Post-
Fukushima
accident

Slovenia

Peer review country report

Stress tests performed on European nuclear power plants

ENSREG
European Nuclear Safety Regulators Group
Stress Test Peer Review Board

1 GENERAL QUALITY OF NATIONAL REPORT AND NATIONAL ASSESSMENTS

The accident at the Fukushima Nuclear Power Plant (NPP) in Japan on 11 March 2011 triggered the need for coordinated action at EU level to identify potential further improvements to NPP safety. On 25 March 2011, the European Council concluded that the safety of all EU nuclear plants should be reviewed on the basis of comprehensive and transparent risk and safety assessments — the Stress Tests. The Stress Tests consist in three main steps: a self-assessment by licensees, followed by an independent review by the national regulatory bodies and by a third phase of international peer reviews. The international peer review phase consists of 3 steps: an initial desktop review, three topical reviews in parallel (covering external initiating events, loss of electrical supply and loss of ultimate heat sink, and accident management), and seventeen individual country peer reviews.

Country review reports are one of the specific deliverables of the EU Stress Tests peer review process. They provide information based on the present situation with respect to the topics covered by the Stress Tests. They contain specific recommendations to the participating Member States for their consideration, good practices identified and, to some extent, information specific to each country and installation. Draft country review reports were initiated during the topical reviews; these were based on discussions with the country involved in the three topics and on the generic discussions within each of the three topical reviews. The limited time available for each country meant that issues identified for each country during the topical reviews required follow-up discussions in more detail, not only between the topical reviews and the country reviews but also during the country reviews.

This Country Report was finalised at the end of the Country Review, after final discussions with the country being reviewed in the course of a specific country visit, including discussions with the regulator and the licensee as well as a visit to the Krško NPP. This visit was designed to directly observe the most significant issues. It is a part of the Final ENSREG Report combining the results of the Topical Reviews and Country Reviews.

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

Slovenia has a single-unit NPP, a 2-loop Westinghouse pressurised water reactor (PWR) with net electrical output of up to 696 MWe. Its commercial operation started in 1983. The Slovenia national report discusses plant features in detail.

The contents and structure of the Slovenian national report (SI-NR) comply with the ENSREG specifications for the earthquake and flooding parts. Extreme weather conditions are not fully covered in the SI-NR, but additional information was provided in the course of the country visit. The report is quite exhaustive with sufficient detail for the assessment of the loss of electrical power and ultimate heat sink. Regarding the assessment of Severe Accident Management (SAM), the report complies very well with the guidance provided in the ENSREG specifications, although there are some minor inconsistencies with the specified structure.

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

The SI-NR provides sufficient information with respect to the design basis in terms of earthquakes and flooding. However, the chapter on other extreme weather conditions is not as complete as previous ones. Regarding loss of safety functions, the information provided in the report is adequate and it is also consistent with the ENSREG guidance. Regarding the assessment of SAM, the adequacy of the information supplied is generally consistent with the guidance provided.

The review of the report resulted in a number of questions. During the Topical review meeting in Luxembourg, the Slovenian representatives provided detailed and sufficient answers and clarifications to the review questions. Some information initially not included in the report was also provided by the country representatives and clarified during the topical review discussions. All remaining issues were discussed and clarified in the course of the country visit.

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

The SI-NR provides satisfactory evidence that the Krško NPP can resist loads induced by earthquake and flooding. However, no detail is provided in the report regarding the design of the NPP to resist extreme weather conditions.

The assessment of the response of the plant to the events considered under the Stress Tests was done using a deterministic approach. Safety analyses performed for design basis events, additional calculations carried out for Stress Tests report, as well as engineering judgments were all used by the licensee in assessing the plant's response to the Stress Test scenarios. The assessments were reviewed by the regulator, the Slovenian Nuclear Safety Administration (SNSA) with the support of the Technical Support Organisations (TSOs).

Comprehensive information on the regulations used in Slovenia, as well as on the original and current licensing basis for the Krško NPP, with respect to the Loss Of Off-site Power (LOOP), Station Blackout (SBO), primary Ultimate Heat Sink (UHS) loss, and primary UHS loss + SBO was provided by the country representatives during the topical review meeting. Routine inspections of design features that have to respond to LOOP, SBO, loss of UHS, or a combination of such consequential events, are performed regularly by the licensee and the regulator, in order to verify the compliance of the plant with the licensing bases. The assessment of the plant's compliance with its current licensing for the events within the scope of the Stress Tests seems to be adequate.

While the licensing basis in Slovenia for the Krško NPP was originally based on US Nuclear Regulatory Commission (USNRC) regulations; today national regulations form the current legislative basis for the NPP operation and emergency plans. The Stress Test basis is in compliance with the 2002 governmental act on nuclear safety, as amended in 2011. Periodic Safety Reviews (PSRs) are conducted every ten years.

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

Evaluation of the Krško NPP seismic margin and flooding margin for a Beyond Design Basis Earthquake (DBE) and Beyond Design Basis Flooding (DBF) is well described and developed. The assessment was done by evaluating the availability of success paths against different values of earthquake and flooding.

The assessments of the current safety margins at the plant as well as possible measures to which can be envisaged to increase robustness of the plant were carried out for all events considered under the Stress Tests. LOOP, SBO and loss of UHS, as well as their combinations, were assessed for the reactor operating at full power. This operating state is considered as the limiting case.

It was stated that shutdown states had also been analysed, including operating modes when the primary circuit is open (e.g. during refuelling), but these were not presented because they were considered not bounding. Gravity filling of cooling water from the Refuelling Water Storage Tank (RWST) is the solution adopted for managing an SBO should the primary system be open. Sufficient information on safety analyses was given the reviewers during the country visit to demonstrate the limiting case. SBO and loss of UHS, as well as their combinations, were also assessed for the spent fuel pool (SFP).

For the preparation of the Stress Test report, the plant performed additional analyses (e.g. evaluations of seismic and flooding margins, additional SBO analyses to support the newest Severe Accident (SA) strategies, drain cycle of the safety-classified (1E) batteries, water heatup and evaporation rate in SFP, and evaluation of SFP criticality). These were all reviewed and supported by TSOs with additional calculations (with different codes), where appropriate.

All the events analysed have been followed up with identification of necessary measures that have already been implemented or are in the course of implementation.

The robustness of the plant is the result of the design features applied and upgrades and modernisations performed since the beginning of its operation in compliance with the USNRC recommendations which serve as a significant regulatory source. Cliff-edge effects and margins have been identified, described and addressed.

The report also includes an extensive description of emergency measures and procedures, as part of the measures to address SA challenges. The procedures include symptom-based Emergency Operating Procedures (EOPs) and Severe Accident Management Guidelines (SAMGs) that have been validated using an SA simulator which is extensively used and could represent an example of good practice.

The assessments of the robustness of the plant, as well as the situations taken into account to evaluate margins, are considered adequate. In addition to fulfilling the Stress Test specifications, the SI-NR also includes an analysis of the impact of an aircraft crashing on the NPP.

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

Slovenian nuclear requirements and safety assessment practices are based on applicable WENRA, IAEA and USNRC technical standards, guides and regulations. Since April 2011, the WENRA reference levels have been fully implemented.

In response to the Fukushima accident, the regulator issued a decision requiring the NPP to perform a Special Safety Review. The programme of this review was in line with the ENSREG specifications for the European Stress Tests. Special inspections were performed by the regulator with the support of TSOs for tests of SBO and UHS design features (Diesel Generators (DGs), batteries and pumps) and also inspections of the condition of Systems, Structures and Components (SSCs) which are part of SBO and UHS design features.

In September 2011, the regulator issued a second decision requesting the plant to reassess the SAM strategy and existing measures, and to implement necessary safety improvements to prevent an SA and mitigate its consequences. This included the requirement not to release more than 0.1 % of volatile fission products and particulates (not including noble gases) during an SA. This evaluation was completed in January 2012 and its action plan was endorsed by the regulator in February. The time period to implement these improvements is from 2012 to 2016. In January 2012, the regulator issued a third decision requiring the Krško NPP to review the basis and assumptions for the Radiological Emergency Response Plan (RERP). This work is still ongoing. The regulator assessed and approved the list of modifications proposed by the licensee and the implementation schedule. Additional evaluations were performed by the licensee in order to determine the adequacy of some proposed improvements.

The regulatory process applied to the actions and conclusions presented by the utility is not discussed in the SI-NR. However, from the topical review presentation and discussions during the country visit, this process has become clearer. The SI-NR did provide information on the various decisions issued by the regulator in response to the demand for a Special Safety Review that was in line with ENSREG specifications for the European Stress Tests. It also includes information on the reassessment of the SAM strategy as well as on the existing design measures and procedures and the implementation of necessary safety improvements to prevent SAs and mitigate their consequences. The SI-NR also mentions that an action plan, to be provided by the NPP, was to be presented to the regulator by January 2012 and that, once approved by the regulator, the improvements should be implemented by the end of 2016.

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

2.1 Description of present situation of the plant in the country with respect to earthquakes

2.1.1 Design Basis Earthquake

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

At a general level, the Slovenian legislation on nuclear safety is relatively compact, does not go much deeper than WENRA reference levels and is mainly based on the 2002 Slovenian Act on Nuclear Safety (amended in 2009 to harmonise it with the WENRA requirements), together with a number of subordinate decrees and regulations. WENRA reference levels on nuclear safety design bases, documentation and licensing as well as on operational nuclear safety have been fully incorporated in those rules.

Furthermore, the Slovenian regulatory basis (and thus also the regulatory basis relative to SAM) relies almost entirely on the applicable USNRC technical standards and regulations, as the US is the NPP vendor country. Due to historical reasons and the deeper nature of these requirements, those USNRC standards and regulations still apply in Slovenia. For instance, all USNRC requirements for a life-time extension are applied (USNRC license renewal rule 10 CFR 54 and NUREG 1800 for the review of the application). Agreements between the Slovenian regulator and the USNRC ensure close cooperation.

The NPP periodically updates a document called 'Regulatory Conformance Program — Compliance Review' which represents the overview of all USNRC regulatory requirements and NPP compliance with them and which is a part of the PSR process. Currently, revision 3 is in place. The following main regulations are in force:

- 2002 Act on Nuclear Safety (amended in July 2011)
- Subordinate decrees and regulations
- Act on Third Party Liability (renewed in 2010)
- Nuclear Safety Directives

2.1.1.2 Derivation of DBE

Based on studies performed before plant construction, a Safe Shutdown Earthquake (SSE) of 0.3g and an Operating Basis Earthquake of 0.15g were used during the design of the NPP in the 1980s. The vertical component used is equal to the horizontal component in all frequency regions.

The soil-structure interaction is considered, the Peak Ground Acceleration (PGA) is valid for free field only and not for the foundation level. The resulting time history analyses are used to develop response spectra with different damping values.

Plant structures, engineered safety features and other safety-related systems and components were classified in accordance with the US standards.

Instrumentation is installed to alert the licensee in the case of an earthquake and to record the severity of the earthquake level but automatic shutdown is not envisaged. Indirect effects have been taken into account, also considering loss of external power supply.

2.1.1.3 Main requirements applied to this specific area

Based on the seismic reassessment from 1992 to 2004, the criterion used for SSE is a 'once in 10 000 years' earthquake.
If an SSE occurs, all Seismic Category I SSCs must withstand the effects of the SSE and assure:

– the integrity of the reactor coolant pressure boundary;
– the capability to shut down the reactor and maintain it in a safe shutdown condition; and
– the capability to prevent or mitigate the consequences of accidents.
Moreover, equipment which is not safety related but could affect the operability of the safety-related equipment is also designed and erected as Seismic Category I components.

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

The original seismotectonic studies were performed before the plant's construction from 1964 to 1968 and intensive studies continued between 1971 and 1975.

The first Seismic Probabilistic Safety Assessment (SPSA) for Krško NPP was finalised in 1995, followed by an update in 2004. The SPSA allowed: (1) the evaluation of the seismic hazard, (2) the development of event tree/fault tree risk models of the plant's response to earthquake induced transients and failures, and (3) evaluation of seismic fragilities of structures and components.

The seismic hazard was defined as the frequency of occurrence of PGA and the fragilities were defined as conditional probability of failure versus PGA.

The development of fragilities also takes into account the shape of the ground motion spectrum that is predicted in the seismic-hazard studies. The integration of the earthquake PGA frequency and the structural and component fragilities resulted in unconditional seismic-induced failure rates of the structures and components.

As part of the first PSR, a new Probabilistic Seismic Hazard Assessment (PSHA) was conducted in 2002-2004 (original in 1992-94, 10 000 years return period, PGA=0.42g (free field)), taking into account more recent geological, seismological, geophysical and geodetic investigations.

The results of the revised assessment of the seismic hazard proved to be more severe than the hazard used in the original SPSA. The frequency of occurrence of the PGA has increased by a factor of about two, but is partly offset by a lower amplification in the ground-motion spectrum.

The PHARE program in 2002 concluded that there are some active faults near the Krško basin, but no capable faults that could extend to within 5 km of the plant. More details are documented in the Updated Safety Analysis Report (USAR). Following this program, an improved regional seismic monitoring system has been implemented.

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

The Krško NPP is in the process of completing its first PSR action plan and the second PSR is underway. Likewise, the process of the plant design life time extension is on-going and the regulator expects that it will be concluded in 2013. Additional geological, seismological and geophysical studies were performed in 2002 and the results of these investigations are presented in technical reports, developed as a part of the first PSR, which presents an updated seismotectonic model of the Krško basin. In this context, major modifications that were performed to improve seismic safety have concerned reinforcement of anchoring and support structures. The Safe Shutdown Equipment List developed by the SPSA in 1994 and 2004 has been the basis for a walk down (1993 walk down of components outside containment; additional walk downs performed in 2003 for the seismic update). For all identified observations, the NPP performed appropriate corrective actions or design changes and resolved all deviations.

2.1.1.6 Conclusions on adequacy of design basis

The original PGA value was 0.3g. Subsequently, additional PSHAs were performed. According to a PSHA study in 1994, a larger PGA of 0.42g was determined. A revised PSHA study in 2004 further increased the seismic hazard to a PGA of 0.56g.

2.1.1.7 Compliance of plant with current requirements for design basis

The SI-NR provides sufficient information to draw the conclusion that the Krško NPP does comply with current requirements for the original design basis of 0.3g.

2.1.2 Assessment of robustness of the plant beyond the design basis

2.1.2.1 Approach used for safety-margin assessment

The plant level seismic margin is assessed by evaluating the availability of success paths following a postulated seismic event, with increasing severity in terms of PGA:

- PGA < 0.15g
- 0.15g < PGA < 0.30g
- 0.30g < PGA < 0.45g
- 0.45g < PGA < 0.60g
- 0.60g < PGA < 0.75g
- 0.75g < PGA < 1.0g
- PGA > 1.0g

Success paths are disabled at increasing levels of seismic input according to the fragility of the SSCs involved. The procedure has been developed for events leading to core damage, containment integrity failure and SFP integrity failure. Indirect effects of the earthquake are taken into account including situations outside the plant, fire and explosion. The procedure is effective in assessing seismic margins and could be easily adjusted to achieve a complete 'deterministic' margin assessment. Failure of dams upstream from the plant due to seismic events has been considered in evaluating the maximum flood. This event is considered not to endanger plant safety because the flow is well below the DBF.

2.1.2.2 Main results on safety margins and cliff-edge effects

A PGAin the range of 0.8g or higher would be likely to cause core damage. At this seismic level, the critical induced sequence is an Anticipated Transient Without Scram (ATWS) with SBO conditions. Seismic ATWS could be caused by a failure of control-rod insertion due to degradation of the fuel assemblies' geometry. Seismic capacities of structures related to primary or secondary pipe breaks are somewhat above these levels. Containment integrity is not assured for events with a PGA higher than 1.0g, leading to early releases and probably to late releases beyond 0.8g due to fuel damage, SBO, and loss of containment heat removal functions. Also for SFP, a PGA equal to 0.9g is considered the level beyond which integrity is challenged. For a PGA of 0.8g, a return period of 50 000 years is estimated.

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

A significant review process (investigations, various studies, PSHA, SPSA, etc.) where seismic issues were identified was conducted during the first PSR.

During the country visit it was clarified that the PSR had led to the installation of the third seismically qualified emergency diesel generator (currently in progress).
The addition of this measure will have a significant impact on reducing plant seismic risk, as identified by PSA models.

2.1.2.4 Possible measures to increase robustness

Likewise, as a result of post-Fukushima analyses, required by the SNSA, the plant has prepared a plan to modernise SAM measures (to be implemented between 2012 and 2016), which includes:

- additional seismic strengthening of DG3 and MD3 bus
- additional bunkered safety injection and auxiliary feedwater pumps
- alternative seismically qualified (2×SSE) UHS
- alternative seismically qualified (2×SSE) means of cooling the SFP.

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

A number of measures have already been implemented at the Krško NPP plant to further increase its robustness:

- Alternative means to provide suction to Auxiliary Feedwater System (AFW) pumps or to provide water to Steam Generators (SGs) directly;
- Alternative means for power supply to Chemical and Volume Control System positive displacement in order to preserve Reactor Coolant System (RCS) inventory and the integrity of Reactor Coolant Pump (RCP) seals in induced SBO or Loss of essential service water system / component cooling system conditions;
- Alternative means for power supply to selected Motor Operated Valves, as necessary for the implementation of alternative methods;
- Alternative means for providing water from the external sources to containment;
- Procedures for local operation of AFW Turbine Driven Pump (TDP) and for local depressurisation by means of SGs power operated relieve valves, both without need of DC or instrument power;
- Alternative means for makeup of SFP inventory.

Planned measures (to be implemented between 2012 and 2016):

- Installation of a bunkered back-up systems for primary and secondary injection
- alternate shutdown station,
- alternative seismically qualified (2×SSE) UHS,
- additional seismic strengthening of DG3 and MD3 bus,
- additional alternative seismically qualified (2×SSE) means of cooling the SFP.

2.1.3 Peer review conclusions and recommendations specific to this area

The DBE has been explained and is acceptable in comparison with international standards. It corresponds to US regulations, US standards and the state-of-the-art at the time of design and construction. Recent PSHAs result in a PGA of 0.56g which is nearly twice the original SSE accelerations of 0.3g. This seems to be plausible, considering that Krško NPP is located in a seismically active region.

- Conclusions: Evidence showed that the Krško NPP can accommodate the new value of PGA of 0.56g or 0.6g. The design basis has not been updated. However, the increased seismic hazard will be considered for future projects, e.g. the third DG building.
- The 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.
- According to information provided in the course of the country visit, soil liquefaction might start at 0.8g.

Recommendation:

- Seismic safety margins are estimated based on the identification of success paths and on the SPSA. The margins are found to be substantial with regard to the DBE. However, there seem to be decreased margins with regard to the updated seismic hazard assessment. It is recommended that the regulator should consider requesting an update of the seismic design basis for future design modifications and consequently the associated PSA model.

2.2 Description of present situation of the plant in the country with respect to floods

2.2.1 Design Basis Flood

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

The NPP was originally designed and licensed based on an USNRC regulation which is used in several areas where domestic legislative requirements do not directly lay down regulations or are not required. The NPP is periodically updating a document called 'Regulatory Conformance Program — Compliance Review' which represents the overview of all USNRC regulatory requirements and NPP compliance with them. Plant design (DBF) is based on an estimated 'once in 10000 years maximum flow of the Sava River and the related protection is based on plant elevation. Besides this design flood, the plant is protected against the Probable Maximum Flood (PMF), i.e. the hypothetical flood considered to be the reasonably most severe possible (defined on the basis of various models in a revised version in 2008-11). No difference in safety systems performance requirements for the two levels is indicated in the report. PMF protection is based on dike elevation. Further studies for improving protection against external floods were performed in 2005, followed by other studies to evaluate PMF, considering possible impacts of planned new Hydro Power Plants (HPPs). These studies confirmed the adequacy of the design basis and the compliance of the plant with this basis, giving credit to the stability of dikes.

2.2.1.2 Derivation of DBF

A flood of 0.01 % yearly frequency (10000 y flood) is stated as the DBF. Input data were flood levels from the period 1926 to 2000. According to the Institute for Water of the Republic of Slovenia, using Log Pearson III distribution, the flow corresponding to a 10000 years flood is 4790 m^3/s. Krško NPP conservatively chose this result as the design flood. In addition to the DBF, the licensee states the amount for the PMF (= 7081 m^3/s) and shows the influence on the plant perimeter. Furthermore, the following cases are reviewed:

- wind waves supplementary to PMF,
- local heavy rainstorms (maximum hourly rainfall intensity),
- flood waves caused by dam failure.

2.2.1.3 Main requirements applied to this specific area

Plant elevation above DBF has been adopted as the main criterion.

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

Three significant floods occurred in the area of the plant in 1990, 1998 and 2007. These events, together with the fact that were several new HPPs on the Sava river in various stages of construction, design and planning, led to a number of studies and analyses related to external flooding hazard for the NPP, during the past decade. The updating of the licensing document is currently in progress and consequently the improvement of flood protection to keep the left bank of the Sava river dry even when flows exceed the PMF flow.

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

The flood hazard is included in the PSR process. Regular survey of protection dikes on a 5-yearly basis is provided by a surveillance procedure. The survey of the dikes includes the removing of obstacles and mowing, review of stability condition of the dikes through tests of strength and deformation properties, tests of soil stability, search for cracks, soil movements and water penetration, review of drainage availability and stability and review of dike erosion. Measurement of the Sava river cross sections from 4 km upstream to 15 km downstream is provided on a 5-yearly basis or after a major flood. The activities also include correction of maps and eventual corrective action in the event of dangerous erosion.

2.2.1.6 Conclusions on adequacy of design basis

The approach to defining flood requirements is consistent with international standards. The robustness of the plant is shown for DBF, PMF and an extreme flood of 10000 m^3/s.

2.2.1.7 *Compliance of plant with current requirements for design basis*

The licensee itself states that the protection of the plant is adequate since the DBF, the PMF, flood waves caused by dam failure and heavy local rainstorms do not jeopardise the safety of the plant. However the evaluated margin is based on the elevation of protecting dikes. Clogging of cooling water intake (condensate cooling water) forcing a shutdown of the plant was discussed in the course of the country visit: in 2003, a quick rise in the river flow and the sudden opening of the Vrhovo HPP dam gates brought large amounts of leaves and other suspended material to the Krško NPP water-intake systems.
Additional procedures have been established to deal with management of suspended materials in the Sava river.

2.2.2 Assessment of robustness of the plant beyond the design basis

2.2.2.1 *Approach used for safety-margin assessment*

A range of flooding events is considered and for each range the success paths are defined as a minimum set of functions required to avoid the reactor core damage state and to preserve the containment integrity. Safety is guaranteed up to a river flow of 7081 m^3/s. A cliff-edge effect can be possible for flows significantly over 7081 m^3/s.

2.2.2.2 *Main results on safety margins and cliff-edge effects*

The robustness of the plant itself beyond the design basis is shown by the PMF and an extreme flood of 10 000 m^3/s. According to the simulations, the plant remains an island without danger of flooding for these discharges. The plant is located 0.15 m above the DBF. The protection from the PMF is assured by dikes around the site. The margin below the dikes is 0.75 m. The licensee states that up to the extreme flood of 10 000 m^3/s all SSCs at the ground level are completely safe. For the extreme flood event, the ground-water level should have no impact on safety-related equipment.
The SI-NR determined that the cliff-edge happens when the river flow is 2.3 times larger than the design basis flood or is 1.7 times larger than the existing probable maximum flood. Such a flood would inundate the plant plain and would have a return period of 1 million years.
Nevertheless, LOOP may occur for flood events larger than DBF. In this case, success paths for LOOP apply.
Should the Essential Service Water System (ESW) intake be clogged by debris transported by extreme floods, the Residual Heat Removal (RHR) system would not be available. In the event of loss of ESW, decay-heat removal would be performed by alternative means (e.g. auxiliary feedwater system).

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

During the country visit, the regulator stated that in the first PSR there were findings related to flooding analysis and flood protection as stated in the USAR and PSA analyses (IPEEE). The PSR action plan resulted in revision of the following flooding analyses:

- DBF, a probabilistic analysis of high river flow events from the period 1908-2000 (10 000 year flood),
- probable maximum flood (PMF),
- flood waves caused by upstream HPP dam rupture,
- flood due to intensive local precipitation (flash floods),
- hydraulic analysis to determine flow-flood level relations.

The results of these analyses showed that the DBF has increased. The PMF and dam rupture waves analyses were revised in accordance with the ANSI/ANS-2.8-1992 standard including reviewing a set of conservative scenarios to determine the event with the highest possible flow. To determine the PMF, a new model of the Sava river hydrology was used, this being calibrated and validated by measured flood-wave profiles. As a result, the PMF increased in comparison to previous values and this required an upgrade of flood protection by raising and reconstructing dikes. Additionally, the PMF on Potočnica creek was also determined. Dam-rupture waves took account of all HPPs upstream of

Krško NPP, those that are in operation, and those in the construction phase. The resulting flood wave is significantly less than DBF and PMF. Intensive local precipitation was previously not evaluated in USAR. Such a flood gives only a minor rise of water level at the plant. The new hydraulic analysis, based on new data on ground elevations, river cross-section profiles and validation by a physical model of the Krško-Brežiško polje, presents data on flood levels with significantly higher quality and confidence level than the previous hydraulic analysis. The design for upgraded flood protection dikes was confirmed also using this hydraulic model. Also, in the design of the flood protection the future HPP Brežice that will increase the river levels at the plant was considered and the results confirmed the dikes were sufficiently high to protect against the PMF, including the effect of wind-generated waves.

The strong point is that the Krško NPP has a whole set of revised flooding analyses, based on modern river flow data as well as meteorological measurements, using models of Sava river flow that were calibrated and validated, and that the plant's flood protection will be conservatively upgraded to a higher level and the protection is also verified using a hydraulic model for present site conditions as well as for the planned construction of a new HPP.

The current (second) PSR will again reassess all of the floods analysed and presented in USAR, as well as changes in flood and meteorological data. Every 10 years the revision of PMF and other flood flow results is considered as part of the PSR.

2.2.2.4 Possible measures to increase robustness

No further measures suggested, apart from increasing the dike height. But as part of the additional plant safety upgrade the structures and components will be flood protected beyond PMF (assuming failure of the dike). The future PSRs will again reassess all of the floods analysed and presented in USAR, as well as changes in flood and meteorological data, so future upgrades of flood protection are possible.

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

A number of measures have already been implemented in order to increase the plant's robustness with respect to external events but which cannot be linked directly to the topic 'Flooding'. They include:

- Alternative means to provide suction to AFW pumps or to provide water to SGs directly;

Alternative means for power supply to the Positive Displacement Pump (PDP) of the Chemical and Volume Control System in order to preserve the RCS inventory and the integrity of RCP seals in induced SBO or Loss of ESW / component cooling system (CCW) conditions;

- Alternative means for power supply to selected motor-operated valves (MOV), as necessary for the implementation of alternative methods;
- Alternative means for providing water from the external sources to containment;

Procedures for local operation of AFW TDP and for local depressurisation by means of SG Power Operated Relief Valves (PORVs), both without need of DC or instrumentation power;

- Alternative means for makeup of SFP inventory.

Krško NPP is implementing the upgrade of the existing flood protection by raising the dikes upstream from the plant, in order to keep the left bank of the Sava river dry even when flows exceed the PMF flow.

During the country visit it was stated that the upgraded flood protection dikes are designed:

- to ensure seismic resistance to DB earthquake (SSE),
- for a combination of events as well as dynamic effects, e.g. combination of PMF and effect of wind-generated waves,
- to be resistant to erosion should water flow over the dikes,
- to be adequately shielded against penetration of water through the dikes or under the dikes,
- without any penetration of the dikes by, for example, water pipelines, gas pipelines or electricity conduits.

Also a third independent DG with a safety bus, which can be connected to both existing safety buses and measures for provision to connect mobile DG of capacity 2000 kVA to switch gear of the third DG.

2.2.3 Peer review conclusions and recommendations specific to this area

The Krško NPP is assessed to be robust for the defined flood events (DBF, PMF, extreme flood). An additional flood-protection measure (increasing the dike height upstream from the plant) is in progress. Safety margins are evaluated in an advanced manner. Methods and input data are specified in a limited manner in the SI-NR, but have been reviewed in the course of the country visit.

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

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

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

The SI-NR does not mention reference documents or standards used for the definition of the design basis, nor PSRs specific to bad weather conditions. Such information was provided during the peer review presentation of written questions as well as during the country visit.

2.3.1.2 Derivation of extreme weather loads

Only maximum and minimum historical values are given in the SI-NR. The report does not describe the potential combination of weather conditions. However, more information is documented in the USAR and was presented during the country visit.

2.3.1.3 Main requirements applied to this specific area

The SI-NR claims that structures that house and protect all safety equipment are designed to withstand severe weather condition that could occur at the site. However, no detail is provided regarding the design value for extreme weather conditions.
Combinations of extreme weather conditions are evaluated and used for the design basis. Return periods and Core Damage Frequencies (CDF) of external flooding, high winds with tornados, and occurrence of low and high temperatures are documented in the USAR.

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

No technical background is provided in the SI-NR. According to information provided in the course of the country visit, the contribution to CDF due to extreme weather conditions is 4.5E-6 /y.

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

External initiating event are to be evaluated during PSR.

2.3.1.6 Conclusions on adequacy of design basis

No strong evidence can be found in the SI-NR to show that the Krško NPP complies with the design basis. However, more information can be found in the USAR of the plant and was also given in the course of the country visit.

2.3.1.7 *Compliance of plant with current requirements for design basis*

There is no evidence in the SI-NR that the Krško NPP complies with the design basis. However, more information can be found in the USAR of the plant and was also given in the course of the country visit.

2.3.2 Assessment of robustness of plant beyond the design basis

2.3.2.1 *Approach used for safety-margin assessment*

No specific information is presented in the SI-NR.

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

The SI-NR provides only limited information and does not include margin analysis. However, this information is available in the USAR and the PSA, and was discussed in the course of the country visit. Extreme weather events are bounded by the SBO and loss of UHS.

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

Neither safety features nor areas for safety improvement have been identified.

2.3.2.4 *Possible measures to increase robustness*

No possible measures to increase robustness have been identified.

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

Several measures were presented:

- During the cold weather season, warm water is diverted from the essential service water to the inlet of the intake structure for de-icing purposes.
- In the event of extremely low temperatures, daily plant surveillance is performed for all open air isolated lines.
- The plant has in place several gas heaters which can be used to heat safety related SSCs even during an SBO.
- Modifications that are to be implemented under the second SNSA decision will use the extended design basis temperatures (this information was given at the topical review).

2.3.3 Peer review conclusions and recommendations specific to this area

The SI-NR provides only limited information. The design basis and the safety margins are presented in a simplified way, mainly providing information on the meteorological history of the site. Based on the first PSR, the SI-NR concludes that the design of the plant against extreme weather conditions is sufficient and no action is needed. However, during the peer review, sufficient information was provided and is documented in the USAR.

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

3.1 Description of present situation of the plant in the country

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

It is stated in the SI-NR that the Krško NPP was designed in accordance with USNRC regulations and standards, which are used in several areas where domestic legislative requirements do not exist or fail to lay down regulations. These regulations are the basis of plant design and features, as described in the USAR. The plant is upgraded and modernised in accordance with new industrial and regulatory requirements and standards, as part of follow-ups to the plant's PSRs.

The NPP periodically updates a document called 'Regulatory Conformance Program — Compliance Review' which represents the overview of all USNRC regulatory requirements and NPP compliance with them and which is a part of the PSR process. Currently, revision 3 is in place. The following main regulations are in force:

- 2002 Act on Nuclear Safety (amended in July 2011)
- Subordinate decrees and regulations
- Act on Third Party Liability (renewed in 2010)
- Nuclear Safety Directives
- The SNSA requirements have been fully harmonised with WENRA reference levels since April 2011.

3.1.2 Main requirement applied to this specific area

Regulatory requirements in force for the Krško NPP with respect to LOOP, SBO, primary UHS loss, and primary UHS loss + SBO are in line with the corresponding IAEA Safety Standard (Safety of Nuclear Power Plants Design, NS-R-1 (2000)). The following regulatory requirements are also cited in the report:

- Rules on operational safety of radiation of nuclear facilities (Section 2.1.3.1)
- Krško spent-fuel storage-area design, in compliance with USNRC Regulatory guide 1.13 (Section 5.2.3.1)

The regulator's main requirements for SBO and loss of UHS:

- The source of the emergency power supply shall be capable of supplying the necessary power to safety-related systems and components in all facility states and during a design-basis event. This shall also be accomplished under the assumptions of a single failure and a total loss of offsite power.
- Residual-heat removal from the reactor core shall be provided following its shutdown from any plant state and during accidents, even under the assumptions of a single failure and of loss of offsite power.

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

The technical background for requirements, safety assessment and regulatory oversight is based on deterministic analyses and on operational experience. A list of the analyses performed by the licensee was provided during the topical review meeting, it being stated whether these analyses had been validated in the licensing process and they had undergone the licensee's Quality Assurance program (C1, C2 and C3 categories).

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

A PSR is performed every 10 years. The first PSR ended in 2003. The NPP is now in the process of completing the action plan resulting from its first PSR and is at the beginning of its second PSR, which will be completed in 2013. Likewise, the process of the plant design lifetime extension is ongoing and it is expected to be concluded in 2013, given that the scheduled end of the lifetime of the Krško NPP is in 2023. Each PSR is an opportunity to verify the compliance of the plant with its design basis and for continuous investments in safety.

3.1.5 Compliance of the plant with current requirements

The country representatives stated that the plant has been upgraded and modernised in accordance with new industrial and regulatory requirements and standards. Examples of the most important modernisations and safety improvements are provided in the SI-NR. New regulations were recently established in Slovenia to incorporate the WENRA reference levels. For the implementation of some new requirements, an action plan was issued and a grace period was given to meet them. As an indirect consequence of the Fukushima accident, the planned completion times for some of the actions were shortened.

3.2 Assessment of robustness of the plant

3.2.1 Approach used for safety margins assessment

A deterministic approach has been used for safety margin assessment for both the reactor and the SFP in the event of LOOP, SBO, loss of UHS, and their combinations. Both calculations and engineering judgments have been used for the assessments performed.

In order to understand the degree of plant robustness, the SI-NR provided a general description of the electrical system for the NPP design, including the switchyard, high voltage grid connections, the gas-steam power plant (GPP) Brestanica, air-cooled emergency DGs, portable DGs, and station batteries.

Similarly, a detailed description of the water supply system for cooling was given in the report, including the essential-service water system, alternative ways of feeding the SGs through AFW and other means, SFP cooling and its alternative means for establishing SFP cooling and making up the loss of cooling water.

During the topical review meeting, additional detailed information was provided in the form of answers to the review questions.

Short description of the electrical power supply solutions

The Krško NPP generator is connected to two 400 kV switchyard buses via a generator load breaker, two step-up 21 kV/400 kV transformers and a substation breaker. The 400 kV switchyard is connected to the 400 kV grid by three high voltage transmission lines. The switchyard 400 kV bus is also extended to the Krško transformer distribution station and connected to a 110 kV switchyard via a 400 kV/110 kV transformer. The two unit transformers are connected between the generator load breaker and step-up transformers and they provide normal on-site power supply for two Class 1E safety buses and two non-1E 6.3 kV busses. All four buses can also draw energy from the station auxiliary transformer powered through a direct underground cable from the Krško transformer distribution station or directly from GPP Brestanica, which is located 7 km from NPP Krško. GPP Brestanica is equipped with three gas-powered units of 23 MW capable of black starting in the event of a breakdown of the 110 kV system and providing electrical power to the Krško NPP station auxiliary transformer in less than 20 minutes.

Short description of the water supply solutions for cooling

The ESW provides cooling water to the CCW and boron thermal regeneration system to transfer the plant heat loads from these systems to the UHS, the Sava River. The system also serves as a backup safety-related source of water for feeding the SGs through AFW. The CCW provides cooling for safety systems and engineered safety feature systems. The system operates during all plant operational phases, performing normal plant functions as well as safety functions. ESW operates during any normal or accident condition of the plant and during an SSE with the loss of offsite electric power and any single-failure event, thus satisfying the safety function and single-failure criterion required for this system. The ESW is classified as a Safety Class 3 and Seismic Category I system and is designed for operation with any water level varying from the original minimum river level to a maximum flood level. The temperature of the river water is considered to be a maximum of 26.7 °C and a minimum of 0.6 °C. A low dam across the Sava River is used to maintain the water level at a nominal elevation. The dam threshold is designed to maintain its function in the event of an SSE and to form a pool of capacity 450 000 m^3 from which the ESW is provided with water together with the bank river protection with the same design basis. The loss of upstream Sava River flow will not disturb the ESW cooling function. The highest water temperature rise in this pool, in the event of loss of river flow, is expected to be 8.1 °C with the very conservative assumption of no heat transfer from the pool during the 30 day cooldown. The potential for freezing in the intake structure and piping has been considered, with necessary design features included to provide freeze protection. Appropriate instrumentation is provided in the control room to indicate the status of the system during normal and accident conditions.

3.2.1.1 LOOP

If offsite power supply is lost, the two 6.3 kV emergency buses MD1 and MD2 are powered from their respective 3.5 MW emergency DGs. These emergency DGs are air-cooled and can therefore still operate in the event of the additional loss of heat sinks. With the available fuel at the site, at least 7 days of emergency DG operation is possible. The operation of emergency DGs can be prolonged by stopping one of them. To shutdown the plant and maintain safe shutdown conditions only one train of safety equipment is needed, one emergency bus and one DG. If one emergency DG is inoperable, then fuel can be transferred from one underground reservoir to another by portable air-driven pump. In addition, fuel for emergency DG(s) can be obtained from any other diesel-fuel storage on the site.

A third emergency DG will also be installed in 2012 in order to reduce the CDF for events initiated by the LOOP. The third emergency DG will be seismically qualified and located in a separate building with the third emergency bus which can be connected to either of the existing emergency buses.

Provisions for house-load operation were also included in the design. At the time of commissioning of the NPP, a test of house-load operation at reduced power succeeded while the test at full power failed. The reason for the failure was investigated and improvements were made but there was no further test.

Each Class 1E train is provided with a complete 125 V DC battery system which supplies DC power to loads associated with the train. The batteries are designed to have sufficient capacity to cope with the SBO for 4 hours, so as to ensure safe shutdown of the unit.

There are also 5 portable DGs. Establishing alternative power supply to the DC distribution panel and to the instrumentation distribution panels from portable DGs assures prolonged availability of DC batteries and of 118 V AC instrumentation power supply (up to 72 hours with the fuel stored at the plant, or even longer if fuel could be supplied from offsite). For long-term operation, external support would be needed for diesel and gasoline supply to run the portable alternative equipment.

SFP cooling pumps are powered from the safety-related 400 V buses. In the event of a LOOP, the safety-related emergency buses can be powered either from the 110 kV switchyard TDS Krško through the station auxiliary transformer or from emergency DGs. If DGs are started and a blackout occurs or the safety-injection sequence is initiated, the breaker for operating the SFP cooling pump will open. One SFP pump will then be started manually as defined by operating procedures.

3.2.1.2 SBO

The SBO scenario considers the LOOP and loss of the ordinary back-up AC power sources. The SBO scenario has been assessed and presented in the report only for the situation with the reactor at power and for SFP. The following features are considered to cope with the SBO and ensure the safety functions are fulfilled:

Reactor:

- Establishing alternative power supply to the bus LD11 and to battery chargers from one of the two portable DGs assures the prolonged availability of DC batteries and of 118 V AC instrumentation power supply.
- If needed, EOPs instruct the operators to disconnect all non-essential DC loads. In this case, the availability of batteries could be extended to more than 13 hours (based on best estimates of DC studies and tests). The procedure describes the shedding logic in several steps.

- Additional portable DGs are available (Severe Accident Management Equipment (SAME)), with the instruction to strip all non-essential DC loads if needed. This will ensure that DGs keep essential instrumentation available for much longer.
- The batteries are designed to cope with a 4-hour SBO, providing safe shutdown of the unit

Krško NPP is designed to maintain safe shutdown conditions for four hours with the following supporting features:

- In the two seismically-qualified condensate storage tanks there is enough water for removing the decay heat through both SGs (each tank has a capacity of 757 m^3) for 4 hours.
- The AFW control valves are air-operated and provided with a 4-hour supply of nitrogen gas to control the AFW TDP and the power-operated relief valves for releasing steam from SGs.
- In the worst case scenarios involving unavailability of the AFW TDP, if temporary SGs injection equipment are deployed and made functional in 1 hour, enough margin exists to prevent core damage.
- Safety batteries' capacity ensures power to 118 V instrument power supply.
- Opening doors ensures appropriate temperature in AFW TDP room and in main control room cabinets.
- Containment isolation can be done with locally-closing isolation valves.
- With local actions to isolate letdown lines, the inventory loss is minimised.

To mitigate deterioration of Reactor Coolant System (RCS) and SFP conditions while AC emergency power is not available, the following EOP mitigation features and actions are considered:

- Maintain auxiliary feedwater flow to both SGs with a turbine-driven auxiliary feedwater pump which can be controlled from the control room (if power from batteries is still available) or locally.
- Minimise the RCS inventory loss by isolating letdown lines.
- Restore power to any AC emergency buses by starting at least one emergency DG or by establishing off-site power supply.
- Depressurise RCS by depressurising the SGs.
- Enhance the cooling of equipment by opening certain doors.
- Initiate SFP makeup using alternative equipment (SAME).
- If needed, initiate flooding of CNT sump by gravity drain from the RWST.

Spent Fuel Pool:

- If loss of all AC power occurs, SFP cooling pumps will be lost and the cooling flow to the SFP heat exchangers will be lost.
- The temperature of the water in the SFP will start to increase.
- Considering maximum possible decay-heat value (8.5 MW) in the SFP, time to boiling is around 4.5 hours.
- Heat removal from spent fuel is now established by water boiling and evaporation in the SFP.
- To maintaining a constant water level in the SFP, water must be delivered at a rate of at least 14.1 m^3/h.

Alternative means for establishing SFP makeup:

- Pumping water with a portable fire pump from the water pre-treatment tanks to the system for purification of SFP water surface.
- Providing water from the fire-protection hydrant network to the system for purification of SFP water surface.
- Pumping water with a portable fire pump from the pool near the water pre-treatment building to the system for the purification of the SFP water surface.
- Pumping water with a submersible fire pump and fire truck from the circulating water intake pool to the system for purification of SFP water surface.
- Pumping water directly to the SFP from the fire-protection system.

3.2.1.3 Loss of ultimate heat sink

In the report there is an assumption that the loss of UHS means the loss of connection between the pumps and the loads. All other systems are assumed to operate normally and water is available from the Sava River. This assumption may not be a conservative assumption since other scenarios causing the loss of UHS can be identified (e.g. combination of loss of the Sava River together with loss of the pool above the dam). The robustness of the water intake to potential blockage by debris should also be

considered, especially because in the recent past (2003) a shutdown of the plant occurred. The upgrading-measures action plan envisages an alternative UHS independent of the Sava River.
The existing fire-protection system with demineralised water available onsite or from the Sava River assures a minimum cooling capacity. This alternative cooling has a limited cooling capacity and allows operation of the centrifugal charging pump, the high head safety injection pump and even the auxiliary feedwater pump, or any other small heat load which it would be necessary to cool.
If the loss of UHS event occurs for states where the heat removal can be performed by the SGs:

- the plant will be put in a 'hot shutdown'.
- the loss of RCS coolant due to RCP seal leakage is compensated for with PDP flow injection from the RWST.
- 'No load' temperature of the RCS is maintained (130-150 °C, pressure 20-25 bars) to ensure enough steam pressure for AFW TDP.
- AFW TDP provides feed flow to both SGs, steaming with SG PORVs, natural circulation of reactor coolant is maintained.

Condensate storage tanks (CST) makeup from available water sources: demineralised water storage tanks, fire-protection tank, condenser, circulating water tunnel, the Sava River, potable water from city of Krško.
Additional features:

- In case of inoperable Costs and operable AFW pumps, water can be delivered to the suction of AFW pumps using portable fire-protection pumps.
- Equipment stored on site would be used; low-pressure (15 bar) as well as high-pressure (30 bar) portable pumps.
- External support from an outside organisation is not expected and is not needed in an early phase of the event (first 72 hours).
- All necessary actions can be performed by shift crew and additional personnel from Technical Support Centre (TSC) and Operational Support Centre (OSC).
- Krško NPP can be in this condition for at least 7 days.

The case with the primary circuit open is considered to be not limiting, given the reduced residual heat. Water makeup will be done from the RWST. This is also possible in the event of SBO (manual valves to open — gravitational make-up). Procedure and training exist for this case.
For the SFP:

- SFP heatup same as with the SBO; actions similar/same as above.
- If the level of the SFP were lost there would be no criticality concern.
- Cooling of SFP is provided by evaporation and addition of water using alternative equipment (B.5.b).
- To verify that cooling is adequate, temperature and level need to be monitored reliably.
- SFP level measurement covers the entire span from normal level to the bottom of SFP.
- Temperature is measured at two different levels.
- Level and temperature indications are on a local panel and on the process computer.

3.2.1.4. Loss of ultimate heat sink with SBO

The loss of the primary UHS combined with SBO results in the unavailability of the existing safety equipment, which needs to have electrical power supply and needs to be cooled. To fulfil the requirements of each safety function, unconventional equipment present on-site can be used.
This scenario is similar to the SBO scenario. After loss of UHS with SBO, decay heat can be removed by turbine driven pump and steam relief into the atmosphere through the SGs. The electrical power supply which is needed to control the relief valves, to control the steam-driven pump and to provide power for I&C, is delivered by the batteries. Also, for the first 4 hours there is sufficient compressed nitrogen in bottles to operate valves. During that period, alternative source of power and compressed air can be established. The speed of the steam-driven pump can be controlled manually as well as release of the steam from SGs to control the decay-heat removal. If the SG relief valves cannot be operated by remote control, they may also be operated locally, using compressed air from a portable diesel compressor and local pressure regulators or manually. The Main Steam Safety Valves can be used for depressurisation of SGs, as an alternative to the SG PORVs.

With stabilisation of the reactor temperature at above 130 °C to have enough steam to power the steam-driven pump, the plant can stay stable as long as there is enough water to remove decay heat from the primary side and any RCS leak is minimised and controlled by depressurisation or injection.

All alternative mobile equipment is located on-site at least 100 m away from the reactor on the highest ground elevation which is safe in case of flooding. Equipment is powered by diesel or gasoline engines, with enough storage capacity for 72 hours at rated load (assuming that emergency DGs do not run, due to the SBO, underground fuel can be used to prolong this time to more than 7 days). For long-term operation, external support is needed for diesel and gasoline supply to run the portable alternative equipment.

To ensure safety beyond 4 hours, the use of one of the two alternative DGs as alternative power supply is proposed. These generators can provide electrical power to parts of the 400 V system. In this way, power for necessary lighting and the 220 V DC charger can be provided. Power is also provided for the positive displacement charging pump , which doesn't need cooling and can provide charging flow from the RWST and/or boric acid tanks to the primary circuit, RCS. This charging flow compensates for inventory losses in the primary circuit and it ensures that recriticality will be prevented during cooldown with the use of borating reactor coolant system.

Operators can also use 400 V power to recharge the batteries, using a method which is described in system operating procedures and is used in regular outages as a temporary modification. Power to the instrumentation distribution panels 2 and 4 can also be established by powering a motor control centre with one of the three 150 kVA portable DGs. If power to 118 V instrumentation system cannot be established, or in the event of loss of the control room, operators can establish alternative power to a shutdown panel using two 220V petrol-driven generators with transformation to 118V, securing essential instrumentation.

Water sources considered for this scenario are CSTs, demineralised water storage tanks, potable water, well water and also the Sava River. External support can also be provided in the form of sufficient water capacity from the Krško potable water source or any other available water source.

Should the steam-driven pump not be available, portable fire-protection pumps can be used to supply water to both SGs. These pumps have enough capacity to remove the decay heat from the core and to maintain the level in both SGs to provide natural circulation on the primary side.

SFP heatup is the same as in the case of an SBO; actions are similar or the same.

Heat removal from the SFP can be achieved through its heat exchanger, through evaporation of water, or a combination of both. Should it not prove possible to operate the heat exchanger, the only option is evaporation of water by letting it boil. In this situation, boron remains in the SFP and there is no concern about criticality. Enough water needs to be provided to replace the evaporated water.

The following water sources can be used for SFP cooling: water pre-treatment tanks, fire-protection hydrant network, carbonate mud pool, circulating water intake and circulating water outlet pool to the system for purification of the SFP water surface, using portable or installed diesel fire pumps.

3.2.2 Main results on safety margins and cliff-edge effects

3.2.2.1. LOOP and SBO conclusions:

- No cliff-edge effects have been identified in the event of LOOP. This accident is a design-basis accident, analysed in the Safety Analysis Report (SAR) for licensing.
- No cliff-edge effects have been identified in the event of LOOP and loss of on-site back-up power sources for a period longer than 7 days because the use of alternative equipment (SAME) assures reactor coolant inventory control and decay-heat removal.
- Restrictions on the using of SAME can only come from the depletion of on-site fuel and oil resources, at which point external delivery is necessary.
- Autonomy of alternative DGs used to supply electrical power is 72 hours with the fuel available on-site (not taking into account the fuel in the emergency diesel tanks, which are DBE qualified).
- The batteries' design autonomy is 4 hours. With the use of mobile DGs provisioned to charge the batteries (and supported by available equipment and procedures), this time can be extended to a minimum of 72 hours. If for some reason the SAME equipment cannot be used, the best-

estimate DC study shows that by disconnecting all non-essential DC loads the availability of batteries can be extended to more than 13 hours (procedures are prepared and available).

- The SFP instrumentation has dedicated batteries with a minimum capacity of 30 hours of continuous measurements.
- A procedure for operation in the event of SBO is available.
- If no water is delivered to the SFP, then the USAR limit of 3.05 m of water above the top of fuel elements is reached in 47 hours. It would take more than 3 days for the spent fuel elements to begin to be exposed to the air if no water were added to the SFP.
- Conclusions related to the cliff-edge in the event of an SBO while the reactor was in shutdown and open were presented during the country visit. The Slovenian representatives declared that this situation was covered by the limiting case of SBO with the reactor operating at power and described the corresponding procedures.

3.2.2.2. Loss of UHS

- No cliff-edge effects have been identified in the case of loss of UHS for a period of more than 7 days because the use of alternative equipment assures reactor coolant inventory control and decay-heat removal.
- The Krško NPP does not have an alternative ultimate heat sink. The installation of a new water line from the Krško HPP was mentioned in the report, but this project was abandoned. Rather, the construction of a seismically-qualified cooling tower has been proposed as an alternative UHS.

3.2.2.3. Loss of UHS with SBO

The SBO for the NPP site with the reactor in service represents the worst case scenario (limiting case). Even in this case, no cliff-edge effects have been identified for a period of more than 7 days, related to loss of the primary UHS, combined with SBO, because the use of alternative equipment assures reactor coolant inventory control and decay-heat removal. Assessment of this scenario yields the following results.

Reactor:

- Stabilisation above 130 °C to have enough steam to drive the AFW TDP. The plant can stay in this condition as long as there is enough water to remove decay heat from the primary side.
- RCS leak is minimised and controlled by depressurisation/injection.
- Using alternative mobile equipment, powered by diesel or gasoline engines (fuel storage capacity for 72 hours, a period which can be prolonged to more than 7 days), Krško NPP can be in this condition for at least 7 days. No cliff-edge effect is identified for more than 7 days, in these conditions.

SFP:

- No cliff-edge effects have been identified for an initial period of more than 7 days because the use of alternative equipment assures spent-fuel heat removal.
- SFP cooling can be ensured by adding cooling water with portable pumps.
- For the worse case (the entire core after an 18-months' fuel cycle is unloaded to the SFP), the time available to establish water injection into the SFP is 47 hours (at that time water would drop to the USAR limit (shielding) value). It was calculated that the fuel would remain covered for 76 hours after event initiation.

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

The strong features of the NPP in the case of loss of the primary UHS and/or loss of all AC power are:

- seismically-qualified plant systems, structures and components important to safety
- sufficient mobile and portable power-generation sources available on-site
- a turbine-driven auxiliary feedwater pump is available for reactor cooling (provided the SGs are available)
- several alternative cooling means are available, or are planned, in case of the loss of primary UHS.

Areas for safety improvements identified:

- additional safety analyses are needed, including transient/incident scenarios when SGs are not available for reactor cooling (see comments above).
- alternative ultimate heat sink.

Nevertheless, the NPP proposed, and the regulator accepted, additional plant modifications with the aim of further increasing the robustness of the plant, with emphasis on providing additional power sources, alternative means of cooling and an alternative ultimate heat sink. These measures, in the short-term and planned, are presented in Sections 3.2.1 and 3.2.5.

3.2.4 Possible measures to increase robustness

The regulator stated that a number of measures to make the operating NPP more robust are already in place or are being planned. Where the reactor is in service, the licensee considers that the measures proposed are expected to increase the plant's robustness against loss of power and loss of UHS scenarios and to prevent cliff-edge effects.

Among other modifications, focusing on power sources and additional means of cooling, already decided or in progress — see Section 3.2.5 -— the construction of a new seismically-qualified backup or emergency control room is also being discussed,.

An additional modification that would increase reactor safety is the construction of an alternative ultimate heat sink. A new alternative UHS, totally separate from the Sava River, is under consideration, and this will be seismically-qualified, probably a cooling tower. The alternative UHS is at the study phase.

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

The Krško NPP is implementing (projects underway and due for completion in 2012) additional safety upgrades, in particular:

- a third independent DG 6.3 kV (in a separate building with the third safety bus which could be connected to either one of the existing two safety buses)
- provision to connect a mobile 2000 kVA DG to switch gear of the third DG
- two petrol-driven 125 V aggregates will be available to provide power to DC system panels in event of loss of DC main distribution panels A and B
- a flood-protection upgrade (increasing the level of the dikes upstream of the site), to keep the left Sava river bank dry even when flows exceed the PMF flood flow

In addition, the Krško NPP is in the process of implementing the following improvements to increase the plant's capability to withstand extreme external hazards:

- acquiring (purchasing) an additional onsite pumping station to assure an additional high-capacity 'portable water ring' around the plant — 'HFS HydroSub 450 floating unit' (as a backup fire-protection system but with enough capacity to be used as an alternative water source for heat removal from the reactor, containment and SFP)
- acquiring (purchasing) two additional high-pressure mobile fire-protection pumps (to remove decay heat in the early stage after reactor shutdown and depressurising SGs)
- installation of some additional quick connection points for mobile equipment
- an alternative system with skid-mounted pump and heat exchanger to cool the SFP.

3.2.5.1 Upgrading programmes initiated/accelerated after Fukushima

In September 2011, the regulator issued a decision requiring the plant to reassess the SAM strategy, and existing measures and to implement necessary safety improvements for the prevention of an SA and mitigation of its consequences. In January 2012, Krško NPP presented the analysis and action plan, this then being reviewed and approved by the regulator. The action plan, expected to be implemented by the end of 2016, comprises the following measures:

- additional seismic strengthening of the DG3 and MD3 bus
- additional seismically-qualified (2×SSE) SI and AFW pumps
- alternative seismically-qualified (2×SSE) UHS
- installation of a special safe-shutdown control room

- alternative seismically-qualified (2×SSE) means of cooling the SFP.

3.3 Peer review conclusions and recommendations specific to this area

A comprehensive description of the behaviour of the plant, as well as the various ways of ensuring fulfilment of the main safety functions during the scenarios of LOOP and loss of UHS, is provided in the report. According to the report, the Krško NPP can withstand such conditions without fuel melting for a period longer than required by ENSREG specifications. Various equipment provided to maintain the plant in a safe state is already installed in the plant or available on site (mobile DGs, etc.). However, some aspects related to the fulfilment of safety functions following LOOP are in place and described in the procedures. The proposed measures would increase the plant's robustness in the areas mentioned.

4 PLANT ASSESSMENT RELATIVE TO SEVERE ACCIDENT MANAGEMENT

4.1 Description of the present situation of the plant in Slovenia

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

At a general level, the Slovenian legislation on nuclear safety is relatively compact, does not go much deeper than WENRA reference levels and is mainly based on the 2002 Slovenian Act on Nuclear Safety (amended in 2009 to harmonise it with the WENRA requirements), together with a number of subordinate decrees and regulations. WENRA reference levels on nuclear safety design bases, documentation and licensing as well as on operational nuclear safety have been fully incorporated in those rules.

Furthermore, the Slovenian regulatory basis (and thus also the regulatory basis relative to SAM) relies almost entirely on the applicable USNRC technical standards and regulations, as the US is the NPP vendor country. Due to historical reasons and the deeper nature of these requirements, those USNRC standards and regulations still apply in Slovenia. For instance, USNRC requirements for life-time extension have been applied (USNRC license renewal rule 10 CFR 54 and NUREG 1800 for the review of the application). Agreements between the Slovenian regulator and the USNRC ensure close cooperation.

In response to the Fukushima accident, the regulator issued a decision requiring the Krško NPP to perform a Special Safety Review, in line with the ENSREG specifications for Stress Tests. In June 2011, a series of minor modifications in the plant were licensed to add alternative possibilities for electrical power supply and cooling of the reactor, containment and SFP should there be a Beyond Design Basis Accident (BDBA). In September 2011, the regulator issued a decision requiring the licensee to reassess the SAM strategy and existing measures and to implement necessary safety improvements for the prevention of an SA and the mitigation of its consequences. The related action plan was presented by the licensee in January 2012 and approved by the regulator to be fully implemented by 2016.

4.1.2 Main requirements applied to this specific area

The main requirements concerning SAM are that:

- the plant must have symptom-based SAM guidelines,
- the Severe Accident Management Guidelines (SAMGs) must be plant-specific and supported by analyses,
- both EOP and SAMG must be validated using a simulator,
- human factors must be analysed and taken into account and
- regular training and exercises must be performed.

Furthermore, USNRC B.5.b requirements on extensive damage mitigation guides covering SFP strategies and reactor and containment strategies apply. It was also mentioned in the report that the safety-related instrumentation systems have to be designed to meet the independence and separation requirements of IEEE 279-1971 and that the habitability systems for the control room are to be designed to adequately meet the requirements of 10CFR Part50, Appendix A, General Design Criterion 19. Finally, it was mentioned during the peer review discussions that in relation to the requirements issued in September 2011 to reassess the SAM strategy the objective not to release more than 0.1 % of volatile fission products and particulates (not including noble gases) during an SA had been established.

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

As mentioned, Slovenian nuclear requirements and safety assessment are based on WENRA, IAEA and applicable USNRC technical standards, regulations and guides. The SAMG have been adopted based on the generic guidelines provided by the vendor (Westinghouse). During discussions it was mentioned that Slovenian SAM is in line with IAEA TECDOC-953.
Furthermore, the report mentions that a PSA model has been developed which also includes the evaluation of large early release frequencies and that a number of modifications have been evaluated with respect to their impact on the PSA model (and thus also on the frequencies of large early releases). In particular, the replacement of the SGs as well as the 'wet cavity' design have been shown to decrease internal-event release categories (RC) frequencies that generate large releases and to increase RC frequencies with very small to small releases. Plant operating experience was used to update the PSA input parameters.

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

Krško NPP is completing its first PSR action plan and is at the beginning of the second PSR, during which the plant's design and operation will be compared against the newest standards and best industry practice. A PSR is conducted every ten years. The PSA was reviewed during the last PSR and is regularly updated after every fuel cycle. As explained during the country review, SAMGs were first reviewed by an IAEA RAMP mission in 2001; the detailed review of SAMGs is included in the program of the second PSR now getting underway.

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

The regulator has confirmed that the SAMG were initially validated with the installation of the full scope simulator in 2000.After every modification, SAMG are updated and validated. The regulator stated that since 29 April 2011 Slovenia has been fully harmonised with WENRA reference levels; however, no explicit statement has been made concerning the compliance of the plant with all current requirements.

4.2 Assessment of the plant's robustness

4.2.1 Adequacy of present organisations, operational and design provisions

4.2.1.1 Organisation and arrangements of the licensee to manage accidents

The emergency preparedness and response in Slovenia in the event of accidents at Krško NPP is conducted at the plant, local, regional and state levels.
The accident response at plant level is covered by the Krško NPP RERP. It includes the Emergency Response Organisation (ERO) covering the main control room and shift organisation, a TSC and OSC. The President of the management board is responsible for the overall Krško NPP emergency preparedness. He acts as the Emergency Operations Facility (EOF) Director. The Technical Director is

responsible for keeping the plant in an overall safe condition. In the event of an emergency, he acts as Emergency director.

The ERO consists of various organisational structures which are activated depending on the emergency level and are located in the Emergency Response Facility (ERF). Until the TSC is operable, the management and coordination of the emergency response is organised within the Main Control Room (MCR) shift organisation. The TSC is organised to perform plant-status evaluation, SAM strategy evaluation and determination and to provide operational support to plant operators. When the transition from EOP to SAMG is in place, decision-making responsibility is transferred from MCR to TSC.

The OSC is organised to deploy the intervention teams on the site and to carry out intervention measures determined in the TSC. The Emergency director directs and coordinates on-site emergency response. The Emergency director also assumes, in the event of a site or general emergency, the functions of EOF director until this position is established.

The off-site structure of ERO, activated in the event of a site or general emergency, consists of the EOF and is located in Ljubljana. The EOF is organised, equipped and located to carry out overall direction and coordination of the Krško NPP's emergency response, support to the TSC and intervention personnel, coordination with authorities involved, evaluation of offsite radiological consequences, recommendations of urgent protective measures for the population and public information. EOF has manpower and scope to take over some of the TSC's functions. Additional support is provided on a contractual basis by external organisations.

Under accident conditions, the MCR is automatically isolated and a cleanup system is started to keep the area habitable. MCR systems are redundant, safety-related, seismically-qualified and draw energy from independent safety-power buses. Breathing apparatus with compressed air tanks are also available. If the MCR has to be evacuated, three evacuation panels are available in the plant with sufficient control and monitoring capabilities for a safe cool-down of the plant to a cold shutdown state using a special set of operating procedures. Also structured and equipped TSC and OSC are on the site.

There are various and redundant communication means inside the plant and between the plant, EOF and other external organisations involved in the emergency response (telephone, wireless VHF, plant paging …). They are powered by separate uninterruptible power supplies. For the extreme case in which all communication links have failed, satellite phones are available.

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

A SAM program has been implemented at Krško NPP and emergency operating procedures have been developed. The EOP aim at preventing core damage. For the low-power and shutdown states, there are some AOP specifically addressing such operating conditions. Those AOP that are used in case of degradation of SSC conditions, equipment malfunctions, and abnormal operation include:

- Shutdown Loss of Coolant Accident (LOCA)
- Loss of RHR cooling,
- Loss of RHR during refuelling.

If, however, core damage is observed, then the transition from EOP to SAMG is made. The SAMG focus on preserving the containment fission-product barrier and on halting the progression of core damage. They are plant-specific and validated using a full-scope simulator (which is especially noteworthy) as well as through emergency exercises. SAMGs are not dependent on power states.

SFP scenarios are also covered by SAMGs.

4.2.1.3 Hardware provisions for severe accident management

The Krško NPP has a large dry containment and associated systems on which the containment functions depend: the containment isolation system, the containment spray system, the containment air recirculation and cooling system and combustible-gas control system.

Each emergency diesel engine has sufficient fuel to run continuously at full load for a period of four hours (provided by each emergency DG's daily tank; with additional dedicated underground (DBE) tanks, both emergency DGs have enough fuel for 7 days of continuous operation). For the mobile DGs, the plant maintains an onsite fuel oil supply for a SAM operation for a period of 3 days. A set of mobile equipment essential for managing a severe accident (SAME) according to EOP and SAMG strategies is stored on-site. The SAME is located to avoid impairments due to severe conditions (earthquake, floods, fire, etc.).
High-pressure core-melt scenarios are prevented through the use of the RCS depressurisation system. In extended SBO sequences in which the batteries or air supply is depleted prior to the onset of core damage, two on-site portable air compressors which could restore instrument air to PORVs, and portable generators for providing the necessary power to the valves are available. Upgrading programmes also envisage the installation of additional solenoid-operated PORV and normally closed MOV in series for ultimate management of feed and bleed.
Protecting the containment from overpressure is achieved by containment-atmosphere spraying and with alternative portable fire pumps if dedicated safety-related sprays are unavailable. It is estimated that the containment should not fail for 7 days. If no other strategy is available, unfiltered venting is performed.
The combustible-gas control system to reduce the hydrogen concentration consists of two redundant electric recombiners which have been designed for design basis accidents (LOCA case) and are meant to be used as a hydrogen-ignition system under SA conditions. Planned upgrading measures envisage that electric recombiners will be replaced in 2013 by passive autocatalytic recombiners covering DBAs and BDBAs.
Flooding of the reactor cavity is identified as a means of avoiding Molten Core-Concrete Interaction if the RPV fails. In order to protect the cavity floor against the corium before the reactor vessel fails, a modification was made allowing the flooding of the cavity by connecting it with the containment sump. Water can also be injected into the containment through other systems such as the containment spray, the RWST with gravity drain and the fire-protection pipes for the reactor coolant pumps.
To avoid potential recriticality, the use of borated water is preferred and this is sourced from the RWST and two boric acid tanks. The tanks can be refilled using portable firefighting equipment.
Radioactivity inside the containment in case of an SA can be assessed by high-range radiation monitors and by a post-accident sampling system of gases in the containment atmosphere.

4.2.1.4 Accident management for events in the spent fuel pools

At the Krško NPP site, the SFP is located within the Fuel Handling Building which is a reinforced concrete structure designed in accordance with the seismic and other criteria for safety structures. Failure of any pipeline cannot drain the SFP below the water level required for radiation shielding. A level of 3.05 m of water above the top of the stored spent fuel assemblies is required to limit direct radiation for the personnel to 25 microSv/h. It is estimated that even 1 m of water above the spent fuel, is enough shielding for operators at the SFP platform to be safe. Approximately two days are needed to reach the 3.05 m water level above the fuel elements with the estimated maximum decay heat and all cooling capacity lost. Three days are needed to uncover the fuel elements when the core has just been unloaded after an18-months' cycle.
High temperature (close to boiling) or a low level of SFP water would require the use of guidelines.
The great diversity of cooling methods guarantee with sufficient confidence that the level in the SFP would not drop below the top of the fuel elements, leading to fuel-cladding degradation and fuel defragmentation causing severe radiological releases. On-line monitoring of the hydrogen concentration at the SFP is therefore not envisaged.

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

In the case of severe external events it is expected that the normal access path to the plant could be restricted. However, as most of the plant workers live in the plant vicinity, it is estimated that a sufficient number of personnel will be able to reach the site. It is not expected that the postulated flooding event will limit free access to the plant from any direction. Most of the SAM measures may depend on the availability of mobile power sources and pumps present on the site. Mobile SAM equipment is stored at least 100 m away from the reactor building. A new building will be ready in 2012 and will be designed according to extended design requirement (PGA=0.6g). Many dedicated connections are provided in plant systems performing relevant functions (e.g. decay-heat removal from SGs and from RCS via feed and bleed, containment flooding, SFP filling up and cooling). In an accident situation, support to the NPP can be provided by the Civil Protection Commander of the Republic of Slovenia and by competent authorities in compliance with their competences and the national RERPs. This type of support is not planned in advance. It could include additional heavy mobile equipment (i.e. DGs, pumps, air compressors, etc.), fuel supply, additional protective and rescue equipment, logistic support, arrangements for medical treatment, transportation and other logistics support. The possibility of military support was mentioned.

4.2.2 Cliff-edge effects and areas for improvements

4.2.2.1 Strong points, good practices

During the peer review process, the following strong points were identified:

- Possibility of independent water injection into the reactor vessel.
- Use of turbo-pump of AFW on manual to supply water to SGs.
- Potential failure of the containment due to over-pressurisation can be significantly delayed by partially flooding it. Containment failure would be prevented for 7 days by spraying the containment using a portable fire pump as an alternative.
- SAMGs have been validated by exercises on the full-scope simulator and were reviewed by the IAEA RAMP mission in 2001. RAMP mission recommendations were resolved after the first PSR in 2004.
- Using the full-scope simulator during drills provides real-time response. Simulation goes up to containment failure and beyond. Longest exercise lasted 2.5 days.
- SAMGs are in place for the reactor as well as for SFP and are independent of the reactor operating state.
- Consideration of extensive damage due to an aircraft crash and implementation of mitigation measures.
- WENRA reference levels have been fully transferred into rules and there is a close follow up of USNRC regulations.
- TSC and OSC are operational within one hour.

4.2.2.2 Weak points, deficiencies (areas for improvements)

During the peer review process, the following possible areas for improvement were identified:

- Hydrogen control has not been designed for SA conditions.
- No filtered containment venting exists.
- In the case of an extensive external event some aggravating circumstances could be expected regarding arrival at the site of the plant’s emergency staff. It was estimated that the bridges over the Sava River represent probably the weakest points regarding access to the facility in the event of a strong earthquake.

4.2.3 Possible measures to increase robustness

4.2.3.1 Upgrading of the plants since the original design

The Krško NPP has in place upgraded EOPs and SAMGs, which provide adequate instructions for staff.

4.2.3.2 Ongoing upgrading programmes in the area of accident management

Krško NPP is in the process of completing implementation (by 2012) of additional safety upgrades, in particular:

- third independent DG with a safety bus, which can be connected to both existing safety buses;
- acquiring an additional on-site mobile 2000 kVA DG;
- provision to connect it to the switch gear of the third DG;
- acquiring an additional on-site pumping station to assure an additional high-capacity 'portable water ring' around the plant;
- installation of some additional quick connection points for mobile equipment.

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

4.2.4.1 Upgrading programmes initiated/accelerated after Fukushima

After the Fukushima accident, Krško NPP performed an initial quick review to identify possible short-term improvements. In June 2011, a series of minor modifications to the plant were licensed to add alternative possibilities for electrical power supply and cooling of the reactor and SFP in the event of BDBA. In response to the Fukushima accident, the regulator issued a decision requiring the Krško NPP to perform a Special Safety Review (the program in line with the ENSREG specifications for Stress Tests). In September 2011, the regulator issued a decision requiring the plant to reassess the SAM strategy, and existing measures and to implement necessary safety improvements for the prevention of an SA and the mitigation of its consequences. In January 2012, Krško NPP presented the analysis and action plan, this then being reviewed and approved by the regulator. The action plan, expected to be implemented by the end of 2016, comprises the following measures:

- Realisation of an additional third train of engineered safety features comprising the already mentioned third DG, MD bus, a high-pressure safety-injection pump and a feed-water pump. This train will be located in the already constructed building protected against external events.
- Alternative UHS,
- Installation of a special emergency control room, to be located in the above mentioned new building,
- Alternative means of cooling the SFP and of decay-heat removal,
- Filtered containment venting,
- Passive Autocatalytic Recombiners for hydrogen control in the containment,
- A new TSC with enhanced habitability requirements.

4.2.4.2 Further studies envisaged

Studies show that supplying the plant subsystems with electrical power is of the utmost importance for nuclear safety. In accordance with this conclusion, the Krško NPP is implementing additional safety upgrades. Those measures include the installation of the third seismically-classified emergency DG (in progress) and acquisition of another (2000 kW) portable DG (with several of them already on site; 2 bigger, 1000 and 600 kW, 3 medium 150 kW, and 4 smaller, 5 kW or less). Also, flood protection will be improved (in progress) and new water pumping stations will be acquired (planned).

The plant has launched additional actions for further evaluation of the post-accident shielding review and to install in the near future some simple shielding arrangements on the piping near the valves which might be accessed during an accident.

It is mentioned in the report that a simple shield arrangement may considerably facilitate access to a few locations or rooms. This would reduce the restrictions on operator presence and/or the dose expenditure for certain post-accident actions and deserve consideration for this reason.

There is a plan to install post-accident area radiation monitors (with a battery power supply and a radio link) within the corridors close to the piping and valves which might or even should be accessed for post-accident sampling.
Radiation-protection technicians are going to be equipped with audio links and sufficient wireless communication channels. Central radio communication equipment and personal electronic dosimetry performance, as well as related power supplies, are going to be evaluated and improved if necessary.

4.2.4.3 Decisions regarding future operation of the plant

The current plan of the licensee envisages a plant life extension beyond 2023 for an additional 20 years. The relevant submission is expected to be approved by the regulator by 2013. This life extension beyond 2023 will be accompanied by two additional cycles of PSR.

4.3 Peer review conclusions and recommendations specific to this area

According to the information provided in the SI-NR, the present accident management organisation appears to be well structured and adequate to cope with different levels of severity in the event of an accident, including severe core damage.
WENRA safety reference levels have been implemented in the Slovenian regulatory process. Moreover, the Slovenian regulatory assessment also applies selected USNRC regulations, standards, guides and good practices.
An especially noteworthy characteristic of the Slovenian SAM organisation is the validation of the SAMG using a full-scope simulator.
Several provisions are already in place to support SAM with the use of mobile equipment. It is important that upgrading measures identified to improve SAM capabilities (e.g. installation of PARs, filtered venting, new emergency control room, third engineered safety features train) are implemented as planned.

List of Acronyms

AFW	Auxiliary Feedwater System
ATWS	Anticipated Transient Without Scram
(B)DBA	(Beyond) Design Basis Accident
CCW	Component Cooling System
CDF	Core Damage Frequencies
CST	Condensate storage tanks
DBE	Design Basis Earthquake
DBF	Design Basis Flooding
DG	Diesel Generator
EOF	Emergency Operations Facility
EOP	Emergency Operating Procedures
ERO	Emergency Response Organisation
ESW	Essential Service Water System
GPP	Gas-steam Power Plant
HPP	Hydro Power Plants
IAEA	International Atomic Energy Agency
LOCA	Loss of Coolant Accident
LOOP	Loss Of Off-site Power
MCR	Main Control Room
MOV	Motor Operated Valves
NPP	Nuclear Power Plant
NUREG	Nuclear Regulatory Commission Regulation
OSC	Operational Support Centre
PDP	Positive Displacement Pump
PGA	Peak Ground Acceleration
PMF	Probable Maximum Flood
PORV	Power Operated Relief Valve
PSHA	Probabilistic Seismic Hazard Assessment
PSR	Periodic Safety Reviews
RC	Release Categories
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RERP	Radiological Emergency Response Plan
RHR	Residual Heat Removal
RWST	Refuelling Water Storage Tank
SA	Severe Accident
SAM	Severe Accident Management
SAMG	Severe Accident Management Guidelines
SAME	Severe Accident Management Equipment
SBO	Station Blackout
SFP	Spent Fuel Pool
SG	Steam Generators
SI-NR	Slovenian national report.
SNSA	Slovenian Nuclear Safety Administration
SPSA	Seismic Probabilistic Safety Assessment
SSC	Systems, Structures and Components
SSE	Safe Shutdown Earthquake
TDP	Turbine Driven Pump
TSC	Technical Support Centre
TSO	Technical Support Organisation
UHS	Ultimate Heat Sink
USNRC	US Nuclear Regulatory Commission
USAR	Updated Safety Analysis Report
WENRA	Western European Nuclear Regulator Association