Westinghouse 2-loop	443	1975	Belgium
Doel 2	PWR, Westinghouse 2-loop	443	1975	Belgium
Doel 3	PWR, Westinghouse 3-loop	1006	1982	Belgium
Doel 4	PWR, Westinghouse 3-loop	1039	1985	Belgium
Tihange 1	PWR, Framatome 3-loop	962	1975	Belgium
Tihange 2	PWR, Westinghouse 3-loop	1008	1983	Belgium
Tihange 3	PWR, Westinghouse 3-loop	1046	1985	Belgium
Temelín 1	PWR, VVER1000/V320	963	2002	Czech Republic
Temelín 2	PWR, VVER1000/V320	963	2003	Czech Republic
Cattenom 1	PWR, 1300 MW class, P4	1300	1987	France
Cattenom 2	PWR, 1300 MW class, P4	1300	1988	France
Cattenom 3	PWR, 1300 MW class, P4	1300	1991	France
Cattenom 4	PWR, 1300 MW class, P4	1300	1992	France
Fessenheim 1	PWR, 900 MW class, CP0	880	1978	France
Fessenheim 2	PWR, 900 MW class, CP0	880	1978	France
Gravelines 1	PWR, 900 MW class, CP1	910	1980	France
Gravelines 2	PWR, 900 MW class, CP1	910	1980	France
Gravelines 3	PWR, 900 MW class, CP1	910	1981	France
Gravelines 4	PWR, 900 MW class, CP1	910	1981	France
Gravelines 5	PWR, 900 MW class, CP1	910	1985	France
Gravelines 6	PWR, 900 MW class, CP1	900	1985	France
Gundremmingen B	BWR, BWR-72	1284	1984	Germany
Gundremmingen C	BWR, BWR-72	1288	1985	Germany
Mochovce 1	PWR, VVER440/V213	436	1998	Slovak Republic
Mochovce 2	PWR, VVER440/V213	436	2000	Slovak Republic
Krško	PWR, Westinghouse 2-loop	688	1983	Slovenia
Almaraz 1	PWR, Westinghouse 3-loop	1004	1983	Spain
Almaraz 2	PWR, Westinghouse 3-loop	1006	1984	Spain
Ringhals 1	BWR, ABB Atom	878	1976	Sweden
Ringhals 2	PWR, Westinghouse 3-loop	865	1975	Sweden
Ringhals 3	PWR, Westinghouse 3-loop	1064	1981	Sweden
Ringhals 4	PWR, Westinghouse 3-loop	940	1983	Sweden
Muehleberg	BWR, BWR/4, Mark I	373	1972	Switzerland
Wylfa 1	GCR, Magnox	490	1971	UK

2 Almaraz NPP, Spain

Almaraz NPP comprises two Westinghouse three-loop pressurised water reactors (PWR). Almaraz 1, net capacity of 1004 MWe, started commercial operation in 1983, Almaraz 2 (1006 MWe) followed in 1984. In 2010, ten-year operating licences for both units were granted (to June 2020).

2.1 Spanish National Action Plan (NAcP)

The Spanish NAcP contains a comprehensive compilation of the actions currently on-going in Spain that are related to the post-Fukushima programs, which have been initiated both at national and international level. With the objective of incorporating all the conclusions of the Stress Test process in the Spanish plants, the Spanish Nuclear Safety Council, Consejo de Seguridad Nuclear (CSN) issued a binding complementary technical instruction (ITC-STs) for each of the licensees [CSN 2012].

The ITC-STs sets an implementation schedule which is divided into three periods: short, medium and long-term, i.e. periods end in the years 2012, 2014 and 2016 respectively. The dates are practically the same for all the plants, with minor differences when referred to plant-specific modifications. The Spanish NAcP contains 39 actions: five “generic requirements”, 25 “improvement implementations” and nine cases where “additional analysis” is needed.

The ENSREG peer review team considered the implementation schedule for the planned improvements as being appropriate, but highly demanding in terms of completing the necessary upgrades. They recommended reinforcing the CSN’s technical assessment human resources. The Council announced its plan to ask the Spanish Government for increased funding to properly manage human resources, increase the numbers of technical staff needed to tackle the new tasks derived from Fukushima and other licensing issues in 2013.

2.2 Efforts to Remedy the Weaknesses the Spanish Stress Tests Described

- CNS requires re-analysing the seismic hazard at each NPP site in Spain. The analysis needs to consider geological and paleoseismological data characterizing relevant active faults of the Iberian Peninsula as suggested by the peer review team. Implementation schedule: 2016.
- Implementation of the necessary improvements to reach a seismic margin of 0.3 g regarding the current design basis earthquake (DBE) is envisaged by 31/12/2014.
- The Spanish licensees have analysed possible secondary effects of earthquakes during the stress sests (31/12/2012). Significant improvements have been identified and scheduled for implementation by 31/12/2014.
- The site is located on the left bank of the Arrocampo brook reservoir; the Valdecañas dam is situated upstream (storage capacity 1146 hm^3). The dam break analysis was re-assessed to check against the dam emergency plans and to resolve the identified inconsistencies. The analysis was completed by 31/12/2012, but the results are not published yet; most likely CNS has not yet assessed the results.
- Improving the external flood protection of buildings containing safety related systems, structures and components (SSCs) is necessary. Implementation is anticipated for 2013.
- Adopting a consistent approach for the return periods associated to heavy rain and extreme temperature scenarios at the individual sites is planned; implementation to be completed by 2014.
- A PSA including external events and assessments of the reliability of accident management under the conditions of external events should be performed until 2016.
- Implementation of the new WENRA Reactor Reference Levels for external events (currently under development) in the Spanish regulation should be finished in 2014.

- If the ultimate heat sink fails, the only possibility to cool the core is via steam generators (SGs). This measure cannot be used in shut down operation modes. However, there are no plans to implement an alternate ultimate heat sink.
- Implementation of actions designed to cope with prolonged station black-out (SBO) include installing new equipment (fixed or mobile) to makeup water for the reactor cooling system (RCS), to electrically supply equipment and instrumentation and to increase the availability of communications and lighting systems is scheduled for completion by 31/12/2014. Possible improvements to reinforce the existing capacities of depressurizing the RCS (protection against "high pressure sequences") are to be analysed by 30/06/2013; however, no schedule for implementing any necessary measures was set.
- Containment integrity during severe accident is not assured yet:
- No adequate measures to manage the large amount of hydrogen expected to accumulate in the case of a severe accident in the containment are installed yet; they are needed to prevent explosions. The installation of passive autocatalytic recombiners (PARs) should by finished by 31/12/2016.
- Potential hydrogen hazard in other buildings surrounding the containment should be analysed by 31/12/2013; no date was set until when necessary measures will have to be implemented as a follow-up to the analysis.
- A dangerously weak point is the lack of a filtered containment venting system to prevent containment overpressure; implementation is planned until 31/12/2016.
- The ITC-STs require the licensees to conduct a complementary analysis covering severe accidents starting during shutdown condition. In this context, the Level 2 PSA including "other modes of operation" should be performed by 31/12/2014. The final implementation of Severe Accident Management Guidelines (SAMG) for accidents initiated during shutdown operation is scheduled for 2016.
- Improvements of the cooling of spent fuel pools (SFP) are necessary. The following measures need to be completed by 31/12/2014:
- Implementation of an alternative make-up and fuel spray
- Implementation of appropriate temperature and level instrumentation
- Implementation of SAMGs addressing mitigating aspects for spent fuel pools
- Analysis of the SFP integrity and cooling (including liner & racks).
- The Spanish NPPs are not equipped with an emergency control room (ECR). The construction of a new on-site AEMC (Alternative Emergency Management Centre) which is protected against earthquakes, flooding and radiation should be operating by 31/12/2015.
- The CSN will review the content of the existing SAM training exercises once the new improvements are implemented at the plants. Regarding training simulators for severe accidents, CSN announced to act in line with national and international experience "and will eventually make the due decisions".
- Precondition for a sufficient accident management is the establishment of a comprehensive set of requirements for accident management integrated within the Spanish legal framework; the completion is scheduled for December 2013. Until the same date, accident management is to be added as an explicit topic in the CSN safety guide on the Periodic Safety Review (PSR).

2.3 Weaknesses the Spanish NAcP Ignored

- One of the EC staff working document recommendations is not mentioned in the Spanish NAcP [EC 2012]: "Within the framework of the on-going analyses on the effects of pipe rupture (non-seismic and seismic), it is suggested to consider in particular verifying that there are no common cause failure issues." Common cause failures are a major hazard for NPPs, because all redundant safety systems fail simultaneously.
- Ageing will become an increasingly relevant issue during the fourth decade of operation. In spite of this effect, thermal power of both units was increased, further accelerating ageing processes.
- Power uprates – the increase of the NPP electricity output - can cause unexpected failures in safety systems that could aggravate accident situations. Power uprates also accelerate the development of accidents thereby decreasing intervention time needed to take action to minimize the accident. Furthermore, in case of a severe accident, the potential radioactive release is considerably higher.
- The reactor and the spent fuel pool are relatively vulnerable against other external events like an airplane crash. In addition to all the topics and actions covered by the stress tests and the ENSREG peer reviews, and in a separate process, the CSN has initiated a program aimed at protecting the plants against serious external events that might be produced by mankind and seriously impacting safety. But the actions being requested by CSN focus on the "mitigation" of the consequences of these extreme situations and not on the prevention.
- A crash of a large or midsize airliner has a high probability to cause major reactor building damage. Such a crash – being an accident or deliberate action – can result in a severe accident.
- The spent fuel pools (SFP) are located in buildings adjoining the reactor buildings. These buildings are ordinary unprotected industrial buildings. If the walls of the spent fuel pool are damaged and the cooling water lost, large amounts of radioactive material will be released.[1]

2.4 Conclusion

Seismic analysis according to the state of art will not be finished earlier than 2016, which might show that seismic hazard resilience is insufficient. Further back-fitting will be probably proved necessary after the PSA systematically analysed the threat of external hazards in 2016.

Currently none of the two units of the Almaraz NPP have effective accident management measures to assure containment integrity during a severe accident. Implementation of filtered venting systems as well as measures to prevent hydrogen explosion are to be installed until the end of 2016. This approach cannot be called "urgent implementation". The ENSREG peer review team asked the national regulators to consider urgent implementation of the recognized measures to protect containment integrity.

Especially worrysome is the fact that mobile equipment is presented as the solution to compensate deficiencies of the reactors and the spent fuel pools. The EC/ENSREG highlighted as good practice the use of an additional layer of safety systems fully independent from the normal safety systems, located in areas well protected against external events, e.g. bunkered systems or hardened core of safety systems. Regarding the bunkered/hardened systems, CSN stated that the ITC-STs explicitly require storing of new mobile equipment in a safe location, well protected against external and internal events. Evidently this was not the definition of bunkered/hardened systems the EC and ENSREG had in mind.

[1] These buildings however are lower than other buildings at the site and therefore not necessarily hit by a crashing aircraft.

The necessary comprehensive back-fitting programme will take at least until 2016. Taking into consideration the staffing problems CSN is currently facing, it is very likely to take longer.

Furthermore, the modification will not remedy all known shortcomings; it is not planned to implement an alternate ultimate heat sink. In addition the design weaknesses will remain: The reactor building and the spent fuel pool building are relatively vulnerable against external events.

In the current condition, the units are not safe and should not operate; or at least with reduced power output only.

3 Doel and Tihange NPPs, Belgium

In Belgium, the subsidiary of the GDF-SUEZ Electrabel is operating two nuclear power plants (NPPs): The Doel NPP comprises four pressurised water reactors (PWR). The twin units Doel 1/2 commissioned in 1975, Doel 3 (1982) and Doel 4 (1985). The units Doel 1/2 are Westinghouse 2-Loop reactors with a net capacity of 433 MWe each. Doel 3 and 4 are Westinghouse 3-Loop reactors with a net capacity 1006 MWe and 1039 MWe, respectively. The site is located on the left bank of the Scheldt river 15 km northwest of Antwerp with 490,000 inhabitants and only 3 km from the border between Belgium and the Netherlands.

The Tihange NPP comprises three pressurized water reactors (PWR): Tihange 1, commissioned in 1975, Tihange 2 (1983) and Tihange 3 (1985). Tihange 1 is a Framatome 3-Loop reactor with a net capacity of 962 MWe; Tihange 2 (1008 MWe) and Tihange 3 (1046 MWe) are Westinghouse 3-Loop reactors. Th site is located on the Meuse River, 25 km southwest of Liege with 200,000 inhabitants and at about 80 km southeast of Brussels; the Brussels Region is densely populated with one million inhabitants.

In July 2012, the Belgian government announced the schedule for the forced closure of the NPPs [WNA 2012a]. All the Belgian units were scheduled for shut-down between 2015 and 2025, roughly in line with their 40th anniversaries.[2] However, exactly the very old unit Tihange 1 is permitted to operate 50 years.

3.1 Belgian National Action Plan (NAcP)

The NAcP contains about 600 site and reactor-specific actions. The number of the related European recommendations or national requirements is mentioned for each action. Until full implementation, this action plan will be updated regularly. The current version presented here was last updated on 14 December 2012 [FANC 2012].

The nuclear authority, the Federal Agency for Nuclear Control (FANC), underlines that some of these actions may be amended or cancelled if their relevance for the remaining operating lifetime of the units would seem unnecessary. This is seen as especially valid in the case of the actions intended for the Doel 1and 2 units which will cease operation in 2015 as a result of the above mentioned decision of the government.

With the exception of the possible implementation of the filtered venting system, the last deadline of the listed actions is 31/12/2014. However several of these actions are analysis that will probably result in necessary back-fittings. The intended target date for implementing all actions is not mentioned.

3.2 Efforts to Remedy the Weaknesses the Belgian Stress Tests Described

- In April 2011 following the Fukushima accident, Electrabel commissioned a probabilistic seismic hazard analysis (PSHA) using a state-of-the-art methodology. This PSHA resulted in a considerable increase of intensity of the design basis earthquake (DBE): For the Tihange site the value of the peak ground acceleration (PGA) increased from 0.17 g to 0.23 g (increase of 35%), for the Doel site from 0.056 g to 0.081 g (45%).
- A more elaborate PSHA study, e.g. with due consideration of results arising from the EC-project SHARE (seismic hazard harmonization in Europe) is required. A detailed study for both sites will be conducted by the Royal Observation of Belgium (ROB); target date is 31/12/2014.
- The method chosen to estimate safety margins and cliff edge effects during the stress tests looks at the probability of the systems, structures and components (SSCs) to withstand a certain Review Level Earthquake (RLE) (Tihange RLE = 0.3g, Doel: RLE = 0.17g).

[2] Current shut down dates: Doel 1/2: 2015; Doel 3: 2012; Doel 4: 2025; Tihange 1: 2025; Tihange 2: 2023; Tihange 3: 2025

- The seismic margin review at Tihange 1 shows that in total 21 systems, structures and components (SSC), e.g. main switchboards and transformers, have a low probability of resisting an earthquake exceeding the RLE. The necessary backfitting (mainly additional anchoring of electrical panels) is to be finished by 2013.
- The consequences of the earthquake induced failure of the fuel tank at Tihange 1, containing 500 m^3 of fuel, was to be analysed by 2012 (status: in progress). Results or necessary back-fitting measures are not announced yet.
- Concerning the necessary reinforcement of the electrical auxiliary building at Tihange 1 only a feasibility study was to be performed by 2012; which is still in progress.
- Reinforcement of the refuelling water storage tank at Doel 1/2 is to be done by 15/12/2014.
- Concerning the reinforcement against earthquake, further actions including inspections and reassessments are listed and are likely to result in necessary backfittings in 2014 or even later:
- For Tihange 2, reassessment of specific anchoring and inspection of certain pipes by 31/12/2013.
- For Tihange 2 and 3, walk-downs are to be carried out for inspection of SSCs to evaluate the necessary reinforcement of anchoring of equipment until 31/12/ 2013.
- For Doel 3 and 4, similar walk-downs were to be carried out in 2012 (status: in progress).
- For Doel, inspections of the reactor and other buildings were to be performed. Target dates are between 31/07/12 and 15/12/3012 (in progress).
- To mitigate the risk of internal flooding induced by an earthquake, only the seismic management procedures were modified: After an earthquake, a person (agent) is to send out as quickly as possible to check if the cooling tower is overflowing. If so, pumps will be shut down rapidly. This action is required for Doel 3 and 4, as well as for Tihange 2 and 3.[3]
- Improvement of the seismic monitoring (instrumentation) is to be done by 31/12/2013.
- EC staff working document underlines the importance to improve the seismic resistance of the Belgian NPPs. It also underlines the importance to improve the flood protection, particular at the Tihange NPP site.
- Flooding hazard for the Tihange NPP site: During the latest flooding reassessment for, new design basis flood (DBF) parameters have been derived. Corresponding water heights of the DBF would largely exceed the site platform elevation (up to 1.70 m), causing flooding of all three units and loss of safety related equipment, including all on site AC power sources and both primary and alternate ultimate heat sink.
- Already at a flow rate with a return period of about 400 years, Tihange 1 would be completely surrounded by water and all buildings except the reactor building would be flooded. Significant damage to equipment would be caused by floods with return periods of 600 to 1,000 years, aggravating the consequences with increasing return periods (i.e. higher river flow rates).
- A peripheral protection of the site which shall consist of a wall including coffer dams to close the opening necessary for normal operation of the NPP is to be implemented by the end of 2014. However Electrabel planned to construct a wall not higher than the water level of the DBF. The peer review team recommended including a safety margin to adequately cover uncertainties

[3] For this both units it is additional planned to study the automatic shut down of one or two pumps in case high water level in a sump by 31/12/2013.

associated with a calculated DBF. The NAcP does not explain whether and if how much, the wall is to be increased.

- Part of the planned flood protection are also local protection measures for buildings containing equipment designed to maintain the units in a safe state by ensuring a "watertight area" for each unit (using coffer dams and other sealing devices) that are to be installed during the flooding alert period.
- When conventional equipment is rendered unavailable through flooding, the non-conventional means (NCM) equipment preinstalled during the alert phase should be used. However, the functionality of the NCM is not assured.
- Procedures for the use for the periodic testing and the maintenance of the flood protection should be set up by 31/12/2014. The flood protection has to be integrated into the internal emergency plan by 31/12/2014. In addition, the early warning system will have to be improved by 31/12/2012 (in progress). Also the emergency intervention strategy and the crisis management, including corresponding procedures should have been improved by 10/12/2012 (in progress).
- The flooding protection of buildings (e.g. by installing seals) is to be implemented by 31/12/2013. The height of the protection is not announced, but a sufficient protection height of about 2 meters to prevent water intrusion cannot be realised.
- The emergency plan now includes means of onsite transport – boats – of personnel and equipment within the units, to and from units.
- The prevention of a severe accident caused by flooding depends strongly on the actions taken by the operator and only one limited measure is included to accelerate manual actions: the replacement of flexible connections as much as possible with fixed and rigid pipes was to be done by 31/12/2012 (in progress). A make-up possibility to inject water to the reactor coolant and a groundwater supply to the steam generators were to be developed 31/12/3012 (in progress). Details are not mentioned.
- The internal hazards potentially induced by extreme flooding (or fire or explosions) when the automatic fire extinction system is lost during flooding is being reviewed and additional measures are to be taken (target date 31/12/2013).
- For the Doel NPP site, the flood level of the design basic flood (DBF: high tide + storm surge) remains below the height of the embankment. But flooding of the site can occur in case of a combination of very high Scheldt river level with an embankment breach. The initiation of an embankment failure can occur for a severe storm with a return period of 1,700 years. In case of an embankment failure, several tens cm of water will flood the site and intrude into several buildings.
- A (volumetric) protection of the concerned safety related buildings is being installed[4], target dates Doel 1/2: 01/04/2013; Doel 3: 01/08/2013 and Doel 4: 15/12/2013.
- Furthermore, a reinforcement of the embankment has been performed and annual inspections and maintenance of the embankment as well as more frequent height measures are arranged in 2012.
- Also one additional means against extreme flooding is listed: the use of mobile pumps during flooding (target date 30/11/2013)

[4] Currently sand bags or mobile barriers are planned to be installed at sensitive building entrances.

- Up to now, the design parameters for extreme weather conditions for the Belgian NPPs are mainly based on historic data and therefore on a return period in the order of 100 years. ENSREG recommends the derivation of design basis parameters with 10,000 years return periods.
- Regarding heavy rainfalls, a reassessment of the capacity of the sewer system for return periods up to 100 years is in progress (target date Tihange: 31/12/2013; Doel: 01/11/2012). However, the above mentioned ENSREG recommendation is not applied. The consideration of extreme temperatures as recommended by the peer review team is also not included.
- The robustness of safety systems of Doel 1/2 and Tihange 1 in case of a beyond design tornado is to be evaluated (deadline 31/12/2013).
- In case of a total SBO and/or loss of ultimate heat sink, Electrabel plans to use new non-conventional means (i.e. mobile devices). However, the operability and practicability of the non conventional means (NCM) is not assured yet, necessary measures are among others:
- Determination of specific provisions for the additional equipment including the non conventional means (operation in adverse weather conditions, integration in the technical specifications, inspection and testing, maintenance…) was required until 30/06/2012, but is still in progress. Improvements or the purchase of new equipment is not mentioned.
- Buildings are able to withstand external hazards for the permanent storage of the mobile non-conventional means are to be built by 31/12/2013.
- A feasibility study will be performed until 31/12/2013 to add a flanged connection to the outside of the nuclear auxiliary building to allow spraying into the reactor building using a mobile pump (to prevent build-up of overpressure in the containment).
- An alternative power supply (380V) for non-conventional and/or safety equipment (compressors, pumps, valves…) is to be installed by 31/12/2013.
- Procedures including the necessary non-conventional means and the intervention strategies[5] are to be provided for Tihange by 31/12/2013.
- Alternative make-up possibilities for safety-related water reservoirs, if necessary with additional connection points is to be implemented at Doel by 2013.
- Additional means to assure primary water supply[6] during increased reactor coolant pressure is to be implemented at Doel 1/2 by 30/11/2014.
- The alternative electric sources currently used to power the instrumentation and control systems and the emergency lighting are to be improved by 31/12/2012 (status: in progress).
- Several studies on different topics are to be performed; however the necessary backfittings are postponed, among others:
- A study for the installation of autonomous electrical generators to repower instrumentation is to be done for Tihange, by 31/12/2013.
- A study regarding the function of the feedwater pump endangered by the loss of room ventilation is to be performed (target date Doel 1/2, Tihange 1&2: 31/12/2013 Doel 3&4, Tihange: 3: 1/12/2014).

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[5] The interventions strategies included rapid depressurization of the primary system to limit damage to the primary pumps seals – instead of the backfitting of temperature resistant primary pump seals.

[6] Backfitting with shut-off valves on the spray system lines to be able to continue injection with the spray system pumps to the shut -down coolant system circuit

- A study about additional strategies for the management of overpressure in the containment building for situations with an open primary circuit (during shut-down states) is to be performed by 30/06/2013.
- A study of the potential design problems with the siphon breakers in the spent fuel pools is required by 31/12/2013. In case of pipe rupture, an insufficient capacity of the siphon breakers may result in the rapid loss of the water covering the fuel.
- It is necessary to evaluate whether the water capacity is sufficient when all units are affected by the loss of the main ultimate heat sink to ensure cooling of the core and the spent fuel. If necessary, a strategy for the optimization of water consumption will be developed (target date Tihange: 31/12/2013; Doel: 01/07/2013). Furthermore, the organisation of the emergency plan and adapted logistics of multi-unit events are to be implemented by 31/12/2013.
- None of Belgian NPPs is equipped with a filtered venting system. ENSREG emphasizes its importance to protect containment integrity and recommended its urgent implementation. Nevertheless only a study of a filtered venting system is to be performed by 31/12/2012 (in progress). The target date for the implementation of the filtered vent systems is obviously not defined yet. The listed target date for Tihange 2, 3 and Doel 3, 4 is 31/12/2017. It is unclear whether the implementation itself or only the date is not fixed. For the oldest plant Tihange 1 and Doel 1/2 the stated target date is "LTO" which probably mean the implementation will only be done in case of LTO (Long Term Operation).
- The evaluation of the hydrogen risk of the spent fuel pools during a severe accident needs to perform by 31/12/2012 (status: in progress). The peer review team recommended, regardless of the outcome of this study, considering the installation of passive autocatalytic hydrogen recombiners (PARs). However, FANC did not explicitly require this until now.
- To ensure containment integrity during total SBO, checks need to find out whether all penetrations through the containment building can be closed in due time and whether the building isolating systems remain functional, in particular during reactor shutdown states (target date 31/12/2013).
- No measures to guarantee operability and habitability condition during SBO for main and emergency control room or a schedule for their implementation are listed. It is claimed that these measures are part of the not included action plan for man-made events.
- The implementation of the revised Westinghouse SAMGs is to be completed by 31/12/2014.
- Treatment of potentially large volumes of contaminated water after an accident is to be developed by 31/12/2013.

3.3 Weaknesses the Belgian NAcP Ignored

Doel-3 and Tihange-2 stopped operating in June and September 2012, respectively, after the discovery of **thousands of flaws in their reactor pressure vessels** (RPV). A new ultrasound measuring technique was used for the first time in June 2012 over the whole surface of the Doel 3 RPV, rather than just around the weld zones. Tihange 2 was stopped in August for a maintenance outage after examinations had found similar flaws as Doel 3 [WNN 2013a].

These flaws (Doel 3: about 8000, Tihange 2: about 2000) are thought to having originated from the casting and forging process when the vessels were manufactured. Both RPVs were produced by the same manufacturer (Rotterdam Drydock Company) in the late 1970s.

After having analyzed this issue, a nuclear material expert questions the assumption that the flaws originate from manufacture since no defects were found during the final tests after manufacturing while the flaws found 30 years later have extensions up to 24 mm wide and up to 100 mm deep and exist in remarkable density. The real nature of the flaws is still unknown and can hardly be determined since sampling cannot be performed without destruction of the RPV. The assumed hydrogen flaking process has a considerable incubation time and is continued during operation. The influence of radiation effects and low-cycle fatigue on possibly manufacture-induced defects has not been considered by Electrabel although it is known the radiation embrittlement of the base metal is underestimated by the predictive curves. The eventual influence of MOX fuelling on radiation effects in the RPV wall has not been considered [TWEER 2013].

A possible failure of the reactor pressure vessels due to sudden crack growth in case of local thermal stresses cannot be excluded. The potential for RPV failure could lead to an uncontrollable loss of reactor coolant and possible melting of fuel rods [NW 17/01/2013]

Doel-3 and Tihange-2 are set to remain shut until at least the beginning of May 2013. In February 2013, FANC asked Electrabel for more information on the plants before it deemed the reactors safe to restart. FANC requested pressure tests in the primary circuit of the reactors and mechanical tests of reactor material. The results are to be submitted to FANC, and the federal government will take the final decision on whether the reactors can restart. The FANC Director pointed out earlier that the government can order the units shut on its own authority even if FANC would allow them to restart [NW 08/11/2012].

All Belgian reactors have been operating for about 30 years, **ageing of materials** being a major safety issue for the plants. This applies in particular to Tihange 1and Doel 1/2 that were in operation for nearly 40 years. Frequency of ageing related incidents will increase. Incidents could also indirectly be caused by ageing: If degraded components are replaced, defective mounting or other errors cannot be excluded.

Regarding separation and independence of safety systems, the NAcP called this a general design criterion. This is indeed not the case for the old units Doel 1/2 and Tihange 1. These old units have several significant **design deficits,** thus the prevention of accidents is not sufficient.

The reactor buildings of the oldest units (Doel 1/2, Tihange 1) are extremely vulnerable against an **aircraft crash** (accidental or intentional) that can seriously damage the external concrete structure, with the possibility of projectiles penetrating into the containment. The highly probable failure of the cooling system would result in a severe accident of the most hazardous category: core melt with an open containment. The radioactive releases would be very high and occur particularly early.

3.4 Conclusion

Backfitting measures to reinforce the plants against earthquake will be finished in several years. However the seismic hazards assessment is ongoing and the earthquake resilience will probably turn out as being insufficient even after all measures have been implemented.

Today, in case of an extreme flooding the water level on the Tihange NPP site will reach nearly two meters, all safety systems of the three units would be flooded and not operational. The staff moving around on boats between the buildings would have to prevent severe accidents using mobile equipment.

Even after the implementation of the flood protections, actions by the staff (close openings, use mobile equipment and so on) are necessary to cope with such an external event. Although the flood hazard will obviously increase in the next decade, sufficient safety margins are probably not used for the protection wall. Thus, flooding will remain a dangerous hazard for the Tihange NPP.

Tihange 1, which would be hit by flooding first, is the least protected unit of the site. Material degradation and design weaknesses of the very old Tihange 1 can significantly aggravate the development of an accident caused by flooding or other external or internal events.

Also the old units Doel 1/2 show several design weaknesses regarding the prevention of severe accident. Nevertheless, FANC announced, that it will not require necessary backfittings measures to protect the units against natural hazards and to improve the severe accidents management, because of its short operation time (2015); an utterly irresponsible approach.

A major weakness of Tihange 1 and Doel 1/2 are the vulnerability against aircraft crashes which can cause the most dangerous severe accident, a core melt accident with an open containment leading to early and large releases.

Obviously Electrabel has no intention of performing comprehensive technical backfitting measures. Electrabel aims to prevent or even postpone backfittings measures. The planned actions are limited to paperwork. Several actions are only feasibility studies or modifications of procedures. Thus the prevention of accidents depends strongly on actions performed by the staff during a severe accidents is developing.

Because several actions with target dates in 2012 are still in progress, a considerable delay of all actions has to be expected.

A major deficiency of all Belgian NPPs is the lack of a filtered venting system. ENSREG has emphasized its importance. The Belgium NAcP ignores this fact and does not mention if at all and when the installation of these systems will be required. Obviously all Belgian NPPs will be allowed to operate for a couple of more years without such systems.

Because of the lack of filtered venting, the probability of high radioactive release in case of a severe accident is very high. It should be kept in mind that Belgium is one of the most densely populated regions in the world. Tihange NPP is situated close to the centre of Liege; Doel NPP is situated close to the centre of Antwerp. In case of a severe accident, the evacuation of all the people on time (before the radioactive release) is impossible.

The flaws in the reactor pressure vessel at Tihange 2 and Doel 3, which can trigger or aggravate an accident combined with all other shortcomings, particular at Tihange 2, can only result in one decision, never start operation of these units again.

Considering all facts, we recommend also to shut down Tihange 1 and 2 as well as Doel 1/2 and 3 immediately.

Tihange 3 needs to be taken out of operation until all measures of flood protection are implemented. However because it is not justified regarding the flood hazards to rely on staff interventions we recommended to prepare the permanent shut down of Tihange 3.

Doel 4 needs to be taken out of operation until all measures of high priority (e.g. filtered venting) are implemented.

4 Fessenheim, Gravelines and Cattenom NPPs, France

All 58 French nuclear power plants (NPPs) are owned and operated by Electricité de France (EDF) and equipped with two, four or even six pressurised water reactors (PWR). The 34 oldest reactors belong to the 900 MW class divided in the CP0, CP1 and CP2 series; 20 plants with 1300 MW reactors consist of P4 and P´4 series. The 1450 MW reactors, or N4 series, comprise four reactors.

Fessenheim NPP belongs to the 900 MW class, model CP0 and is the oldest operating reactor in France. It started commercial operation in 1978. The NPP is situated in a seismic area, near the German border; 30 km from the German city Freiburg.

Gravelines NPP is the biggest nuclear power plant in France and comprises six reactors. All units belong to the 900 MW class, model CP1. Units 1 – 4 started commercial operation in 1980/81, units 5 and 6 followed in 1985. The NPP is situated on the French coast of the British channel between Calais and Dunkirk.

Cattenom NPP comprises four reactors that belong to the 1300 MW class, model P4´. Commercial operation of the four units started successively in 1987, 1988, 1991 and 1992. The NPP is situated at the Mosel river and about 50 km south of the city of Luxemburg.

In July 2009, the Nuclear Safety Authority (ASN) approved EdF's safety case for 40-year operation of the 900 MWe units, based on generic assessment of the 34 reactors. Each individual unit will now be subject to inspection during their 30-year outage. ASN ruled in July 2011 that Fessenheim 1 can be operated for ten more years if it complies with nuclear safety requirements. Amongst these is a requirement to strengthen the concrete basemat, a task which must be completed before 30 June 2013.[7] In 2012, the government announced that both Fessenheim reactors would close by the end of 2016, for political reasons and regardless of safety evaluations [WNA 2013b], effectively over-ruling the prior decision by the ASN. A national debate is underway to discuss France's 'energy transition', the results of which will be used in formulating a new energy policy bill in mid-2013 [NW 14/02/2013].

In July 2010, EdF said that it was assessing the prospect of 60-year lifetimes for all its existing reactors [WNA 2013b].

4.1 French National Action Plans (NAcP)

In France, the stress test process fitted into a dual framework: firstly a European framework with the organisation of the stress tests, and secondly in a national framework with the performance of a safety audit of the French civilian nuclear facilities in the light of the Fukushima Daiichi accident, as demanded by the Prime Minister on 23rd March 2011.

In addition to the stress tests, French Nuclear Safety Authority, the Autorité de Sûreté Nucléaire (ASN) conducted a campaign of inspections targeting topics related to the Fukushima Daiichi accident, during the summer of 2011. The results of these inspections were taken into account in the development of the NAcP.

Representatives of the French High Committee for Transparency and Information on Nuclear Security (HCTISN), the local information committees (CLI) and several safety regulatory bodies from abroad were invited to attend the technical meetings as observers and to take part in the targeted inspections carried out by ASN. Some observers provided input to the analysis of the reports submitted by EDF.

In comparison to the plans the other countries drew up, it is relatively easy to comprehend the French NAcP.

[7] The basemats are only 1.5 meters thick, which does not guarantee corium retention for 24 hours. EDF plans to thicken the basemat by 50cm, as well as to increase its surface area by allowing corium to flow from the reactor pit through a purpose-built channel into an adjacent room, the floor of which will also be thickened

4.2 Efforts to Remedy the Weaknesses the French Stress Tests Described

- Until now France has not evaluated the design basis earthquake (DBE) using state of the art methods, but relied on a deterministic approach only. A probabilistic seismic hazard assessment (PSHA) as recommended by ENSREG is to be implemented in the framework of the forthcoming periodic safety reviews, i.e. taking take several years.
- ASN requested EDF to conduct a more in-depth seismic margin assessment (SMA), which was performed during the stress tests in a simplified way. The review of the equipment likely to suffer cliff-edge effects, and the initiating of the necessary corrective measures is to be done until mid-2014. No schedule for completion was set.
- A study to compare the seismic instrumentation currently used in France with that used internationally to determine the need of its replacement is to be performed by 31/12/2013.
- Necessary backfitting of fire-fighting systems (fire detection and fixed extinguishing systems) to withstand an earthquake is to be done by 31/12/2013.
- Necessary backfitting measures of the hydrogen systems, of the equipment that could damage lines carrying hydrogen as well as of hydrogen detectors and their shut-off valves (located outside the reactor building) to withstand a design basis earthquake are to be performed by 31/12/2013.
- *Gravelines*: A reassessment of the seismic hazard revealed the need for reinforcement measures. The work is scheduled to be completed by 2017.
- Earthquake induced flooding represents a hazard for *Fessenheim*: The seismic robustness of the Grand Canal d'Alsace embankments and other structures designed to protect the NPP against flooding and the possible consequences of a failure of these structures were not analysed. Such a study is to be conducted by 31/12/2013.
- For F*essenheim*, where the heat sink lies at a higher elevation than the site platform, there is also a risk of a water channel emptying onto the site. A study on preventing this hazard (improvement of the robustness of the shut-off valves up to a beyond-baseline level) is to be performed by 31/12/2013.
- Today it is not possible to compare the levels of design basis flood defined according to the French requirements with the methodologies used in other European countries. ASN will publish a new guide regarding the external flood risk which includes a probabilistic exceedance target of 10^{-4} per year (as recommended by ENSREG) in 2013.
- *Gravelines:* Not all modifications and tasks resulting from the experience feedback approach after the flooding of the Blayais NPP in 1999 were implemented yet. These modifications (e.g. elevating and strengthening the wave protection, electrical back-up for the plant sewer system pumps) are to be carried out by 31/12/2014
- ASN requires strengthening the flood protection above of the current baseline safety requirements, because the studies performed by IRSN during the stress tests revealed cliff-edge effects close to review flood levels (DBF). The modifications to reach safety margins regarding flooding events are to be completed for Cattenom by 31/12/2015; for Fessenheim by 31/12/2016; for Gravelines by 31/12/2017.
- The peer review team emphasised the need for a systematic design basis and safety margin assessment with respect to extreme weather conditions. Analyses were performed on the possible impact of strong wind events and the resistance of the equipment against extreme hail loading and extreme lightning. The results were integrated in the required definition of the "hardened safety core".

- ASN asked EDF to propose a hardened safety core ("noyau dur" (ND) in French) of robust material and organisational measures designed in response to the extreme situations studied in the stress tests, by 30/06/2012. The hardened safety core includes systems that are independent and diversified with respect to the existing systems in order to limit common mode risks. The systems, structures and components (SSCs) shall be protected against on-site and external hazards. A specific meeting of the Advisory Committee of Experts for nuclear reactors was scheduled for 13 December 2012 to decide on the objectives associated with the hardened safety core.
- The advisory committee will in particular consider a difference of opinion between EDF and ASN's technical support organisation, IRSN, on what requirements for seismic risk assessments should underpin the last-resort measures. Installation of the hardened safety core will be finished by 2025 [NW 13/12/2012].
- None of the French reactors is equipped with an alternative ultimate heat sink, but recent events highlighted the vulnerability of the ultimate heat sinks. A situation with loss of UHS can be induced by a DBE or by flooding slightly beyond the DBF and will affect all units at a site. In those cases, the core could become uncovered in just a few hours. EDF started to reinforce the robustness of the UHS. An overall review of the design of the heat sink was to be submitted before the 30 June 2012. Analysis of this issue is in progress.
- With regard to total loss of heat sink situations, the means of ultimately restoring sustainable cooling of the reactors and pools are to be examined by 31/12/2013.
- For the *Gravelines site*, the retaining walls along the sides of the intake channel need to remain stable to prevent the loss of the ultimate heat sink. A study to evaluate the behaviour of this channel during beyond basis design earthquake was to be performed by 31/12/2012.
- EDF presented the planned modifications for installing technical backup devices for long-term heat removal from the reactor and the spent fuel pool in the event of loss of UHS (emergency water supply resources). These devices must meet the requirements on the hardened safety core.[8] No schedule for implementation was set.
- Are proposal for an emergency water make-up for the injection of borated water into the reactor core when it is open during station black out (SBO) situations, and the decision concerning whether this will be included in the hardened safety core is to be submitted by 30/06/2013.
- One additional electrical power supply[9] for each reactor on the site capable of supplying the systems and components of the hardened safety core during SBO situations is to be installed by 31/12/2018. In the meantime, a temporary system at each reactor for supplying the I&C (Instrumentation and Control) system and the control room lighting is to be installed by 30/06/2013.
- The battery discharge time, which is in the range of 1 hour, has been identified as the cliff edge effect for all reactors (loss of information in the control room and of the instrumentation and control). However, increasing battery autonomy is not an immediate task, only to be completed until 2014.

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[8] This backup ultimate heat sink would be achieved by installing hardened motor-driven pumps to pump water from a dedicated well, except for a few sites where this is not possible and a special reservoir would be created instead [NW 13/12/2012].

[9] These systems must meet the requirements concerning the hardened safety core per requirement.

- The fuel building[10] is not designed to contain steam generated by the boiling of the water of the spent fuel pools (SFP) during events with a pressure increase. A study of behaviour of the fuel and the water present in the SFP under loss of cooling and loss of water situations (in particular the radiological ambient atmosphere in a pool boiling situation, along with the hydrogen concentrations that could be reached in situations involving a loss of ventilation in the fuel building) including measures to be taken was to be performed by 31/12/2012. No schedule was set for the implementation of these measures.
- To prevent accidental rapid draining of the SFP, measures to prevent complete and rapid siphon emptying of the pool in the event of a break of a connected pipe is to be performed before end of March 2014. Furthermore, automatic isolation of the cooling system intake line is to be implemented by 31/12/2016.
- Devices to measure the temperature and water level of the spent fuel pool as well as the radiation level in the fuel building during SBO are to be implemented by 31/12/2013.
- A new on-site emergency plan baseline was issued for all sites since 15 November 2012. It takes into account accident situations simultaneously affecting several facilities on a given site. The integration of the new provisions for handling the extreme situations (affecting several reactors on the same site, and for all operating states) into the accident operations procedures and the severe accident management guidelines (SAMGs) is to be completed by 2015.
- A Nuclear Rapid Response Force (FARN), i.e. specialised teams capable of relieving the shift teams and deploying emergency response resources in less than 24 hours, with operations starting on the site within 12 hours following their mobilisation, was to be deployable to intervene on one reactor of a site by 31/12/2012; for intervening simultaneously on all the reactors of a given sites by 31/12/2014, only for Gravelines by 31/12/2015.
- The mobile equipment necessary for emergency management was not managed satisfactorily; the storage conditions did not guarantee permanent availability, particularly in the event of external hazards. These mobile devices necessary for emergency management need to be stored in appropriate premises or zones able to withstand the earthquake and flooding – to be completed by 30 June 2013.
- Habitability and accessibility of the main and emergency control room in the case of filtered venting is not guaranteed. Therefore EDF is planning to reinforce the electrical back-up of main control room ventilation and filtration by an ultimate backup diesel generator. Before this modification is implemented, the Nuclear Rapid Response Force (FARN) is intended to deploy means to ensure the electrical back-up of these equipment items for the damaged reactor. The long-term planning will make the emergency management rooms, the availability of parameters used to diagnose the status of the facility, the communication means necessary for emergency management, and the meteorological and environmental measurements part of the hardened safety core.
- The installed filtered venting systems are not resistant against earthquakes; also, the filters are not designed to retain iodine which is mainly responsible for exposure of people living in the NPP vicinity. A detailed study of the possible improvements to the venting-filtration system, taking into account the existing deficiencies (resistance to hazards, limitation of hydrogen combustion risks, efficiency of filtration in the case of simultaneous use on two reactors, improved filtration of fission products, in particular iodines, radiological consequences of opening the device for the site and the control room) is to be performed by 31 December 2013. However, no schedule was set up for the necessary back-fitting measures.

[10] It consists of a metal cladding roof and a thin concrete wall (about 30 cm).

- Redundant means to detect vessel melt-through and hydrogen in the containment are to be installed for Fessenheim, Gravelines by 31/12/2016 and for Cattenom by 31/12/2017:
- A feasibility study for the installation or renovation of a geotechnical containment or equivalent technical measures to prevent the transfer of radioactive contamination to groundwater and, by means of underground flow, to the surface waters, in the event of a severe accident leading to corium melt-through of the vessel was planned to having been performed by 31 December 2012.
- Gravelines: A leak of toxic gas at nearby industrial facilities (port of Dunkirk) could make it impossible for the operators to stay inside the reactor, because it is not protected against such accidents. Any modifications to be made to the NPP itself or the operating procedures as a result of a study assessing the risk posed by nearby industry facilities during extreme situations was to be proposed for Gravelines by 31/12/2012 (and are to be proposed for Fessenheim and Cattenom by 31/12/2013). No implementation date for these measures was scheduled.
- The management of large volumes of contaminated water is to be considered in 2013.

4.3 Weaknesses the French NAcP Ignored

- Conditions concerning the use of **outside contractors** were assessed during the complementary safety assessment (CSA) outside the scope of the European stress tests. ASN commented the results by stating that EDF has not adequately demonstrated that the scope of the activities subcontracted is compatible with the licensee's prime responsibility for safety. Regarding the envisaged back-fitting measures, this is a very important issue.
- In December 2011, Greenpeace activists trespassed on two EDF nuclear reactor sites to highlight the **security issue**. Design weaknesses of the old reactors increase the "success" of a terror attack. To implement more stringent measures of passive protection (alarm systems, fences, and video surveillance) at nuclear sites cannot compensate these facts.
- *Fessenheim and Gravelines*: High vulnerability against external events because the reactors are protected only with a single-walled containment structure.
- The double-walled containment of the Cattenom NPP was designed to provide better resistance to external initiating events. But the absence of an inner metallic liner has made the reactor more vulnerable to disruption from internal threats such as hydrogen explosions [MAKHIJANI 2012].
- **Ageing** is a major safety issue of the old French NPPs (900 MW class including Fessenheim and Gravelines). Faults caused by ageing of material have the potential to aggravate or even trigger an accident. An example for a safety relevant ageing fault is the occurrence of micro cracks in a bottom-mounted instrumentation penetration nozzle on the reactor vessel of Gravelines-1. The cracks were detected with non-destructive examinations conducted during the reactor's 30th-year outage in summer 2011.
- All six units of Gravelines are authorized to use **MOX fuel**. The consequences of a severe accident are more serious than those involving only uranium dioxide fuel.
- On 18 January 2012, EDF notified ASN that the absence of a siphon breaker on the fuel storage pools of Cattenom 2 and 3 had been detected during an inspection carried out as part of the complementary safety assessments (CSA). In the event of an incident, the injection pipe could extract the water from the pool through a siphon effect instead of injecting it, which would lead to a drop in the water level. A significant drop would lead to the damage of the fuel assemblies. Owing to its potential consequences, this event was rated level 2 on the INES scale. The absence of a siphon breaker is on no account the first non-conformance the inspections in the

frame of the CSA revealed. During the conformance checks conducted in August 2011, ASN observed 35 non-conformances during spot test. This high figure and their safety relevance indicate the operator´s insufficient **safety culture**.

- According to a recent study published by the Institute for Radiation Protection and Nuclear Safety (IRSN), for France alone the costs of a major accident with an uncontrolled release of radiation could exceed 430 billion Euro ($548 billion), requiring long-term evacuation of more than 100,000 people [NW 14/02/2013].

4.4. Conclusion

The French NPP belonging to the 900 MW and 1300 MW class show considerable deficiencies. Safety important equipment, in particular the filtered venting system, but also the fire fighter system lack seismic qualification.

EDF and the nuclear authority ASN try to direct attention to the future protection level which will be reached by the "hardened safety core". But this will not be the case before 2025. However, to assess the hazard, the current situation needs to be considered: regardless of its low probability, an earthquake, flooding or another hazard can occur any day from now on over the period of the next twelve years.

The evaluations of the natural hazards including safety margins were not sufficiently reliable, thus the definition of appropriate site specific requirements for the hardened safety core will take years. The operator EDF and nuclear oversight ASN, respectively IRSN as its technical support organisation (TSO) already started a "tug of war" about these requirements.

But there is another point to consider even if the hardened safety core will really be implemented in 2025: Some of the back-fitting measures required as a result of the stress tests, EDF was already planning in the framework of the utility's plan to receive the permit for 60-year reactor operation. Life time extension for the old dangerous plants means ageing becomes an increasing safety issue for the very old plants, faults cause by ageing could trigger accidents which are not incorporated in the scope of the hardened safety core. Furthermore there are design weaknesses that cannot be remedied, e.g. the low protection against terror attacks.

The old *Fessenheim NPP* is the most vulnerable plant, and at the same time threatened by earthquake as well by flooding induced by an earthquake. Analyses are on-going, but remedy measures, if they are possible at all, are not scheduled for implementation.

Gravelines NPP comprises six units: located at the coastal site, but with insufficient flood protection, suffering ageing related problems, plus using MOX fuel which increases the consequences during potential severe accidents. The only solution for this safety risk: ASN issues the order for shut down.

The inspections related to the CSA including the INES 2 event at Cattenom NPP revealed the shortcomings in the safety culture. Thus, *Cattenom NPP* has to stop power operation, at least until all envisaged backfittings are completed and additionally the complete plant has been properly checked.

5 Gundremmingen NPP, Germany

Gundremmingen NPP consists of two boiling water reactors (BWR) of the German construction line 72 with relatively high power output: net capacity per unit 1284 MWe, 1288 MWe respectively. Commercial operation started in 1984/1985. The site is located at the Danube River about 90 km northwest of Munich; distance to Austria is around 100 km.

Right after the Fukushima accident, German NPPs were subjected to a two-month safety review by the Reactor Safety Commission (RSK).[11] Furthermore an Ethics Commission "Secure Energy Supply" re-assessed the risks associated with the use of nuclear energy. These projects resulted in an amendment of the Atomic Energy Act (August 6, 2011): The operational licences for the seven oldest NPP (commissioning before 1980) and the incident-prone Krümmel NPP were declared expired. The licences for the operating NPPs will expire on a step-by-step basis between 2015 and 2022. Gundremmingen B has to stop power operation in 2017, Gundremmingen C in 2021. Gundremmingen A was shut-down after the largest accident in Germany in 1977.

5.1 German National Action Plan (NAcP)

The above mentioned RSK safety review included, in particular, natural hazards and postulated unavailabilities of safety and emergency systems. To assess the robustness of the plants, three respective topic-specifically defined degrees of protection were introduced.[12]

In its statement of 16 May 2011, the RSK made first recommendations on the robustness of the German nuclear power plants. On the basis of further consultations, the RSK supplemented its recommendation on 26 and 27 September 2012. RSK also took into account the peer review process recommendations of the ENSREG stress tests for preparing their own recommendations. Also GRS[13] prepared recommendations by order of the national regulator on the conclusions drawn from the Fukushima Dai-ichi accident for German NPPs to improve control of beyond-design-basis events. Both recommendations are compiled to the NAcP [BMU 2012].

The NAcP comprises 23 actions which are explained in some detail and refer to all related ENSREG recommendations. A comparison between the NAcP and the European recommendations is quite complicated. The specific action plan for Gundremmingen NPP only announced 13 very general measures without descriptions of any details.

5.2 Efforts to Remedy the Weaknesses the German Stress Tests Described

The last re-evaluation of the seismic hazard of the Gundremmingen NPP site is twenty years old (from 1993) and thus completely outdated. The margins as well as the cliff edge effects for seismic events have not been determined. Nevertheless, the NAcP does not require any analysis concerning earthquake resistance. Performing a seismic probabilistic safety analysis (PSA) to identify deficiencies is also not required yet.

The water level of the calculated design basis flood (DBF) is 33 centimetres higher than the grade elevation. Thus, some parts of the plant would already be flooded in this case. Protection of safety relevant safety systems is only assured by protection of the buildings (e.g. cable penetrations are sealed). Experiences with flooding events in other NPPs showed that these protections measures can fail. Furthermore the area surrounding the site is completely flooded.

The NAcP requires that the flood protection of German NPPs need to fulfil at least Level 1 of the criteria specified in the RSK safety review, which is not the case for Gundremmingen B/C. The safety

11 During the safety review, the operators had to shut down the operating NPPs commissioned prior to 1980.

12 Man-made hazards were also examined, such as aircraft crash and blast waves, but the discussions are not finished yet.

13 Gesellschaft für Anlagen- und Reaktorsicherheit, leading German technical support organisation (TSO)

can be demonstrated only by applying probabilistic considerations:" Alternatively, it may be demonstrated on the basis of site-specific conditions that a postulated discharge quantity, which is determined by extrapolation of existing probabilistic curves to an occurrence frequency of 10^{-5}/a, will not result in the loss of vital safety function. In this respect, the uplift resistance of canals and buildings is to be considered."

Review and improvement of flood protection was performed for Gundremmingen B/C in 2012, but no information about the results is available whether the review calls for improvements of the flood protection and if so, which deadline for back-fitting was set. The ENSREG recommendation to use a protected volume approach to demonstrate flood protection for identified rooms or spaces is only partly taken up in the NAcP; BMU claimed that further discussions with regard to beyond design basis flooding are on-going.

This leads to the assumption that Gundremmingen NPP flood protection was a paper exercise conducted to demonstrate the low probability of flood events.

Regarding flooding margins, the NAcP requires a systematic analysis to prove that the safety is ensured in case of beyond design flooding. The only result of this analysis for Gundremmingen NPP so far: to improve accessibility of the plant grounds in a flood, boats were purchased in 2012.

German regulator did not care to integrate all ENSREG recommendations when compiling the NAcP. For example: The peer review team recommended considering the assessment of margins with respect to extreme weather conditions. Because studies and discussions of the RSK on this topic are not finished, Germany has not included specific requirements regarding extreme weather conditions in the NAcP. The NAcP did not bother to take up the suggestion to require the implementation of advanced warning systems for deteriorating weather. Extreme weather conditions could aggravate flooding events for the Gundremmingen NPP.

In case of a total station black-out (SBO) and loss of ultimate heat sink (UHS), accident management (AM) measures have to ensure heat removal from the spent fuel pool, located outside the containment. The heat removal takes place by evaporation. The evaporation losses of water can be made up only by mobile pump(s). The permanently installed injection path into the spent fuel pool that is accessible from outside the reactor building is to be installed in 2013.

Currently, no severe accident management (SAM) measures for the mitigation of radioactive releases or preventing hydrogen explosions after severe damage of spent fuel in the pools are available. The backfitting of hydrogen recombiners in the area of the spent fuel pool is planned (deadline 2014).

The demonstration of integrity for spent fuel pools when the temperature rises to 100 °C is to be finalised by 2013. If any backfitting measures are necessary, these will be done later.

Obtaining and providing a mobile emergency power generator and connections points protected against external hazards for the supply of the accident overview measuring systems and for reactor pressure vessel (RPV) feeding is in progress (deadline 2013).

The introduction of improved accident management measures to prevent core melt is required by 2013. This action aims to increase a) the pressure, at which RPV injection via mobile pumps is possible and b) furthermore to get an additional option of being able to use fire engines as mobile pumps for RPV injection.

Based on the results of the plant-specific safety review of German NPPs in the light of the events in Fukushima, the RSK concluded that the successful use of accident management measures under long-term SBO conditions and severe accidents condition is not assured.

The peer review team pointed out in most cases detailed qualitative descriptions of the measures that would be undertaken in case of various severe accident scenarios are presented without comments regarding their adequacy also under extreme conditions.

In general the feasibility and operability of accident management measures (e. g. injection possibilities for the cooling of fuel assemblies) under adverse conditions is not proven.

However the systematic review of the robustness of accident measures with consideration of external hazards is scheduled for completion by the end of 2013. The implementation of further improvements is expected to be necessary; i.e. that current accident management measures are not expected to prevent core melt accidents with large radioactive releases after an earthquake or flooding event.

Severe Accident Management Guides (SAMGs) to cover beyond design basis accident scenarios are not established yet. Development and preparation of Severe Accident Management Guidelines (SAMG), as well as introduction and instruction at the plant is to be finalised by 2013.

Review of the availability of the emergency control room (remote shutdown and control station) during and after an external hazard, and if necessary its re-location is required (deadline 2014).

5.3 Weaknesses the German NAcP Ignored

- The vulnerability against a deliberate aircraft crash is not mentioned: According to a study on behalf of the national regulator (BMU), a crash of a Boeing 737 against the reactor building can cause a severe accident. In case of (1) a major destruction of the reactor building or (2) a damage of the control room by fire and debris combined with leakages in the cooling system, a severe accident could occur.
- The spent fuel pools are located inside the reactor building, but above and outside the containment (like in the Fukushima Daiichi NPP). In case of a severe accident, there is no barrier to the environment. Thus, the vulnerability against a terror attack is relatively high. In case of a damage of its structures and the loss of cooling water, a severe accident with a major radioactive release will occur. The stored MOX fuel increases the potential exposure by inhalation.[14] In total, 3219 spent fuel assemblies could be stored in the spent fuel pool of each unit. This is about four times more than is placed in the reactor cores (784 assemblies).
- The operator intends to conduct a power-uprate of both units which decreases safety margins for accident management measures and increases the radioactive release in case of an accident [NORDB 2013].
- After having visited the Gundremmingen NPP, the ENSREG fact-finding team voiced concerns about the scope of back-fitting measures: A challenge may exist in implementing improvement measures for plants with (legally) limited operational time. For complex measures requiring long lead times for analysis and implementation, a plant might be closing in on its scheduled shutdown at the time an improvement measure would be in place finally. Regardless of this circumstance, nuclear safety is an overriding priority and has to be maintained at high level up to the end of the operation time [ENSREG GE 2012].
- The regulatory body in Germany is composed of authorities of the Federal Government (BMU[15]) and authorities of the Länder governments. Licensing and supervision, inspection and enforcement as well as plant specific safety assessments and reviews of nuclear power plants are executed by the Länder. The NAcP is defined by the national regulator BMU, but the plant specific actions are defined by the Länder. This double layered system takes time and results in insecurities concerning competencies and sometimes resulting in a decrease of safety requirements.

[14] Last year the operator announced not to use MOX anymore, but it will be stored are stored in the spent fuel pool for several years [GF BAYERN 2012].

[15] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)

5.4 Conclusion

The evaluation of the design basis earthquake (DBE) was not done adequately; existence of a safety margin was not demonstrated. The NAcP does not include analysis concerning seismic hazards yet. In case of a design basis flood (DBF), the site will be flooded. The only response to this issue: the NPP purchased boats.

Besides earthquake and flooding, also terror attacks could cause a severe accident. A large amount of radioactivity can be released not only from the reactor core but also from the spent fuel pool that is located outside the containment.

However, the prevention of severe accidents at Gundremmingen NPP relies on outdated accident management measures unable to respond to external hazard conditions or the need of long-term heat removal. Only the latter weakness will be remedied next year. The operability of accident management measures during and after an earthquake or flooding has to be reviewed. The time schedule for resulting improvements and the scope of taking external hazards into account are not defined yet.

The German Regulatory body needs to follow the ENSREG advice *that nuclear safety is an overriding priority and has to be maintained at high level up to the end of the operation time* and deliver the list of measures needed or rather the safety goals to be achieved to the operator RWE/EON; the decision whether the investment still makes sense lies fully with the operator, responsibility with safety with the regulator. In the current condition, the units are not safe and should be shut down.

6 Krško NPP, Slovenia

Krško NPP is a 2-loop Westinghouse PWR with a net capacity of 688 MWe operating since 1983. Krško NPP is located on a site prone to flooding and in a seismically active region. Within the 25 km radius around the NPP, 55,000 people live in Slovenia and 147,700 people in Croatia.

Currently, a lifetime extension process is ongoing. The operator envisages a life extension for additional 20 years.

6.1 Slovenian National Action Plan (NAcP)

The core of the NAcP and post-Fukushima improvements represents the planned Safety Upgrade Program (SUP) which was ordered, reviewed and approved by the Slovenian Nuclear Safety Administration (SNSA). This upgrading program was already envisioned in the Slovenian legislation from 2009. It required from the plant to upgrade its systems, structures and components (SSCs) to cope with severe accidents in the period after plant lifetime extension will have been completed [SNSA 2012].

In response to the Fukushima accident and the progress made in the licensing process for lifetime extension, the SNSA decided to speed up the implementation of severe accident management measures. Thus in September 2011 the SNSA issued a decision requiring the plant operator to reassess the severe accident management strategy, existing design measures and procedures and implement necessary safety improvements for prevention of severe accidents and mitigation of its consequences. This evaluation was finished in January 2012. The action plan was reviewed and approved by the SNSA and according to the schedule will be fully implemented within the Safety Upgrade Program (SUP) by 2016.

The Nuclear Authority SNSA underlined that the implementation of SUP reduces the core damage risk at Krško NPP by half and the risk of radioactive releases in case of a severe accident will be reduced by 70%.

All measures of the NAcP are given in a table including the related ENSREG recommendations.

6.2 Efforts to Remedy the Weaknesses the Slovenian Stress Tests Described

The Krško NPP is located in a seismically active region. The national stress tests report refers to several active faults which were identified in the immediate region of Krško. Analyses included paleoseismic investigations, concluding that no relevant paleoseismic tracks were found

In line with US NRC nuclear regulation and standards the peak ground acceleration (PGA) of 0.3 g was used for the safe shutdown earthquake (SSE). Seismic hazard assessments in 1994 and 2004 led to raising the PGA values for the SSE: In 1994 to PGA= 0.42g and in 2004 to PGA= 0.56g, which is nearly twice the original PGA.

Nevertheless today Krško NPP complies only with current requirements for the original design basis of 0.3g. But the additional systems, structures and components (SSCs) which will be implemented within the SUP, will be designed and structured in accordance with the design extension conditions (DEC) requirements specific for the Krško NPP design and site location. However the extended design condition seismic value is 0.6 g PGA. This value offers nearly no seismic safety margin (0.04g) regarding the current value of the SSE.

SNSA claims that in case of an earthquake with a PGA over 0.6 g, core cooling can be assured by alternative means, but pointed out that implementation of alternative means requires that manual actions are performed in relatively short time.

An earthquake with a PGA in the range of 0.8 g or higher would be likely to cause core damage. Mechanical damage could disturb the reactor core geometry and thus the insertion of the control rods.

Radioactive releases cannot be excluded. A recurrence period of 50,000 years was estimated for seismic events with a PGA of 0.8 g.

The plant is located in an area prone to flooding. The average altitude of surrounding area is about 154.5 meters above sea level. The plant itself is located at 155.20 m on a plain, which is 0.69 m below the water level of the probable maximum flood (155.89 m). Thus flood protection has to be assured by dikes around the site. Currently the dike is only 0.15 meter higher than the probable maximum flood. Increasing the dike height upstream from the plant is in progress. The improved flood protection dikes are designed to ensure seismic resistance to safety shutdown earthquake without safety margins.

Another flood protection upgrade is in progress until 2015: The nuclear island and the newly installed equipment will be additionally flood protected against the failure of flood protection dikes or high river flows exceeding flood protection dikes by 0.4 m.

SNSA plans to include in its legislation requirements regarding both the use of advanced deteriorating weather warning systems and the use of seismic monitoring systems by 2014. Implementation of these systems in the NPP which is recommended by ENSREG) is not scheduled yet.

To prevent total station-black out (SBO), the SUP includes a comprehensive safety upgrade of AC power (deadline 2015). Regarding DC power supplies, the plant has in place several mobile diesel generators for recharging the batteries; improvement for the connection between diesel generators and charging buses is planned, as well as installation of additional train of batteries.

To prevent the loss of ultimate heat sink (UHS), an alternate UHS is to be installed (deadline 2015). The alternate UHS is to be seismically qualified and independent from the ultimate heat sink (Sava River).

To assure containment integrity during a severe accident, the safety upgrades program (SUP) includes the implementation of containment filtered venting systems and passive auto-catalytic recombiners (PARs) to avoid hydrogen explosion:

- The filtered venting system is scheduled for implementation by 2013.
- The installation of PARs in the containment is to be done by 2013. The topic “presence of hydrogen in unexpected places” is intended to be covered with the analysis that will represent basis for the installation of PARs within the SUP. It is not explicitly stated if the installation is to be done also by 2013.

To assure core cooling in case of SBO and/or UHS, the installation of additional high pressure pump for feeding steam generators (SGs) is scheduled by 2015. Furthermore additional pumps (low and high pressure, as well as a special pump for seal injection[16]) will be implemented by 2015. The pumps will be installed in the separated bunkered building with dedicated source of water for 8 hours and with provisions to refill by mobile equipment from different water sources.

Dedicated beyond design basis accident (BDBA) I&C capable of monitoring and controlling from the existing as well as the new emergency control room is to be installed by 2016.

The spent fuel pool (SFP) robustness will be enhanced within the safety upgrade program (SUP): The installation of fixed spray system around the SFP with provisions for quick connection from different sources of water and providing of mobile heat exchanger with provisions to quickly connect to SFP, containment sump or reactor coolant system (deadline 2015).

However the installation of dedicated I&C for the SFP is not scheduled yet. It is only mentioned that SNSA need amend its legislation to include requirements for BDBA I&C for SFP by 2014. To include

[16] The Krško NPP has considered installing temperature resistant reactor pump seals, but decided not to install them. Instead additional the above mentioned charging pump will be installed within the SUP.

spent fuel pool accidents in the PSA 2 is not planned, which is not in compliance with the state of the art.

The Krško NPP has in place a probabilistic safety analysis (PSA) Level 2, including all external hazards, but only for full power modes. A full scope PSA Level 1 and 2 for low power and shutdown modes events shall be implemented by the end of 2015. The SUP includes increasing shutdown safety by installing an additional BDBA safety train.

A new emergency control room (including expansion of existing remote shutdown panels) in the above mentioned separate bunkered building is to be installed by 2016.

The establishment of new technical support centre and upgrade of existing operational support centre (emergency operating facilities) is to be finished by 2015.

An especially noteworthy characteristic of the Slovenian SAM organization is the validation of the SAMG using a full-scope simulator.

SNSA plans to assign dedicated inspections to verify the external hazard protection equipment and to systematically review and inspect SAM equipment, SAMGs, test and maintenance procedures, as well as full scale training events at the Krško NPP by 2014.

SNSA plans to consider preparing a national strategy (also amending legislation if needed) in regard to the handling of large volumes of contaminated water after and during a severe accident.

The Krško NPP also prepared an analysis of the impacts of aircraft crashes on the plant. While this report is confidential and was not part of the peer review process, the national regulator states that the plant is well prepared even for such events. However, there is no proof to underpin this statement. It can not be assumed that this reactor type would withstand a crash of an airliner.

6.3 Weaknesses the Slovenian NAcP Ignored

- The Japanese Nuclear Regulation Authority (NRA) is currently considering to refuse issuing the restart permission for NPPs which are located in regions with active seismic faults. Since the Fukushima accident in March 2011, only two of the 50 NPPs are in operation [NATURE 2013].
- The EC staff working document recommended completing the severe accident management (SAM) upgrading measures as soon as possible [EC 2012]. This statement means translated into "normal language": the current situation is dangerous.
- Even after implementation of all upgrading measures both the calculated core damage frequency (CDF) of $8.46*10^{-5}$/year and the large early release frequency of $2.5*10^{-6}$ /year remain relatively high.

6.4 Conclusion

Krško NPP, in operation for 30 years, is situated in an area highly inadequate for an NPP because it is prone to earthquakes and flooding. Nevertheless, currently the means of the severe accident management are not sufficient to prevent severe accidents or even to mitigate their consequences.

In conjunction to the ongoing lifetime extension process (for additional 20 years), the comprehensive safety upgrading program (SUP) is to be finished by 2016. For some safety relevant equipment (e.g. spent fuel pools instrumentation and seismic monitoring systems), the deadline for implementation is not scheduled thus implementation will be probably later than 2016.

But the key issue will remain: Despite the Nuclear safety authority SNSA and the operator being fully aware that Krško NPP is situated in a seismic active region, obviously insufficient measures are taken. Even after implementation of the SUP, the resistance against earthquakes will not have reached the necessary level. The plant operates and will continue operating for two more decades with an almost zero seismic margin.

Furthermore, a beyond design earthquake could also cause a dam break and a consequential flooding of the site.

Both operator and regulator SNSA claimed that the plant and the operator are able to cope with manual action with the consequences of a beyond design accident to a certain degree and prevent major radioactive releases. After having assessed all facts, this claim cannot be upheld. But even if the operator were right with this assumption, a severe accident caused by beyond design earthquake, flood or combination of both cannot be excluded solely arguing the low probability of occurrence.

It certainly was a good decision to postpone issuing the permission for life time extension to after the implementation of the safety upgrade program (SUP) will be completed. However accelerating the implementation of the limited safety upgrade cannot contribute much to the safety of the people and the environment.

Due to the undoubtedly high seismic hazards and the inadequate scope of the safety upgrade program we recommend to permanently shut-down Krško NPP as soon as possible.

7 Mochovce NPP, Slovak Republic

The construction of the Mochovce NPP started in 1981. In 1996, a "Mochovce NPP Nuclear Safety Improvement Programme" was developed in the frame of unit 1 and 2 completion project. Today, Mochovce NPP comprises two pressurised water reactor (PWR) units VVER 440/V213, operating since 1998 and 2000 respectively, and two units VVER 440/V213 under construction. Due to construction delays, start-up is currently expected in 2014 and 2015. The plant is situated 90 km north-east of Bratislava.

The latest Periodic Safety Review (PSR) of Mochovce 1 and 2 (EMO 1/2) was completed in 2009. Based on the results the Nuclear Regulatory Authority (ÚJD SR) issued the operational permit for subsequent 10 years of operation. The permits are associated with approval of safety upgrading program aimed at closer compliance of the safety level with contemporary safety standards. The program includes also implementation of comprehensive severe accident mitigation measures [UJD 2012].

7.1 Slovak National Action Plan (NAcP)

The majority of tasks resulting from the NAcP are covered by ÚJD SR decisions issued in the past and in particular after completion of the PSRs. According to these decisions, the operator will report annually to ÚJD SR on the course and the results of the implementation. The measures of the NAcP are divided into three groups: short-term (to be finished by 31/12/2013); medium-term (to be finished by 31/12/2015) and additional measures, which may result from analyses, defined by medium-term measures and will be implemented after 2015 [UJD 2012].

The NAcP contains a comprehensible presentation of the envisaged actions in response to the recommendation of EC staffing waring document and ENSREG.

7.2 Efforts to Remedy the Weaknesses the Slovakian Stress Tests Described

Concerning seismic hazard, a value of the peak ground acceleration (PGA) of 0.1 g was used for the plant construction. During a reassessment in 2003, the value was increased to 0.143 g. ÚJD SR decision No. 100/2011 ordered the implement seismic resistance to a new value of 0.15 g by December 31, 2018.

The ENSREG peer review team recommended considering prioritization of the seismic upgrading measures. The NAcP includes the recommendation and requires implementing the seismic reinforcement of relevant systems, structure and components (SSCs) based on the valid UJD SR decision No 100/2011, taking into account the set order. The seismic reinforcement of structures with the highest priority is planned to be finished by 31/12/2015.

However, no analysis of the resilience of this equipment under beyond design earthquake conditions is available yet. Therefore cliff edge effects cannot be excluded. The NAcP requires analysing seismic margins of selected SSCs by 31/12/2013.

The protection against the design basic flood (DBF) is adequate mainly due to the relatively high difference in altitude between the site and the closest rivers. To assess safety margins at Mochovce, analysis of the maximum potential water levels on the basis of 10,000 annual values is required; places where water accumulates are to be identified. Immediate implementation of temporary solutions and the proposal of a final solution are scheduled to be finished by 31/12/2013.

Concerning extreme weather events, precise quantitative specification on the cliff-edges is not available yet. Evaluation is required of the resistance of selected SSCs against extreme weather events (floods caused by heavy rain, high and low external temperatures, direct wind and other relevant events) on the basis of updated new studies on meteorological conditions, and to consider events with intensity corresponding to the probability of occurrence once per 10,000 years or less. The plan for implementing these measures needs to be prepared by 31/12/2013.

Furthermore the NAcP requires the implementation of the warning and notification system in case of deteriorating weather and of the procedures for NPP operating staff response by 31/12/2013; and the preparation of regulations to address qualified plant walkdowns with regard to natural risks[17] by 31/12/2015.

To prevent total station black-out (SBO), it is planned to install a 400 kV circuit breaker in the local substation to enable disconnection of units from the power grid and thus to enable operation in the home consumption mode in the case of damaged transmission lines; however deadline is not scheduled yet. Furthermore emergency power sources are to be diversified by deploying mobile diesel generators (DG) that can also charge the accumulator batteries; to be finished by 31/12/2013.

Prevention of the loss of the ultimate heat sink (UHS) with the help of an independent diversified alternate UHS does not exist nor is it planned. The following back-fitting measures are envisaged regarding alternative cooling and heat sink:

- To diversify the emergency feedwater source to steam generators (SG) by assurance of mobile high-pressure sources by 31/12/2013
- To review physical availability of technology needed for gravity filling of SG from feedwater tanks in case of SBO by 31/12/2013
- To finish required modifications of existing equipment for connection of diverse mobile feedwater and power sources resistant to external events by 31/12/2015
- To analyse and if needed to ensure means for cooling water make up from in-site and off-site water sources in the case of lack of cooling water, incl. preparation of respective procedures by 31/12/2013.

The severe accident management (SAM) implementation project, initiated in 2009, was accelerated after the Fukushima accident, with the new deadline being 2015. The measures being implemented include dedicated means for the primary circuit depressurization, hydrogen management using passive autocatalytic recombiners (PARs), in-vessel corium retention by strengthening of the reactor cavity and providing for its flooding, dedicated large external tanks (with the boric acid solution) including dedicated power source and pump aimed at possible spent fuel flooding, and serving as a supplementary source of coolant for the reactor cavity flooding, modifications enabling coolant make-up to the reactor cavity, spent fuel pool and external source tanks using mobile source connected to the external connection point on walls of the reactor and auxiliary building, and associated I&C.

According to ÚJD SR, large part of the required plant modifications has been already implemented (e. g. installation of PARs). However the SAM project being currently implemented is based on originally defined scope (before Fukushima accident) with assumptions for occurrence of a severe accident on only one of two units. The analysis and the modification of the SAM project from the viewpoint of severe accident management at both units are necessary. The plan of implementation of additional measures shall be prepared by 31/12/2014.

It seems that the implementation of a filtered venting system is not envisaged because the NAcP only requires analysing the need for filtered containment venting and other potential technical measures for long-term heat removal from the containment by 31/12/2015. In this regard ÚJD SR points out activities in this area at other operators of VVER-440/V213 NPP types are taking into account for the decision. (To install a filtered venting system is not planned at the four VVER-440/V213 units at the Paks NPP.)

[17] to provide a more systematic search for non-conformities and correct them

The update of the severe accident management guidelines (SAMG) with regard to potential damage of infrastructure, including long-term accidents and accidents with an impact on several units and neighbouring industrial facilities is necessary; however only an analysis and plan of implementation of additional measures is scheduled to be conducted by 31/12/2015.

Regarding SAM exercises until 31/12/2014 the conditions for cooperation in emergency response control during external events and severe accidents with selected external organisations will be prepared: by in parallel the review of the national emergency arrangements based on the outcomes of the “HAVRAN exercise” undertaken until 31/12/2014.

In the area of severe accident prevention and consequence mitigation, the following measures were announced:

- To analyse the availability of important parameters, and if needed, to ensure mobile measuring units which can use stabile sensors also without standard power supply by 31/12/2015.
- To prepare operating regulations and implementation of training programmes for operators of mobile devices by 31/12/2015.
- To analyse the conditions of the environment of rooms with safety relevant equipment during long-term station blackout (SBO), loss of ultimate heat sink (UHS) and severe accidents. However, the schedule is not ambitious, the plan of the required measures is due by 31/12/2015 only; no schedule was set for necessary back-fitting measures.
- To obtain data documenting seals of reactor coolant pumps at long-term failure of cooling and to prepare a plan of potential necessary measures by 31/12/2013. The backfitting of temperature resistant seals are not mentioned.
- To analyse the SAM project from the viewpoint of resistance of seals and penetrations of the containment under severe accident conditions and of potential migration of hydrogen to other places by 31/12/2015
- To prepare solutions for treatment of large volumes of contaminated water after an accident at a study level from the conceptual viewpoint by 31/12/2015.

In addition to the actions recommended by ENSREG, preparing a concept of large area fire control, including fire control documentation, analysing the equipment and training of the staff is taking place until 31/12/2015.

7.3 Weaknesses the Slovakian NAcP Ignored

One of the most important modifications concerning the prevention of major radioactive releases during accidents is the external cooling of the reactor pressure vessel (RPV). This so-called in-vessel retention (IVR) concept aims to ensure the integrity of the RPV during a severe accident. Proof that this concept fulfils all the functions intended was until now delivered only with limited experimental analyses. Therefore the peer review team recommended considering a failure of the reactor pressure vessel (RPV), despite the fact this is claimed to be very unlikely. However, consequences of RPV failure are not evaluated in the NAcP.

The reactor buildings do not provide sufficient protection to the plant against external impacts like airplane crashes or explosions. The spent fuel pool (SFP) is located outside the containment barrier in the reactor hall. Taking into account the existing risk of terrorism, it is irresponsible to operate a nuclear power plant with such a high vulnerability to external attacks.

7.4 Conclusion

Earthquake is a major hazard for Mochovce NPP, comprehensive upgrades are envisaged. But the necessary back-fitting program will take several years: Measures of high priority are scheduled for completion by 2015, other measures even later – 2018. Furthermore after the completion of the seismic margin assessment, further back-fittings measures need to be performed. In total it will take probably over six years to achieve the planned level of resilience against earthquakes.

Establishing protection against external flooding and severe weather events will take also several years.

Severe accident management measures will not be implemented before 31/12/2015. Some indispensable measures will be performed even later; after that the issue of severe accidents will still be open because there are no guarantees that these modifications can definitely prevent major radioactive releases.

Obviously the original design of Mochovce NPP has a number of safety deficits; the idea of the Slovak Nuclear Authority ÚJD and the operator ENEL being that upgrades would compensate for those deficits. However, this goal cannot be achieved. On the one hand the VVER 440/V213 reactors have safety deficits which cannot be upgraded, e.g. thickness of the confinement walls. On the other hand the high number of upgrading measures significantly increases the enormous complexity of the nuclear power plant. Both mutual interactions between these modifications and installation failures need to be taken into account, which can cause the unavailability of necessary safety systems during accident sequences.

Under these circumstances it is hard to recognise nuclear safety as being the guiding principle of the Slovak Authority: ÚJD accepts that seismic measures will not be ready in the next six years. Those measures which might be the key in case of an earthquake the NPP cannot fully resist – Severe Accident Measures – are not due before 2015 and currently there are no guarantees that these modifications can definitely prevent major radioactive releases.

In general the NAcP analysis showed that planned back-fittings are not going to cover the whole extent of what is technically possible. A measure commonly installed to prevent major radioactive releases in case of a severe accident – a filtered containment venting system will not be implemented at Mochovce 1 and 2, but the plant is supposed to keep operating for another 10 years.

The picture we see here, Mochovce 1 and 2 being a nuclear power plant with severe design deficiencies and no intention to use all technical means to reach a higher nuclear safety level only allows to recommend permanent shut-down.

8 Muehleberg NPP, Switzerland

Muehleberg NPP (373 MWe), in operation since 1972, is a General Electric Boiling Water Reactor (BWR/4) with a Mark I containment, which is the same type as unit 2-4 at Fukushima-Daiichi. The plant is located at the Aare River, only 14 km west of the city of Bern with 125,000 inhibitants.

In 2009, the Swiss environment ministry issued an unlimited-duration operating licence to the Muehleberg NPP. This decision, however, was overturned in March 2012 by the country's Federal Administrative Court (FAC), which decided the NPP can only operate until 28 June 2013 [WNA 2013a]. Operator BKW has lodged an appeal against the FAC's ruling. On 28 March 2013, the Federal Court overturned the decision by the FAC and thus Muehleberg NPP is holding an open-ended operating licence [SWISS 2013].

8.1 Swiss National Action Plan (NAcP)

In the Swiss NAcP prepared by the Swiss Federal Nuclear Safety Inspectorate (ENSI), a clearly arranged table of all required and planned actions is missing.

ENSI has set the goal of investigating the identified issues and implement the derived measures by 2017. ENSI will update the "Action Plan Fukushima" annually and will report on the status of implementation [ENSI 2012].

8.2 Efforts to Remedy the Weaknesses the Swiss Stress Tests Described

An earthquake exceeding the design basis can possibly occur at the Muehleberg site. The seismic hazard assessment of the PEGASOS project (2004) indicates that the current design maximum PGA of 0.15g for safety significant buildings and systems could be exceeded at a frequency of approx. 6×10^{-4} per year, which is not extremely rare. In order to reduce the uncertainty of the PEGASOS results, the PEGASOS Refinement Project (PRP) was initiated. The PRP project is expected to be completed in 2013 and the final report will be submitted to ENSI. ENSI will conduct a follow-up regulatory review of the new hazard assumptions and the operators have to submit updated proof that each NPP can cope with the seismic load expected at the site.

The potential failure of the Wohlensee dam located 1 km upstream is a serious seismic hazard for the Muehleberg NPP. The dam is very old and might break in case of a severe earthquake. After the dam break, clogging of the NPP cooling water intakes has to be expected, potentially causing the reactor cooling to fail. To evaluate this hazard, new studies were prepared and the goal of proving the seismic robustness of the Wohlensee dam was achieved; however, some open issues remain. The Muehleberg NPP provided the required answers, which are currently under review by ENSI.

Regarding seismic robustness of the containment and primary circuit, ENSI will complete the reviews for all the NPPs by issuing evaluation reports in the course of 2013. Possible further actions will be decided upon in 2013.

In 2013, ENSI will set up a working group to investigate the necessity to implement automatic scrams triggered by seismic instrumentation. However, international practice should also be taken into account as a basis for the decision-making process. Once the information is collected and structured, ENSI will issue an evaluation report. Based on these results a backfitting demand could be sent to the licensees, if considered necessary.

ENSI will follow up on the impacts of a total debris blockage of hydraulic engineering installations at the Beznau, Gösgen and Muehleberg NPP. A statement on the licensees' reports will be issued by ENSI in the course of 2013. If the statements do not prove sufficient safety, further actions will be decided.

Margins for extreme weather events (besides winds and tornadoes) and combinations thereof were not considered. In 2012 ENSI defined specifications for analyses on the protection against extreme weather conditions, including combinations thereof, to be performed by the licensees. The probabilistic hazard analyses, as well as the proof of sufficient protection of the NPPs against these hazards, have to be submitted by the end of 2013, including submission of the existing margins. Subsequently ENSI will evaluate the licensees' reports in 2014.

In addition to the normal heat sinks, at all Swiss NPP core cooling and residual heat removal can also be achieved by use of well water as an alternate ultimate heat sink, the only exception being Muehleberg NPP. Because of the lack of sufficient ground water on site, an alternate or diversified ultimate heat sink does not exist yet. In order to assure core cooling and residual heat removal in case of loss of the ultimate heat sink, ENSI ordered the Muehleberg NPP to implement a diversified heat sink that is independent from the Aare river by the end of 2017 (project DIWANAS). Muehleberg NPP will fulfill this order by providing alternate cooling water to the special emergency system SUSAN from a protected well that is fed by another river (Saane River).

The peer review team stated that hardware provisions for severe accident management seem to be adequate and robustly designed, resulting in significant safety margins, however the above mentioned OSART Team observed shortcomings regarding the use of the provisions:

- The instructions provided by AM / SAMG procedures, the information on priorities and on rules of usage provided for effective implementation during emergency situations and the assessment of negative impacts are not always provided in detail.
- The use of the containment venting system under all expected conditions and the link to the use of the containment spray system are not clearly described in relevant documents: operating procedure, AM and SAMG.

Furthermore, there is no comprehensive evaluation of the instrumentation required in order to initiate and implement the individual severe accident management measures (prior to a containment integrity failure). Possible improvements of the SAM instrumentation will be analysed.

On venting strategies, ENSI has received recommendations about the use of passive means for hydrogen control as well as on the issue of inertisation of the filtered containment venting system piping as a result of the country peer review. As a consequence, ENSI has started discussing the boundary conditions for further analyses to be conducted by the licensees. The need for passive autocatalytic recombiners has also been studied. ENSI will issue a request to all Swiss licensees for additional studies and possibly backfitting measures. After evaluation of the licensees reports a decision on hardware resp. procedural measures will be taken.

Within its action plan for 2013, ENSI will request the NPPs to investigate systematically the issue of migration of hydrogen. This investigation will also cover the ingress of hydrogen into adjacent rooms in the plant.

For Severe Accident Management mobile equipment plays an important role, which is stored on-site. In addition to the on-site stored mobile equipment, a flood-proof and earthquake-resistant external storage facility is in place (at Reitnau) since June 2011. It contains various operational resources, in particular mobile motor-driven pumps, mobile emergency power generators, hoses and cables, radiation protection suits, tools, diesel fuel and boration agents. The storage facility is accessible by road or by helicopter.

In 2012, ENSI conducted inspections at all Swiss NPPs regarding the habitability of communication in emergency control rooms. The final assessments of these inspections are not yet available, as the operators were to submit the concepts for assuring emergency control room habitability to ENSI in February 2013.

ENSI reassessed the spent fuel pool (SFP) cooling, integrity, and instrumentation in the light of the Fukushima events and required the following back-fitting measures to be implemented:

- Two additional feed lines for SFP cooling without the need for entering the SFP buildings or rooms as an AMM (by 2012)
- Accident-proof SFP level and temperature measurement instrumentation (by 2014)
- A new SFP cooling system that is qualified as safety system (by 2015)
- A diversified heat sink which also serves for SFP cooling (by 2017)

Muehleberg NPP is an old reactor and does not fulfil the Swiss nuclear regulator´s requirement of strict physical separation of redundant safety systems. At the lowest elevation of the reactor building (in the annulus space), several components including pumps and heat exchangers for the emergency core cooling are installed without physical separation. In case of internal flooding, several systems could be affected simultaneously, possibly resulting in a cliff edge effect. ENSI required the implementation of measures that reduce the internal flooding hazard. However, the scope of the backfitting measures (e.g. installation of additional valves in lines) is limited because there is not enough space to construct additional walls to achieve physical seperation.

Regarding SAM Training, a revised regulatory guideline (ENSI-B11) will give ENSI the possibility to require staff exercises lasting up to 24 hours. Exercise scenarios integrating an increased deployment of equipment stored at the external storage facility are being considered.

In February 2013, ENSI will publish its action plan “Fukushima 2013” which will require an investigation of the handling of radioactive water in case of a severe accident.

In 2012, ENSI required a long term operation concept after a core damage accident with large release for each NPP. In 2013, ENSI will assess these concepts with regard to the existing emergency facilities and international standards.

8.3 Weaknesses the Swiss NAcP Ignored

- The very old Muehleberg NPP has obvious design weaknesses which cannot be eliminated: The generic assessment for BWR-4 / Mark I containments estimated that the end cap could lift, resulting in containment failure at pressures and temperatures of appr. 0.6 MPa and/or 370ºC – occurring easily during severe accidents. This happened in the case of the Fukushima accident in 2011.
- Muehleberg NPP has been in operation for 40 years, thus ageing of components and equipment is an important issue. Small failures could develop into breaks (pipes and tanks), pumps, valves and other equipment could fail. To limit ageing related failure at least to a certain degree, a comprehensive ageing management program (AMP) is necessary. But the AMP shows shortcomings because it does not contain all generic IAEA AMP attributes. Furthermore the ageing management review for some systems, structures and components (SSCs) for Long Term Operation (LTO) is incomplete [IAEA 2012]. These are two of several issues the IAEA Operational Safety Review Team (OSART) observed during the Muehleberg NPP mission from 8 to 25 October 2012. The OSART mission is designed to review operating practices.
- The OSART team pointed out another issue of importance regarding ageing related problems and accident prevention: Analysis of events is not performed in a timely manner and applying sufficient level of detail. Root causes, human factor and corrective actions are not always defined in a specific and measurable way.
- An important shortcoming regarding the expected backfitting measure the OSART Team observed: The modification programme is not tracked in sufficient detail to ensure that modifications are identified and finished a timely manner. A backlog exists on closing modifications and there is no tracking indicator on implemented modifications remaining open. Forty-four modifications implemented since 2009 have not been finished.

- An important safety issue has been left unsolved for years, but tolerated by ENSI: During a routine inspection in 1990, fissures were detected on the core shroud. The core shroud does not function as a barrier to contain radioactivity, however, it is important for the safe reactor shut down.. The fissures increased in length in the past years. In 2000, the operator changed the chemistry of the reactor water to inhibit the growth of the fissures, but the growth of the fissures was not stopped only reduced. So-called anchor bolts has been installed on the core shroud as a precautionary measure, but expert assessment (TÜV Nord 2007) commissioned by ENSI came to the conclusion that the implemented measures are not adequate for the long-term operation of Muehleberg. ENSI only requested the operator to submit a revised solution proposal for long-term operation, which was submitted by the end of 2010 [ENSI 2013]. This is now under review, but this NPP is still in operation.

8.4 Conclusion

Although the probability of an earthquake exceeding the plant's design limit is low, the possibility of a severe earthquake persists, which could trigger a severe accident. The hazard of flooding endangering the NPP cannot be excluded in case of an earthquake induced break of the Wohlensee dam. The key issue – the possible earthquake intensity – remains open. It could turn out that the current protection against earthquakes is utterly insufficient.

Backfitting measures of the spent fuel pool and the installation of an alternative ultimate heat sink is to be completed in 2017. Therefore the protection against external hazards is not secured for the next five years. Regarding the observed backlog of modifications, completing all backfitting measure is likely to take even longer.

Another serious deficiency, the issue of preventing hydrogen explosions in the containment, remains unsolved for the time being and no plans concerning backfitting were announced. The hydrogen issue was also highlighted by the ENSREG peer review team.

The SAM provision will be quite useless when the staff is not able to use these provisions appropriately as the IAEA OSART team pointed out.

Muehleberg NPP, one of the oldest operating NPP in Europe, has design weaknesses that cannot be eliminated (e.g. containment, lack of physical separation of emergency cooling systems). Furthermore ageing is an increasing issue of the 40 year old plant. Particularly negative effects of ageing will not be eliminated by the inadequate ageing management program.

Muehleberg NPP combines a high number of serious safety issues: seismic hazard both for the plant and the close-by dam is high, fissures on the core shroud, severe design shortcomings of an old reactor plus operational weaknesses and an inefficient ageing management allow for only one recommendation: immediate shut-down.

9 Ringhals NPP, Sweden

The Ringhals NPP is situated on the west coast of Sweden about 60 km south of Gothenburg. With a total net capacity of 3747 MWe, it is the largest nuclear power plant in Sweden. The plant comprises four reactors: Ringhals 1 is a boiling water reactor (BWR), in operation since 1976. Ringhals units 2, 3 and 4 are pressurised water reactors (PWR), in operation since 1975, 1981 and 1983 respectively.

9.1 Swedish National Action Plan (NAcP)

The Swedish NAcP listed the measures in three different categories – 2013, 2014 and 2015 – according to the year when the measures have to be completed [SSM 2012]. However, the Swedish Radiation Safety Authority (SSM) explained that measures consisting of investigations are considered completed when the report of this investigation is submitted by the deadline given. All necessary actions resulting from the investigations are to be fully implemented before the end of 2020.

Site-specific action plans form the basis of the Swedish NAcP, although not each individual site or unit-specific measures have been reviewed yet.

The NAcP does not present a systematic comparison of the ENSREG recommendation and the actions to be taken. Plant specific actions are not mentioned at all, which makes the understanding of the Post-Fukushima plant´s safety very difficult.

After having visited Ringhals NPP in September 2012, the ENSREG fact-finding team concluded: The plant is advised to update the action plan taking into account the full set of ENSREG recommendations. The plant and SSM should establish the processes to ensure that the plan is implemented in accordance with the established schedule, and in particular that the important safety modifications will be implemented in the near future [ENSREG SE 2012].

9.2 Efforts to Remedy the Weaknesses the Swedisch Stress Tests Described

The original design of the Ringhals units did not take into consideration protection against <u>earthquakes</u>. Ringhals became subject to general requirements imposed on resilience against earthquakes when the new Swedish regulations entered into force in 2005. The deadline for taking measures was determined to be 2013 to allow licensees sufficient time to fulfil the requirements. Work is currently on-going at all units in order to fulfil the regulation regarding design basis earthquake (DBE). Identified deficiencies are for example the spent fuel cooling systems, the roof of the reactor building at Ringhals-1; anchors at Ringhals-2, -3 and -4; control room ceiling at Ringhals-3 and -4.

In April 2012, the ENSREG peer review team recommended to the Nuclear Authority SSM to consider a more timely manner for the implementation of seismic flooding related back-fittings. However the NAcP does not mention that SSM would have required speeding up of the back-fittings.

The protection against earthquake-induced flooding of damaged water storage tanks is not sufficient yet. The NAcP demands investigations regarding these secondary effects of earthquakes by 2014. The utilities are also obliged to review the procedures and training program for seismic monitoring, followed by implementing them by 2014.

The peer review revealed that the methodology used for seismic hazard assessment (SHA) is not fully compliant with current international standards and research results. Therefore, SSM will start a research project concerning the influence of paleoseismological data on the existing model regarding frequency and strength of the ground response spectra in 2013.

The analysis of the maximum earthquake severity which the plant still can withstand without loss of fundamental safety functions or severe damage to the fuel becoming unavoidable was not performed yet. The NAcP asked for an investigation of seismic margins; an evaluation of structures, systems and components (SSCs) against ground motions exceeding DBE is to be performed by 2015.

The Ringhals units are located near the sea and thus they can be significantly affected by extreme flood events. The full compliance for protection against external flooding in accordance with the current Swedish requirements (2005) is expected to be reached in 2013.

A new evaluation of the protection against flooding as recommended by ENSREG (volumetric approach) and scheduled for completion by 2014. This study serves to identify critical areas and spaces regarding flooding of the sites and consider the need of further protection of the buildings containing safety related equipment located in rooms at or below ground level.

The site ground elevation is only 35 cm above the seawater level of the calculated design basis flood (DBF), but this water level does not include possible waves. Once the seawater level (including waves) rises higher than 65 cm, large amounts of water will enter the units through various openings; fuel damage is possible.

An analysis of the combined effects of waves and high water including potential dynamic effects is scheduled for completion by 2015. SSM underlined the fact that historically extreme sea water levels in Scandinavia have always been accompanied by very high wind speeds.

EC staff working document recommended analysing the combination of high sea water level and other external phenomena [EC 2012]. The NAcP required the analysis of a combination of high sea water and strong wind. Combination with swell and organic materials is not mentioned.

The NAcP requires a flooding margin assessment by 2014 as the initial ENSREG specification for the stress tests laid down: Conducting an analysis showing step by step increased flood levels beyond the design basis and identification of potential improvements.

In conjunction with the recommendation regarding flooding margin assessments, a formal assessment of margins for all external hazards (including seismic, flooding and severe weather), plus identification of potential improvements is to be performed by 2015.

After having visited the plant, the ENSREG fact-finding team concluded: The definition of high sea level for assessment of the margin against flooding remains an issue to be further considered since the site platform is at about 3 m level in comparison with the high sea level 2.65 m, which could be a concern regarding adequacy of the margin. Specification of the protection against flooding over 3 m will be considered in the long term actions for beyond design basis improvements. In connection with this issue the team visited the on-site emergency control centre (ECC) and underlined the importance of re-assessing the vulnerability of the ECC [ENSREG SE 2012].

The current Swedish regulation addresses extreme weather without quantification of the loads. An investigation of plant characteristics in extreme weather conditions is required to be performed by 2015. This investigation will assess plant robustness against extreme weather combined with events such as ice storms and heavy snow load on structures. Some shortcomings were already identified (e.g. vulnerability of the reactor building of unit 1 against tornado and heavy snow load) but it is likely that further analyses will identify additional deficiencies.

SSM is obliged to initiate a study with the target of a more precise assessment of extreme weather conditions in 2013. The study will be performed as a research project in cooperation with industry.

In case of loss of off-site and emergency power (Station Black-out (SBO)), various mobile units can be used. If these devices are unavailable, under current conditions fuel damage becomes unavoidable after approximately 16 hours for Ringhals-1 and after approximately 9 hours for Ringhals-2, -3 and -4.

To prevent SBO situations, the reassessment of the AC and DC power supplies and distribution systems is required by 2014.

Furthermore the fundamental design principles of an independent core cooling system for injection of water to the reactor pressure vessel to handle SBO should be defined by 2013; however, no schedule for implementing any of the necessary measures was set.

The primary ultimate heat sink for all units at Ringhals is sea water.[18] Ringhals-2, -3 and -4 (PWR) have another option to release residual heat to the atmosphere via the steam generators. However, this procedure is dependent on the water sources available for the auxiliary feedwater system, and is thus, limited. Ringhals-1 (BWR) has no alternate ultimate heat sink at all.

In case of a total loss of power (SBO) or loss of Ultimate Heat Sink (UHS), currently no system is available for cooling the spent fuel pools (SFP). The only usable source for the preparation of make-up water necessary for the pools is fire fighting water. Manual actions must be performed before the onset of harsh conditions (humidity, temperature, radiation) in the spent fuel area. For cooling of the spent fuel pool, the installation of permanent pipes for make-up water from a protected location is to be considered by 2014.

Alternative means of cooling and residual heat removal for the reactor cores and the spent fuel pools as well as alternative means of cooling the safety systems needs further evaluation and reassessment by 2015.

The containment filtered venting system is not designed for accident scenarios with the duration and aggravated conditions at the site as it occurred during the Fukushima accident. Therefore, the use of the containment filtered venting system during prolonged severe accident conditions of more than 24 hours is also scheduled for review until 2014.

New analyses will also be needed for the issue of long-term management of hydrogen in the containment. Similarly the possibilities and consequences of hydrogen accumulating in the reactor building and suggesting necessary instrumentation and management should be investigated by 2014.

To prevent a severe accident or to mitigate its consequences, the following issues need to be taken up:

- Investigation of the effects of simultaneous events affecting all reactors at the site by 2015
- Enhancement of accident management programmes for all plant states including spent fuel pools and multi-units events by 2014.
- Considering an extended scope of training and drills (regarding multi-unit accidents under conditions of infrastructure degradation) by 2014.
- Reassessment of the integrity of the primary system (including reactor pumps seals) and of the spent fuel pools by 2013
- Reassessment of the operability and habitability of the Main and Emergency Control Rooms as well as the Emergency Control Centre by 2013.
- Reassessment of the risk of criticality and/or re-criticality by 2014
- Reassessment of the instrumentation and monitoring by 2015
- Evaluation of the need for mobile equipment by 2015
- Evaluation of the need for external support and for resources by 2015
- Evaluation of the accessibility of important plant areas by 2015
- Reassessing the use of severe accident mitigation systems by 2015
- Investigating the need for means to manage large volumes of contaminated water by 2015.
- Development of strategies for managing loss of containment integrity by 2014.

[18] The Ultimate Heat Sink (UHS) removes heat from the primary cooling circuit and other essential systems necessary to avoid a severe accident.

9.3 Weaknesses the Swedish NAcP Ignored

In July 2009, the Ringhals NPP has been placed under special investigative measures by the Swedish Radiation Safety Authority (SSM) to address shortcomings in safety culture after a series of failures jeopardising reactor safety since 2005. But obviously this situation has not changed sufficiently. On 22 November 2012, SSM announced to continue its special oversight [NW 29/11/2012].

In May 2011, the management decided to start a containment pressure test three days earlier than scheduled, but forgot to inform the personnel. A short circuit in a vacuum cleaner forgotten in the containment caused a fire. The fire generated a substantial amount of ash that is difficult to remove from the containment. During cleaning measures, old scrap from welding work was found in important safety systems (containment sprinkler systems) at Ringhals-2 and later in Ringhals-4. Considerable modernisation conducted at those units in the 1980s and 1990s and it is possible the scrap had been there since then. That the scrap was not detected earlier is alarming and shows that the safety systems were not tested properly over many years.

Ageing of materials is a major safety issue at all units, especially at Ringhals-1,-2. The ENSREG stress tests do not investigate the quality of the plants' safety-related systems and components, such as the material of pipes, reactor vessel, valves and pumps, control and instrumentation equipment. The tests take no account of degradation effects, even though these could significantly aggravate the development of an accident caused by an external event.

9.4 Conclusion

The evaluation of the Ringhals NPP in the light of the Fukushima accident and in accordance with the ENSREG stress tests specification has revealed a number of shortcomings.

In spite of this, almost all planned "actions" of the Swedish NAcP are more or less only investigations that are scheduled to be finished by 2015. The deadline for the implementation of resulting back-fitting measures is 2020.

Decisions about back-fitting measures were not made yet. Therefore an assessment of the scope of back-fitting measures is not possible. Current discussion presents the use of mobile pumps or diesel generators as a satisfying solution to compensate deficiencies of the safety systems.

Despite the fact that Sweden is an area with low seismic activity, an earthquake can occur. Currently, the four Ringhals reactors are not able to withstand a design basis earthquake (DBE). But also after finishing the back-fitting measures in 2013, the protection will not be adequate because the methodology used for seismic hazard assessment is not fully compliant with current international standards and research results. Reassessments of seismic hazards for NPPs almost always show that the protection level is insufficient.

Obviously neither the operator nor the regulator is aware of flooding hazard. The design basic flood (DBF) is not calculated according to the-state-of-art. Furthermore, the regulator SSM does not comply with the entire ENREG/EC recommendations of re-calculating the flooding hazard. A very serious safety issue is the lack of an alternate ultimate heat sink. Any problem with its water intakes at the sea will affect all units.

The next years will be the prolongation of the status quo: An external event will affect all four units simultaneously, but at the same time staff at the NPP will not be able to cope with a severe accident at all four units at Ringhals site simultaneously. This might result in very serious consequences: Large radioactive releases from the reactor cores and the spent fuel pools.

Neglect of safety culture at Ringhals NPP has been a serious problem for many years. That more cases of undetected sloppiness like the old scrap increase the risk of the plants cannot be excluded. It is worrisome that problems with safety culture persist. This could result in partly or total failure of safety systems in the course of an accident. Particular for the older units Ringhals 1 and 2 ageing is an increasingly urgent safety issue.

Obviously the Swedish Nuclear Authority (SSM) and the operator plan to have Ringhals NPP operating for eight more years with the known shortcomings. In view of the existing risk and insufficient safety culture, the units have to stop operation as soon as possible – at least until the reinforcement against earthquake and protection against flooding is performed as well as all other known deficiencies are remedied

10 Temelín NPP, Czech Republic

Temelín NPP consists of two units containing pressurized water reactors (PWR) of the type VVER 1000/V320. They are in commercial operation since 2003 (unit 1), 2003 (unit 2). During construction, several technical modifications were implemented to achieve "western" safety standards. Temelín NPP is located in South Bohemia, about 25 km north of České Budějovice.

After having visited the Temelin NPP, the ENSREG fact-finding team pointed out that the regulatory authority State Office of Nuclear Safety (SUJB) has a good and open communication with the licensee (CEZ). They agreed on a safety enhancement program (that includes the stress tests recommendations) as a condition for the next 10-year licence.[19] Among them is a comprehensive safety enhancement program to be implemented in the next years. Another important decision is due in 2014 regarding the strategy for containment integrity during severe accidents including the option of filtered venting [ENSREG CZ 2012].

10.1 Czech National Action Plan (NAcP)

The NAcP of the Czech Republic defines 76 actions/activities for Dukovany and Temelin NPPs [SUJB 2012]. All measures contained in the NAcP are to be completed by the end of 2015. However this is not the final date of implementation of necessary backfitting. Those measures which consist of performing a study or analysis may result in the need to identify new measures. The NAcP explains that: "many of listed measures are already in an advanced stage of implementation since they were proposed before the Fukushima events on the basis of Periodic Safety Reports results." This could be the reason why in some cases the context between ENSREG recommendation and the implementation activities is not easily understood.

10.2 Efforts to Remedy the Weaknesses the Czech Stress Tests Described

- According to SUJB, the <u>seismic resilience</u> of buildings and selected parts of the NPP proved that relevant safety systems and structures significantly exceed the value of DBE. However, secondary effects of earthquakes were not assessed. A seismic PSA including earthquakes, induced floods or fires with a proposal for remedial measures are to be performed by 2015.
- The reinforcement of the fire brigade building to withstand earthquakes is to be completed by 2014.
- Furthermore an assessment of the consequences of the <u>seismic hazard</u> for the site (e.g. damaged of the infrastructure) was to be performed in 2012 (status: in progress).
- The availability of regional <u>weather forecasts</u> and predictions for the shift engineer decision on the future operation and activities is to be ensured by 2013.
- To increase the <u>resistance against rainfall</u>, the flood protection of the diesel generator (DG) was to be improved by 2012 (in progress).
- The peer review team emphasised that the procedures for special handling of <u>weather related threats</u> need to be elaborated and some specific additions might be necessary to the emergency management procedures. The considerations for extreme low temperatures may be too simple, not taking into account the realistic related effects, e.g. station blackout. Some more refined analyses and verification of current analyses are judged to be necessary. Procedures for managing extreme conditions at the site regarding wind, temperature, snow, and earthquakes are

[19] Current valid licences were issued by SÚJB for the first unit on October 4, 2010 and for 2nd unit on May 25, 2012. Both licences are valid for 10 years.

to be developed by 2013. However, it is not mentioned whether the analysis the peer review team recommended was performed.

- Safety margins of external hazards are not sufficiently evaluated. First the methodology for the evaluation of design resistance to natural hazards needs to be developed. This is in progress in cooperation with the others operator / regulators (deadline 2013).

Because the ultimate heat sink (UHS) is dependent on power supply, loss of UHS is an inevitable consequence of station black-out (SBO). The time available to recover the lost heat sink before fuel damage in the worst case is only 2.5 hours (coping time).

To ensure an alternative heat sink (for core cooling and heat removal) the plan foresees pumping water from fire trucks into the steam generators (SG) via the emergency feed-water system. This water will evaporate in the secondary side of the steam generator and the steam will be released into the atmosphere. At the Temelin site, fire trucks are available; the installation of water connection points on relevant systems is ongoing and supposed to be finished by 2013.

The fire trucks constitute the Czech response to the following ENSREG recommendation calling for "provisions for the bunkered of ´hardened´ systems to provide an additional level of protection ... designed to cope with a wide variety of extreme events including those beyond the design basis."

The coping time could be prolonged by feeding the steam generators (SG) from feedwater tanks relying on gravity.[20] But an analysis about gravity feeding use for SG in emergency operation procedures (EOPs) is required only by 2014. The implementation of measures is not mentioned.
The NAcP lists the following measures (provisions) to prevent core melt accidents:

- An additional stable source of power supply (SBO-DG) to increase resistance against station black-out (SBO) scenario (deadline 2014).
- Alternative measures to ensure recharging the batteries in case of SBO and measures to extend battery discharging time (deadline 2014).
- An alternative fuel filling for long-term operation of diesel generators (DG) including providing of fuel sources (alternative supply of diesel fuel from a tank truck) (deadline 2013).
- Back-up water supply into the steam generators (SG) from external mobile equipment using external connection points (deadline 2013).
- Back-up coolant supply into depressurised reactor and storage pools[21] with additional and sufficient sources of coolant (deadline 2014).
- Alternative methods of monitoring key parameters necessary for accident management (deadline 2012).
- To ensure monitoring, heat removal from the I&C systems for long-term monitoring of key parameters during SBO (deadline 2015).
- Heat removal from the key safety components during SBO (loss of ventilation) (deadline 2015).
- Alternative mobile devices for alternative pump and power supply (deadline 2014)
- Periodic verification of the functionality and periodic practicing of using the alternative mobile devices (deadline 2015)

In case of a severe accident with core melt, the retention of the molten core inside the vessel is not

[20] This measure is implemented at the other Czech NPP (Dukovany) and could prolong the coping time for about 10 hours.

[21] The time until the water in the spent fuel pools starts boiling (SFP) is 2 hours, while the time available until the fuel is uncovered is 20-30 hours.

possible. The design of the VVER-1000/V320 containment and the reactor cavity are such that any water supplied to the containment through the spray system or other means would not reach the reactor cavity. Thus, there is no possibility to directly flood the melt pool in the cavity. The peer review team stated: In general, the core melt coolability, stabilisation and termination of severe accidents is still an open issue for the Temelin NPP.

The current severe accident management (SAM) includes instructions for using ventilation systems which were not originally intended for venting: this unfiltered release would lead to the emission of large amounts of radioactive products into the environment. The installation of a filtered venting system, allowing to avoid containment overpressure in case of a severe accident, is depending on the selected strategy for molten corium stabilization as well as the strategy to prevent overpressure of the containment in case of severe accidents.

- Analysis and a proposal for a strategy and schedule for implementation of measures for preservation of long-term containment integrity (to stabilize melt and prevent overpressure) are to be done by 2014.
- ENSREG emphasised the need for additional investigations of the potential for re-criticality of the molten core for the relevant SAM strategies. The issue of re-criticality is not explicitly mentioned in the Temelin action plan.
- The habitability of the main and emergency control rooms (MCR/ECR) in case of containment failure during a severe accident was not analysed. Such analysis is to be performed by 2013. Additional power sources and ventilation systems will be implemented at Temelin NPPs to ensure continued operability and adequate habitability conditions in the event of a station black-out by 2015.[22]
- The existing hydrogen removal system is intended for design basis accidents (DBAs) only. Currently, it is under consideration to modify the hydrogen management system to be used under severe accident (SA) conditions, by installation of PARs. According to the peer review team, installation of additional hydrogen recombiners for severe accident conditions is planned for 2014 (Unit 1) and 2015 (Unit 2). The NAcP stated „completion of projects to increase the capacity of the system for the hydrogen disposal during severe accidents is in progress" (completion 2013-2015). The plan does not state whether this measure will also be implemented in the spent fuel pool to prevent hydrogen explosions during severe accidents as recommended by ENSREG.
- The verification of the correctness of assumptions about the functioning of the severe SAM equipment during beyond design conditions and external risks, including possible measures to ensure functionality according to severe accident management guidelines (SAMGs), is to be completed by 2014.
- An upgraded probabilistic safety analysis (PSA) Level 2 for the identification of plant vulnerabilities, quantification of potential releases related to extreme external conditions is in progress. Actually, this should have been the basis of the development of the severe accident management.
- Severe accident management guidelines (SAMGs) for accidents during shutdown conditions and in the spent fuel pools (SFP) are to be developed and implemented by 2014.
- Sufficient number of personnel for multi-unit accidents is to be ensured by 2013.
- Trainings for severe accident management according to SAMG, including multi-unit accident should be developed by 2014.

[22] The action plan mentions this action for Dukovany only; most likely this is only a mistake in listing.

- Analyses of potential accident scenarios resulting in large volumes of contaminated water including definition of remedial measures are to be performed by 2015.

10.3 Weaknesses the Czech NAcP Ignored

The original design basis earthquake (DBE) was derived from a comparison of different approaches including deterministic and probabilistic assessments which uses a subjective expert judgement which was not validated. The hazard is being re-evaluated using modern standards; however, the results are still to be validated. The design basis earthquake (DBE) is defined by peak ground accelerations PGA=0.1 g, which are comparable to I=7°MSK [23]

According to the SUJB, this figure already includes a sufficient margin to the maximal peak ground acceleration PGA of 0.08 g. The national stress tests report concludes: "There are no tectonic structures within the Czech Republic that would be able to generate strong earthquakes. The evaluation of the historical data and long-term monitoring revealed that the site of the Temelín NPP is seismically very quiet." Several international expert studies already found his assessment of seismic risk in Temelín to be insufficient and not reaching the state of the art. Initiated by the Joint EU-Czech Republic Parliamentary Committee, the Czech and Austrian experts intensively discussed this topic in 2007/2008. This resulted in implementing two Czech-Austrian projects ("Interfacing Projects", CIP and AIP) which are currently being conducted and will deliver a data base for the seismological assessment of the site.

The seismicity issue is just one example for how CEZ and SUJB do not take the lessons from Fukushima and the very idea of stress tests seriously: both still refuse to consider events and sequences beyond the design basis when defining the plants ability to withstand accidents. Another example is the assessment of the plant´s ability to cope with a station blackout (SBO) by excluding external and internal hazards. The following SBO definition was used by CEZ in the operator report and taken over by SUJB in the national stress tests report: „*No design accident or failure was registered immediately before or after the SBO; the following in particular are excluded: Seismicity, fire, floods. All systems in the power plant, besides those systems that caused the loss of power supply for own consumption, continue to function or are able to function*.

10.4 Conclusion

The National Report presented by the Czech nuclear regulator considers only the minimum of initiating events: earthquake, flood and extreme weather and the obligatory assessment of loss of UHS and SBO. Safety margins were not evaluated. Therefore the weaknesses are not known yet, and upgrading measures could not be required. The discussion about the seismicity is still not solved which means an earthquake could cause a severe accident.

The seismicity issue is one example showing how CEZ without SUJB intervening do not take the lessons from Fukushima and the idea of the EU stress tests seriously. This fact led the peer review team to formulate a number of recommendations; however these are not followed adequately by the regulator. Until now it is not clear which of the measures currently under consideration will actually be selected for implementation. For several key issues (e.g. hydrogen management, corium cooling), evaluations are on-going or being started. Filtered venting is not explicitly addressed in the NAcP despite the fact that is recommended by ENSREG.

Currently it is not clear whether technical back-fitting of the Temelin plants can achieve the required safety level; however, the operator and the Czech authorities seem not to intend implementing the hardware applied at other plants.

[23] 10,000 years recurrence interval, 95% non-exceedance probability

The stress test revealed that Temelin 1 and 2 is not prepared to withstand an accident caused by a natural hazard like an earthquake and which obviously could affect both units. To present the water supply with fire trucks as idea to remedy to this dangerous situation reveals a dangerous approach to safety culture.

The heavy reliance on fire trucks and action undertaken by the plant staff during a severe accident for cooling the reactor is an unacceptable measure in the light of the fact that already after 2.5 hours without cooling fuel damage sets in. Temelin NPP has no means to cope with a severe accident at this point because it lacks both the measures to cool the molten core and the filtered containment venting system. Thus a severe accident with a major radioactive release would result.

All in all, we recommended to shut down Temelin NPP immediately, at least until appropriate hardware for severe accidents management (e.g. filtered venting) will be implemented and the staff training will be performed.

11 Wylfa NPP, UK

Wylfa NPP, in operation since 1971, is located on the North coast of the island of Anglesey in North Wales. The adjacent Irish Sea provides the ultimate heat sink. The two units at Wylfa were both scheduled for shut down at the end of 2012, but the operator Magnox Ltd. decided to shut down unit 2 in April 2012 so that unit 1 could continue operating until 2014 [WNN 2012].

Magnox reactors are cooled by pressurised carbon dioxide gas (CO_2); the moderator is graphite. The fuel is natural uranium clad in a magnox (magnesium non-oxidising) alloy. Wylfa 1 is the last Magnox reactor still in operation.

11.1 UK National Action Plan (NAcP)

The Office of Nuclear Regulation (ONR) explained that the NAcP has been developed from a number of UK ONR reports produced in response to Fukushima. The NAcP is therefore not a stand-alone report; rather it is a summary of the current status of, and future activities that are planned for, implementation of the lessons learnt [ONR 2012a].

The general approach to progressing the work described in NAcP report has been the same for all types of the UK's NPP. These are Magnox, Advanced Gas Cooled (AGR) and Pressurised Water Reactors (PWR).

However, ONR stated, differences do occur due to the shorter life of the last operating Magnox reactor (Wylfa 1). Less focus has been placed on long-term study work which might not report back within the operational time. ONR underlines as a consequence a number of prudent improvements have already been implemented which have tended to be fairly straightforward measures designed to provide an immediate safety benefit [ONR 2012b].

11.2 Efforts to Remedy the Weaknesses the UK Stress Tests Described

- Several uncertainties exist with regard to the calculation of design basis earthquake (DBE). There is no satisfactory evidence of capability of all UK NPPs for earthquake beyond the design basis. The UK regulator followed the recommendation to introduce a specific program for additional review regarding the design basis, adequate margin assessment and identifies specific potential plant improvements. However, for Wylfa only a seismic margins study is performed. Furthermore a review of resilience against extreme hazards was done; resilience enhancements are to be implemented by 2013.
- Secondary earthquake effects are addressed; a systematic review of the potential for seismically induced fire is to be performed by 30/06/2013. However, because an adequate seismic hazard assessment is lacking, there is no basis for this review to deliver sufficiently reliable results.
- Wylfa does not have an automatic seismic shutdown system. Therefore the operator has to initiate the reactor trip manually in response to a signal from the seismic monitoring system (already available).
- The currently available design basis flood (DBF) assessments of NPP sites in the UK did not take into account recent tsunami research work. However ONR believes that these studies are unlikely to significantly affect previous understanding of maximum credible tsunami heights.
- For flooding hazards, independent reports have been commissioned by ONR. This pilot will form the basis for the assessment of flooding margins. However, the operator Magnox does not intend to undertake full flooding margin assessments for Wylfa. Only a review of the existing flooding studies was conducted, resulting modifications of site resilience are to be implemented by 30/09/2013. However, without any appropriate assessment of the flood hazard, it cannot be evaluated whether the flood protection is sufficient. Quite the opposite has to be assumed

regarding the general shortcomings in the flood assessment in the UK. Nevertheless, ONR is satisfied with this approach.

- Standards for early warning of extreme events are to be developed by 31/03/2013.

To improve the prevention of severe accidents or to mitigate its consequences, a limited amount of actions are foreseen:

- Additional generators for emergency electrical on-site supplies (DC and AC) were provided and the CO^2 and fuel stocks on site were increased.
- Regarding provision of alternative means of cooling, Wylfa has only increased the on-site water stocks in hardened structures and purchased a water tanker to transport water from a nearby freshwater source to site. ONR assessed this as proportionate considering the remaining operating time of the plant.
- Resilience enhancements to assist operator access are to be implemented by 31/12/2013.
- Additional pumps to support reactor boiler feed and general duties are to be provided by 31/12/2013.
- The necessary improvement of the on-site emergency facilities with regard to resistance against external hazards and working conditions in case of severe accident is not required for Wylfa.
- The implementation of backup equipment for spent fuel pools (SFP) is not required.
- The reactor is fitted with an iodine absorption device that may be used to remove radioactive iodine from the primary circuit gas and can, therefore, mitigate releases to the environment to some degree. However this system is only designed for DBA and is not comparable to a filtered venting system. Backfitting is not required.
- A Level PSA 2 is to be performed, but only with a limited scope by 30/09/2013.
- The implementation of severe accident management guidelines (SAMGs) is to be completed by 31/12/2013. But the new guidelines will not include all necessary issues.

11.3 Weaknesses the UK NAcP Ignored

The Wylfa 1 is in operation since 1971. Both the ENSREG but also the UK stress test report did not recognize material degradation as the main contribution to safety problems. Ageing effects which cause material degradation are not considered in the stress test report. Specific ageing effects for Wylfa could trigger dangerous incidents or aggravate accident situations. The combination of external impacts (for example: earthquake) and material degradation can have significant impacts on the development of accidents.

Wylfa does not have a secondary containment. The massive concrete reactor pressure vessel is the last barrier to retain radioactive emissions from the reactor core. Containment function relies on the stability and leak-tightness of pipings and welds penetrating the reactor vessel wall.

The support and safety systems are very simple compared to the complex systems of light water reactors. They generally fall short of modern standards due to their lack of diversity and separation, particularly the electrical systems [HIRSCH 2005].

A fire risk exists, since a significant mass of graphite is located in the core which can ignite after an air intrusion. Air intrusion after pressure vessel failure, and subsequent graphite ignition, could lead to a large release [HIRSCH 2005].

Horizon is preparing a project to build new nuclear power plants of two or three ABWR units at Wylfa site [WNN 2013b].

11.4 Conclusion

The operator obviously does not have much interest in improving the safety of the old Wylfa reactor. The Office of Nuclear Regulation (ONR) shares this approach towards the only still operating Magnox in UK and this lack of interest is mirrored by the ENSREG peer review team.

It is irresponsible to assume that in a NPP of this age and deficiencies all safety relevant components will stay intact during an external impact (e.g. an earthquake) or under severe accident conditions. Nevertheless, improvements of severe accident management are limited to the use of mobile equipment.

ONR considered investigating the natural hazard issue as not worth the effort because Wylfa 1 nearly reached the end of its operational lifetime. This is not acceptable in the light of the design weaknesses. An evaluation of the natural hazards of the site would be important because Hitachi owned Horizon is preparing a project to build a new NPP of two or three ABWR units at this site [WNN 2013b]. The results could postpone or even preclude this project.

The operator but also the Nuclear safety authority accept the following situation: The natural hazard issue is not investigated thus the protection against hazards is insufficient, at the same time the severe accident management which would be crucial if such a hazard occurs cannot provide an adequate response. This irresponsible approach is being explained by the short operational time still left over for this reactor. The consequence of the reactor not fulfilling the needed safety level and upgrading it considered as not worth the effort leave only the following options: keeping an obviously unsafe reactor on the grid or immediate shutdown of Wylfa 1.

12 Conclusion

The Fukushima catastrophe was the horrible result of decades of mistaken safety philosophy, a very lax safety regulation under strong industry influence on the regulators – not only in Japan. The first shock led to the honest attempt to change this, to also involve events which are definitely possible but were kept out of the safety cases by using probabilities. When it was possible to “prove” an event as having too low probability, it could be ignored.

On 12 October 2012, Tokyo Electric Power Co (TEPCO) admitted that the company had failed to prevent the Fukushima accident, reversing its earlier statement that the accident could not have been foreseen. A TEPCO task force has identified several factors that had led to the accident in March 2011 [NW 18/10/2012]: TEPCO did not learn a lesson from the incident in France of loss of off-site power due to flooding at the Blayais NPP on December 27, 1999, furthermore no safety measures aimed at preventing and mitigating a severe accident had been adopted since 2002. The task force attributed those facts to multiple root causes:

- First, the management assumed a severe accident was extremely unlikely in Japan, and feared that retrofitting safety systems would increase anxiety among the public, especially among the residents near the plant.
- TEPCO also feared safety retrofitting would require a costly shutdown period.

The TEPCO task force also underlined that there were not enough engineers at the site who were familiar with safety systems’ designs, operation manuals and their locations.

Basically all circumstances leading to the Fukushima accident exist for the European NPP as well – only the tsunami risk does not apply for all NPP but e.g. for several UK NPPs. However the risk of flooding events or of earthquakes exists to a different extent for all NPPs. Also common to all NPPs: the operators insist on the low probabilities to avoid high investments and anti-nuclear activities of the public, very much as the same reasons as TEPCO in Japan until Fukushima.

The EU tried to respond to this “new experience” of Fukushima by conducting the stress tests and hoping that the results will lead to higher safety. This report investigated the result, the very concrete measures each nuclear safety authority will require its operators to implement and until which date.

Transparency is another important tool to control nuclear risk; while ENSREG certainly recognizes this fact, not all national nuclear regulators and operators act accordingly to fulfil this need of higher transparency.

It is evident that some countries treated this task rather as a formality or paperwork than a plant safety upgrade program. (The ENSREG peer review hopefully will insist on introducing additional measures to the national plans in those cases where the national regulator required less safety measures than the stress tests peer review recommended.)

In general, there are different possibilities for operator and nuclear authority to remedy the shortcomings the stress tests revealed:

- A quick response, but without any guarantee that the measures are sufficient (e.g. Wylfa, UK).
- A comprehensive evaluation of possible hazards and protections measures, which will take more than ten years (e.g. Gravelines and Cattenom, France).
- Business-as-usual, e.g. Temelin, Czech Republic). The idea of the stress tests is more or less ignored. Instead the already ongoing measures are listed, major hardware improvement avoided.

None of those possible variants increase the nuclear safety to an acceptable level. The very obvious solution - permanent shut down – needs to be considered and is in several cases the only safe option. This applies in particular to those plants where significant improvements cannot be achieved by the planned deployment of mobile equipment only or by having plants on the grid in the current status for many more years while evaluations and assessment are under preparation and again later backfittings would start. In some cases this is officially scheduled to take over ten years time.

The National Reports are heavily relying on the new magic solution to severe deficiencies at the plants due to design or the site: mobile equipment, which is easy to plan and store in the plant and therefore a cheaper solution compared to comprehensive measures. But under severe accident conditions, it is very unlikely that the proposed mobile equipment can be put to work as quickly as necessary; to rely to such a large extent on manual actions is in regard of the consequences of a severe accident irresponsible. Furthermore, the new mobile equipment is useless if the staff training and response during the accident is not perfectly according to plan. However not only the “know-how” but also the “know-why” is very important. This is also one important lesson learnt from the Fukushima accident.

Limited backfitting measures do not significantly improve the safety level because they cannot compensate the increasing threat of hazards (e.g. by climate change) and of ageing effects. Furthermore, the experiences show that back-fitting measures could cause new faults (e.g. because of defective mounting, forgotten scrap etc.).

Comprehensive plant modifications which would actually improve the safety level are technically impossible or would be done only in exchange for prolonged operation times, at the same time carrying the risks of aging plants as mentioned above.

Thus, our conclusion: Up-to now, no lessons learnt from the accident at Fukushima.

At all European nuclear power plants severe accidents can occur – any time.

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