REPUBLIC OF SLOVENIA
MINISTRY OF AGRICULTURE AND THE ENVIRONMENT
SLOVENIAN NUCLEAR SAFETY ADMINISTRATION

Slovenian Report for the Second Extraordinary Meeting of the Parties of the Convention on Nuclear Safety

Report on actions, responses and developments influenced by the Fukushima Dai-ichi NPP accident

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Publisher:
Slovenian Nuclear Safety Administration
Litostrojska 54
1000 Ljubljana
Slovenia

Phone: +386 1 472 11 00
Fax: +386 1 472 11 99
E-mail: snsa@gov.si
Web site: www.ursjv.gov.si

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EXECUTIVE SUMMARY

After the Fukushima Dai-ichi accident the operator of Krško NPP has performed a quick review trying to identify possible short-term improvements. The result was the procurement of additional portable equipment, e.g. diesel generators, pumps and compressors as well as several smaller modifications on the plant itself and in the emergency operating procedures and severe accident guidelines, which will enable the use of this new equipment for the mitigation of consequences in case of a severe accident. These modifications were in large extent implemented by the end of June 2011 and also considered in the stress test report. Based on the Krško NPP application, the Slovenian Nuclear Safety Administration (SNSA) licensed this series of minor modifications in the plant which add alternate possibilities for electrical power supply and cooling of reactor and spent fuel pool in case of beyond design basis accidents.

In response to the Fukushima accident the SNSA issued a decision to the Krško NPP to perform a Special Safety Review. The programme of this review is completely in line with the ENSREG specifications for European Stress Tests. The Krško NPP has fulfilled its commitment in time and sent the full scope Stress Test progress report to the SNSA by 15th August 2011. Likewise, the Final report was prepared and sent to the SNSA by the end of October 2011. The SNSA made a detailed review of the progress report and presented to the plant the findings and comments, which were taken into account in the Final report. Later the SNSA reviewed and approved the Final report and based on it by 31st December 2011 prepared the National Stress Test Report.

For the preparation of the stress test report the plant performed some additional analyses (e.g. evaluations of seismic and flooding margins, additional station blackout analyses to support the newest severe accident strategies, drain cycle of the batteries supplying power to the instrumentation of safety systems, water heat-up and evaporation rate in the spent fuel pool, evaluation of spent fuel pool criticality). These were all reviewed and approved by the technical support organizations with additional calculations (with different codes) done where appropriate. All these analyses and technical support organization reports were received by the SNSA.

Besides the stress test report, which covers the extreme natural conditions, the Krško NPP has also prepared an analysis regarding the impacts of aircraft crash on the plant. It shows that the plant is well designed and built, and with additional severe accident management equipment available onsite, prepared even on such events. This report due to its sensitive nature is confidential and will remain as such.

In addition to obligate the plant to perform the stress tests, the SNSA also issued a decision requiring from the plant to reassess the severe accident management strategy, existing design measures and procedures and implement necessary safety improvements for prevention of severe accidents and mitigation of its consequences. This evaluation was finished in January 2012.

The seismic events at which late radioactivity releases into the environment would be likely to occur are considered to be of peak ground acceleration in the range of 0.8 g or higher. This estimate is dictated by the fact that core damage is considered likely at this range of seismic events. Seismic events at which early radioactivity releases into the environment would be likely to occur are considered to be of PGA significantly exceeding 1 g. At these seismic levels the collapse of shield building cannot be excluded. Under such circumstances the integrity of containment isolation paths cannot be assumed.

Plant building entrances and openings are constructed above the elevation of the 10,000-year flood. So the plant is safe for the occurrence of the Design Basis Flood. Plant is also protected against the probable maximum flood with the appropriate design of the Sava river interface structures (dikes), the evacuation of greater quantities of water via the Sava river right bank inundation (the NPP is located at the left Sava river bank) and with the protection dikes for protection of plant site against probable maximum flood with additional waving due to winds.

Regarding the extreme weather phenomena no additional new analyses were done after the Fukushima accident. These phenomena are very well analyzed and described in the plant's USAR as well as in the plant Probabilistic Safety Analysis. Local meteorology is well known and taken into account in the design of the plant. Most of the design bases are based on at least 1,000 year period value or higher for extreme weather conditions. With conditions exceeding design bases values the plant would shutdown but remain safe.

The Krško NPP has sufficient power generation sources (permanent, mobile or portable), as well as equipment available onsite for delivering enough quantities of cooling water to steam generators, reactor, containment and spent fuel pool. The alternative equipment is supported by sufficient fuel supplies providing at least 3 days of independency from offsite (not taking into account the fuel stored for emergency diesel generators). All alternative equipment is part of the plant and its configuration control so equipment is periodically tested and maintained on the regular basis. In place are also procedures that provide instructions on when and how the equipment is to be used. It is also incorporated into the normal training process so the use of the equipment is regularly trained.

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. The accident management organization is well structured and adequate to cope with different levels of severity in case of accident including severe core damage. Emergency operating procedures together with plant specific severe accident management guidelines are in place with all necessary equipment safely stored onsite. Severe accident management scenarios (together with the use of the appropriate equipment) are regularly trained and exercised with the plant's full-scope simulator, which also enables regular validation of the plant's severe accident management guidelines.

In the preparation for the Integrated Regulatory Review Service (IRRS) mission the Slovenian Nuclear Safety Administration reviewed the national responsibilities and arrangements between the SNSA, several advisory bodies and technical support organizations and there were not any issues requiring immediate action based on lessons learned from the Fukushima Dai-ichi accident. The SNSA is committed to address any relevant implications and lessons learned from the Fukushima Dai-ichi accident for further improvement of its regulatory process. The IRRS mission conclude that the activities of SNSA are clearly separated from those organisations and bodies that may have responsibilities in the operation of nuclear facilities or any role in the promotion of nuclear energy. SNSA is able to exercise its authority and to take timely decisions in order to prevent any radiation or nuclear risk or in handling a nuclear emergency situation.

In January 2012 the SNSA issued the 3rd decision regarding the Fukushima event, with which it required from the Krško NPP to review the basis and assumptions for the Radiological Emergency Response Plan. The main intention was to reassess the basic emergency planning assumptions like emergency zone radii and planned protective measures for the public, which were influenced by the US practice at the time of the construction of the Krško NPP four decades ago.

Slovenia is a party to numerous multilateral conventions as well as Slovenia concluded a significant number of bilateral agreements. In the multilateral arena the domestic legislation gives the authority to the Slovenian Nuclear Safety Administration for the implementation of agreements and conventions. Slovenia is a member of the IAEA since 1992. The Slovenian Nuclear Safety Administration is regularly represented in the meetings of WENRA and is active in its working groups. Director of the SNSA Mr. Andrej Stritar was elected as the first Chairman of the ENSREG. Since May 2011 Slovenia is a member of the OECD/NEA and its Data Bank. In the Slovenian Nuclear Safety Administration the IAEA standards are widely used in the preparation of secondary legislation, as well as to formulating the law requirements. Slovenia hosted different international missions, which reviewed operational safety of nuclear power plant, safety of research reactor, radiation safety, transport safety and physical protection. The last international mission was IRRS mission in September 2011. In general the IRRS team found legal system adequate and praised Slovenian response to Fukushima accident.

CONTENTS

INTRODUCTION

This Slovenian Report for the 2nd Extraordinary Meeting of the Parties of the Convention on Nuclear Safety describes the activities undertaken by the Krško NPP and the Slovenian Nuclear Safety Administration as a response to the Fukushima Dai-ichi NPP accident. These activities cover various areas, but they were all aimed at a single goal: To increase nuclear safety. This report is structured around the main activity in the European Union initiated in the aftermath of this event, i.e. the performance of the **stress tests**. A short overview of the stress tests and the methodology is given in the following paragraphs.

In May 2011 the European Commission and ENSREG (European Nuclear Safety Regulator Group) during preparation of actions in the nuclear energy field after Fukushima (Stress Tests) agreed to work on two parallel tracks:

– A Safety Track to assess how nuclear installations can withstand the consequences of various unexpected external events. These can range from natural disasters to human error or technical failure and other accidental impacts, such as transport accidents.

– A Security Track to analyse security threats and the prevention of, and response to, incidents due to malevolent or terrorist acts.

In this report only Safety Track is considered. The *stress tests* are defined as a targeted reassessment of the safety margins of nuclear power plants in the light of the events which occurred at Fukushima: extreme events challenging the plant safety functions and leading to a severe accident. This reassessment consisted in a verification of the preventive measures and in an evaluation of the response of a nuclear power plant when facing a set of extreme situations, chosen following a defence-in-depth logic (initiating events, consequential loss of safety functions, severe accident management issues). The preferred approach is deterministic, i.e. sequential loss of defence is assumed in the defined extreme situations. For a given plant, the reassessment has shown the effectiveness of the preventive measures and on the response of the plant, noting any potential weak point and cliff-edge effect, for each of the considered extreme situations. The licensees have the prime responsibility for safety. Hence, it was up to the licensees to perform the reassessments, and to the regulatory bodies to independently review them.

This report has seven main chapters. In the first chapter is the explanatory text for the next three chapters, which are entitled "External Events", "Design Issues" and "Severe Accident Management and Recovery", and which are all based on the stress tests. The first chapter also provides the two main issues required by the instructions for writing this report, i.e. the activities performed by the operator and the activities performed by the regulator. The last three chapters cover national regulatory infrastructure including technical support organizations, off-site emergency preparedness (the on site emergency preparedness for a single Slovenian NPP is given in fourth chapter) and the international cooperation, which is focused around activities, which are known in the IAEA terminology as a global nuclear safety regime.

The last phase of stress test process comprised peer reviews of the national reports, which the regulators submitted to the European Commission by the 31st December 2011. In the period January – April 2012 national and European Commission experts conducted peer reviews, which took place in Luxembourg, where all reports were examined based on questions sent by the experts beforehand. After that the country visits took place in the every country, where open issues were clarified, the country specific reports were finalized. In Slovenia country peer review was organized from 12th to 15th March 2012 and the Slovenian country peer review report is enclosed as a separate document to this report.

Slovenia, as the smallest nuclear country in the world, has only one nuclear power plant Krško with only one unit. It is a 2-loop Westinghouse designed nuclear power plant (NPP) with the net electrical output of up to 696 MWe. Its commercial operation started in 1983.

During almost 30 years of operation various safety reviews and improvements, upgrades and modernizations were performed in the Krško NPP. The most important examples from the past are plant modernization with power up-rate and steam generator replacement, Probabilistic Safety Analysis (PSA) related studies and upgrades (e.g. fire protection upgrade), adoption of Severe Accident Management Guidelines (SAMG), seismic reviews, analyses and upgrades (e.g. a decision for installation of the 3rd emergency diesel generator), wet reactor cavity, plant specific full scope simulator, etc. The Krško NPP is currently working on the 2nd Periodic Safety Review (PSR), which is to be finalized in 2013. Likewise, the process of the plant design life time extension is on-going and it is expected to be concluded this year.

In addition to obligate the plant to perform the stress tests, the SNSA also issued a 2nd decision in September 2011 requiring from the plant to reassess the Severe Accident Management strategy, existing design measures and procedures and to implement necessary safety improvements for prevention of severe accidents and mitigation of its consequences.

This evaluation was finished by the operator in January 2012. Its action plan was reviewed and approved by the SNSA in February 2012. As it can be seen from the Table 2 in chapter 1.1.2, the proposed improvements have tendency to increase reliability of AC power, core cooling, spent fuel pool cooling and containment integrity, as well as to reduce possible fission products and to provide emergency control provisions in case of beyond design basis accidents. The time period to implement the envisioned improvements is from 2012 to 2016.

In January 2012 the SNSA issued the 3rd decision regarding the Fukushima event, with which it required from the Krško NPP to review the basis and assumptions for the Radiological Emergency Response Plan. The main intention was to reassess the basic emergency planning assumptions like emergency zone radii and planned protective measures for the public, which were influenced by the US practice at the time of the construction of the Krško NPP four decades ago. Very similar request was few weeks later issued by the US NRC to the operators in United States.

1. OVERVIEW OF ACTIVITIES AFTER FUKUSHIMA DAI-ICHI ACCIDENT

This chapter is the introduction to the next three chapters, which describe the important topics analyzed within the stress tests performed in the EU countries after the Fukushima Dai-ichi accident and finalized at country level in March 2012. The chapters to follow are in line with the instructions for writing the report and follow defence-in-depth logic, i.e. initiating events are described in chapter on "External Events", loss of safety functions is analyzed in "Design Issues" and severe accident management issues in "Severe Accident Management and Recovery". However, in this chapter the activities of the operator, the Krško NPP, and the regulator are discussed in the subchapters below.

The chapter on "External Events" comprised earthquakes, floods and extreme weather conditions. It covers design basis earthquake, which was analyzed before the plant construction and later re-evaluated many times within Probabilistic Seismic Hazard Analysis and within the seismic PSA (SPSA). For stress test purposes the safety margins were evaluated for different peak ground accelerations (PGA) to identify range of earthquakes leading to severe fuel damage, to loss of containment integrity and to have consequences for the spent fuel pool (SFP). Also the effects of earthquakes on the potential flooding caused by the seismic failure of the hydro power plan dams upstream of the Krško NPP were reviewed including the damming, i.e. forming a lake behind a natural dam caused by a landslide or rock fall due to the earthquake. The important external events are flooding due to increased flow of river Sava and extreme weather conditions. Flooding issue was analyzed by determining the maximum probable flow and appropriate dikes were constructed to protect the Krško NPP from flooding. The stress tests evaluated safety margins against flooding, which are summarized in 2.2. Extreme weather conditions, also extensively analyzed in this chapter, include severe winds, low river flow, extreme temperatures of river and air, snow, rain and different combinations of aforementioned weather conditions.

The third chapter was entitled "Design Issues". This chapter deals with the loss of power and loss of cooling, thus it describes the electrical power supply system and the water supply for cooling. The scenarios of interest are loss of off-site power, followed by the station blackout (SBO), then loss of ultimate heat sink (UHS) is analyzed and also the combination of both SBO and UHS is presented. The safety margins were again determined and the analysis did not reveal any cliff-edge effects. Under cliff-edge effects it is meant that at certain value of the parameter under investigation (e.g. temperature, flow, acceleration, etc.) the effects (e.g. fuel damage, radioactive release) increase abruptly.

The fourth chapter is about "Severe Accident Management and Recovery". Here a combination of descriptions is given on on-site emergency preparedness and on actions led from the control room and the support facilities, which are aimed to cope with the beyond design basis accidents. Also information about training and exercises is included. The equipment availability for severe accident management is presented along with safety systems and design characteristics utilized for preventing severe accident scenarios. In the light of Fukushima events a decrease of the spent fuel pool (SFP) water level is discussed. The hardware and other modifications were proposed to minimize probability of a severe accident, as well as upgrades of monitoring systems to receive more reliable information about plant status during severe accidents conditions. These improvements are mainly in the

Table 1 (implemented modifications) and in the Table 2 (planned modifications) in the subchapter 1.1 "Activities Performed by the Operator". To improve personnel response and utilization of procedures training program, which is based on systematic approach to training process, is conducted.

1.1 ACTIVITIES PERFORMED BY THE OPERATOR

1.1.1 Description of Actions

Immediately after the Fukushima accident the operator of the Krško NPP initiated the event analysis with a purpose to identify possible short term actions that would raise the plant's preparedness for severe accidents. The Krško NPP partly implemented this analysis in advance, when implementing the B.5.b requirements (post 9/11 requirements developed by the US NRC), which were required by the SNSA with the decision issued in 2008, so the post-Fukushima actions were based also on that analysis. The result was the procurement of additional portable equipment, e.g. diesel engines, pumps and compressors as well as several smaller modifications were performed in the plant itself, as well as amendments to the emergency operating procedures and severe management accident guidelines were made, which will enable the use of this new equipment for the mitigation of consequences in case of a severe accident. These modifications were in large extent implemented by the end of June 2011 and were also considered in the stress test report submitted to the European Commission.

All the modifications and procurement of new equipment that resulted out of the above mentioned activities are shortly described in the Table 1 below. In addition two other modifications that resulted from previous periodic safety review (i.e. the 1st PSR) and have great impact on the plant's robustness in regard to extreme external events (third emergency diesel generator and upgrade of flood protection dikes) are added in the table.

In September 2011 the SNSA issued a decision requiring from the plant to reassess the severe accident management strategy, existing design measures and procedures and implement necessary safety improvements for prevention of severe accidents and mitigation of its consequences. This evaluation was finished in January 2012. The action plan was reviewed and approved by the SNSA and shall be completely implemented by the end of the year 2016. See also Table 2 in subchapter 1.1.2 Schedules and Milestones.

In addition to listed modifications the operator will reassess possibilities for alternative spent fuel strategy. The appropriate further steps will be taken based on that reassessment.

The Krško NPP is also reviewing the basis and assumptions for emergency preparedness and response taking into account the Fukushima Dai-ichi accident. The outcome will be included in the appropriate on-site (operator's) and off-site (local and national) emergency plans. This review was required by the decision by the SNSA in January 2012.

Table 1: Implemented “Post-Fukushima” improvements in the Krško NPP

Modification or equipment procurement	Description	Concerns topic
Portable generator 5 kW (2 pcs)	To be used as a backup source for powering essential instrumentation	All, particularly SBO
Portable generator 2.6 kW (2 pcs)	To be used as a backup source for powering essential instrumentation	All, particularly SBO
Mobile diesel generator 150 kW (3 pcs)	To be used as a backup source for powering essential instrumentation or equipment (e.g. motor operated valves)	All, particularly SBO
Mobile diesel generator 600 kW	To be used as a backup source for powering essential equipment (e.g. battery chargers, pumps)	All, particularly SBO
Mobile diesel generator 1000 kW	To be used as a backup source for powering essential equipment (e.g. battery chargers, pumps)	All, particularly SBO
Mobile diesel generator 2000 kW	To be used as a backup source for powering essential equipment (e.g. battery chargers, pumps)	All, particularly SBO
Portable oil free compressor (2 pcs)	To be used as a backup source of instrument air (e.g. for operating air valves)	All
Portable fire protection pump 60 m^3/h / 1.5 MPa (2 pcs)	To be used as a backup source of feedwater for steam generators	All
Portable fire protection high pressure pump 30 m^3/h / 3.2 MPa (2 pcs)	To be used as a backup source of feedwater for steam generators	All
Submersible pump 2.8 kW / 7 m^3/h / 0.2 MPa (4 pcs)	To provide low pressure sources of water to high pressure pumps	All
Trailer with portable pump 60 m^3/h / 1.1 MPa / suction from 35 m	To be used as a backup source of water for filling steam generators, spent fuel pool, containment, etc.	All
HFS HydroSub 450 floating unit 720 m^3/h / 1.1 MPa / suction from 45 m 2,900 m 8�017 hoses Trailer with hose layer container	Assure additional high capacity »portable water ring« around the plant (as a backup fire protection system, but with enough capacity that it could be used as alternative water source for heat removal from the reactor, containment and spent fuel pool)	All
Portable transformer 230/118 V / 3 kVA (2 pcs)	To transform voltage for essential instrumentation	All

Modification or equipment procurement	**Description**	**Concerns topic**
Tractor "Arion 630C" 103 kW, with additional equipment, e.g, air compressor, fork lift, equipment for ploughing (removing debris, etc.)	To be used as means of transportation of different equipment (e.g. portable diesel generators, pumps, barrels of oil, etc.), for transferring the fuel between tanks/barrels and equipment, for ploughing/clearing way at the site, etc.	All, particularly Severe Accident Management (SAM)
Installation of quick connection points for feeding the SGs	Installation of quick connection points (for standard fire hose connections) to enable feeding of steam generators from several water sources	All
Installation of quick connection points for flooding the containment	Installation of quick connection points (for standard fire hose connections) to enable flooding the containment from several water sources	All
Installation of quick connection points for alternative sources of instrument air	Installation of quick connection points for quick connection of portable oil-free compressors to instrument air system or directly to end users	All
Installation of quick points for manual steam generators relief valve control	Installation of quick connection points for quick connection of alternative sources of instrument air as well as manually controlled air regulator to enable manual control of steam generator power operated relief valves	All
Installation of quick connection points for filling the spent fuel pool	Installation of quick connection points (for standard fire hose connections) to enable filling the spent fuel pool from several water sources	All
Installation of alternative measurement system for spent fuel pool temperature and level	Installation of alternative measurement system with alternative independent power supply (portable DGs or batteries)	All
Installation of the 3rd emergency diesel generator (result of the 1st PSR)	3rd emergency diesel generator in a separat building with extended seismic and flood protection design basis. The bus of the 3rd EDG will be able to connect to either of two existing safety related buses	All
Upgrade of flood protection dikes (result of the 1st PSR)	With the upgrade of flood protection dikes (SSE qualified) the plant can withstand the 1.5 times the value of probable maximum flood, $PMF_{Krško}$ = 7081 m^3/s For information, the protection against 10,000-year flood (4790 m^3/s) is assured by the elevation of plant plateau	Initiating events (flooding)

1.1.2 Schedules and Milestones

The implemented actions, described in Table 1 (subchapter 1.1.1) above, represent just the first phase. The schedule of actions to be implemented by the 2016 is in the Table 2. Among modifications and equipment procurement the installation of filtered venting system and the installation of passive auto-catalytic recombiners in the containment are the first two modifications to be implemented by the end of 2013.

Table 2: Planned "Post-Fukushima" improvements

Modification or equipment procurement	Description	Concerns topic	Scheduled finish
Additional high pressure pump for reactor coolant system injection	Additional high pressure pump for reactor coolant system injection in the separated bunkered (2×SSE and PMF flood protected) building with dedicated source of borated water for 8 hours with provisions to refill by mobile equipment from different water sources	All	2015
Additional high pressure pump for feeding steam generators	Additional high pressure pump for feeding steam generators in the separated bunkered (2×SSE and PMF flood protected) building with dedicated source of water for 8 hours with provisions to refill by mobile equipment from different water sources	All	2015
Alternative air cooled ultimate heat sink	Alternative air cooled ultimate heat sink (2×SSE and PMF flood protected)	Loss of ultimate heat sink	2016
Additional low pressure pump for spraying and flooding the containment	Additional low pressure pump for spraying (pressure control) and flooding the containment (preventing core concrete interaction in case of failed reactor pressure vessel). This pump will also be located in the separated bunkered (2×SSE and PMF flood protected) building with dedicated source of water for 8 hours with provisions to refill by mobile equipment from different water sources	All	2015
Filtered venting system	Filtered venting system capable of depressurizing containment and filtering over 99.9% of volatile fission products and particulates (not including noble gasses)	All	2013

Modification or equipment procurement	Description	Concerns topic	Scheduled finish
Installation of passive auto-catalytic recombiners in the containment	Replacement of electric recombiners with passive auto-catalytic recombiners in the containment	SAM	2013
Installation of emergency control room	Installation of emergency control room in the separate bunkered (2×SSE and PMF flood protected) building with all instrumentation and control needed for safe shutdown of the plant and maintaining the safe shutdown conditions.	SAM	2016
Installation of separate dedicated beyond design basis accident insturmentation and control	Installation of separate dedicated instrumentation and control capable of monitoring and controlling both from the existing as well as the new emergency control room also in case of most severe accidents	SAM	2016
Long term habitability of emergency control room and support staff facility	The above mentioned emergency control room will enable long term habitability of control room staff even during severe accidents (air filtering, radiation protection). For the same conditions also new facility for supporting staff will be designed and build	SAM	2016
Mobile heat exchanger	Mobile heat exchanger (cooled by mobile equipment or air) with provisions to quick connect to spent fuel pool or reactor	All	2016
Installation of permanent sprays around the spent fuel pool	Installation of permanent sprays (2×SSE qualified) around the spent fuel pool with provisions for quick connection of mobile equipment and different sources of water. Spraying of spent fuel pool is needed in case of loss of their integrity.	All, but particularly in case of loss of spent fuel pool integrity due to strong earthquake	2015
Acquiring the technology and material for quick filling of possible ruptures in spent fuel pool	Acquiring the technology and material for quick filling of possible ruptures in spent fuel pool	Initiating events (earthquake)	2016
Additional flood protection of nuclear island and newly installed equipment	Nuclear island and above described newly installed equipment will be additionally flood protected against the failure of flood protection dikes or high river flows exceeding flood protection dikes by 0.4 m	Initiating events (flooding)	2016

Modification or equipment procurement	Description	Concerns topic	Scheduled finish
Protection against extreme air temperatures	The above described newly installed equipment will be protected against extreme outside 10,000-year temperatures (-33 to +45 °C)	Initiating events (extreme weather)	2016

1.1.3 Results

Preliminary PSA calculations show that improvements listed in the above tables will have great impact on the plant's Core Damage Frequency (CDF) as well as the release frequencies. Precisely the CDF reduction due to the improvements will be in the order of 50%, while release frequency from the containment will be reduced for about 70%. The impact on the scenarios leading to large early release (LERF) will be smaller and the reduction of total LERF will be about 5%.

1.2 ACTIVITIES PERFORMED BY THE REGULATOR

After the adoption of the stress tests specifications in May 2011 by ENSREG and European Commission the SNSA immediately issued the decision for the Krško NPP to perform the special safety review of which program was completely in line with the adopted stress tests specifications. Like envisaged in the specifications, the plant gave progress report to the SNSA by August 15, while final report was prepared by the end of October 2011. Several additional analyses were performed by the operator and were reviewed and supported by technical support organizations with additional calculations where necessary. All the above was reviewed by the SNSA, open issues were cleared and the national report was prepared, very much based on the operator's report.

In addition to obligate the plant to perform the stress tests, the SNSA also issued a 2nd decision in September 2011 requiring from the plant to reassess the Severe Accident Management strategy, existing design measures and procedures and to implement necessary safety improvements for prevention of severe accidents and mitigation of its consequences.

This evaluation was finished by the operator in January 2012. Its action plan was reviewed and approved by the SNSA in February 2012. As it can be seen from the Table 2 in chapter 1.1.2, the proposed improvements have tendency to increase reliability of AC power, core cooling, spent fuel pool cooling and containment integrity, as well as to reduce possible fission products and to provide emergency control provisions in case of beyond design basis accidents. The time period to implement the envisioned improvements is from 2012 to 2016.

In January 2012 the SNSA issued the 3rd decision regarding the Fukushima event, with which it required from the Krško NPP to review the basis and assumptions for the Radiological Emergency Response Plan. The main intention was to reassess the basic emergency planning elements like emergency zone radiuses and planned protective measures for the public, which were influenced by the US practices from the time of the construction of the Krško NPP in four decades ago. Very similar request was few weeks later issued by US NRC to the operators in United States. This work is still going on and is expected to be finished by the end of 2012.

The SNSA’s conclusion, which is based on analyses considered in the stress test report, is that the Krško NPP is well designed against all credible and even some very unlikely external threats at the site. Moreover, with additional planned and ongoing modifications, it will further increase its robustness and thus nuclear and radiation safety of its employees and public in general.

2. EXTERNAL EVENTS

2.1 EARTHQUAKE

The design basis earthquake, which was analyzed before the plant construction and later re-evaluated many times within Probabilistic Seismic Hazard Analysis and within the seismic PSA (SPSA) is described in subchapter 2.1.1. For the stress test purposes the evaluation of earthquakes was performed, which provides assessment how these earthquakes can contribute to severe fuel damage. In the same way the loss of containment and spent fuel pool cooling was analyzed. In addition seismically induced flooding by the dam failure(s) and damming upstream of the Krško NPP was also considered in subchapter 2.1.2.4.

2.1.1 Design basis earthquake-DBE

The Krško NPP is located in a seismically active region. At the time when the Krško NPP was designed and constructed the US NRC nuclear regulation and standards were used. Based on the Regulatory Guide (RG) 1.60 "Design Response Spectra for Seismic Design of Nuclear Power Plants, revision 1", issued in 1973, the project acceleration of 0.3 g was used for Safe Shutdown Earthquake (SSE) and 0.15 g for Operating Basis Earthquake (OBE). The vertical component used is equal to the horizontal component in all frequency regions. The seismic system analysis of Seismic Structures Category I is performed with dynamic analysis using time history method on a modal model. The model consisted of mass points and stiffness elements composed in seismic models. The soil structure interaction is considered in this model since the Peak Ground Acceleration (PGA) is valid for free field only and not for the foundation level. The resulted time history analyses are used to develop response spectra with different dumping values.

Regional geologic investigations for site selection began in the sixties. The location was later explored in detail with geomechanical, hydrogeological, geophysical and seismological investigations. These were performed in several stages. In the seventies the investigations included refractional measurements, soil survey, microseismical ground noise measurements, laboratory tests, gamma-gamma measurements, geoelectrical sounding of terrain, and density determination, all with the purpose to be used for geotechnical model of terrain evaluation and for the definition of the parameters of the earthquake effect.

The first stage of the investigation covered the period 1971, 1972 and 1973 and included boring of the site up to 12 – 13 m in depth, refractional measurements of P and S wave velocities, geoelectrical trial boring of the terrain, gravimetric soil survey, and micro-seismic ground noise measurement. These investigations were carried out in the wider surroundings of the NPP and used for evaluation of its suitability and in the selection of the final location.

The second stage of the investigation was carried out in the second half of 1973 according to the IEEEs program. It covered seismic refraction measurements of P and S wave velocities and microseismic ground noise measurements at the Krško NPP site. These investigations were used for the geotechnical model of terrain evaluation as well as for the definition of the parameters of the earthquake effect.

The third stage was carried out in the middle of 1974. This stage included 30 geomechanical borings of 30 – 90 m in depth, laboratory material tests, and distribution of seismic P and S wave velocities according to cross-hole methodology up to 45 m in depth.

The fourth stage was carried out at the end of 1974 as a supplementary investigation. It covered 24 new geomechanical borings with additional laboratory tests, measurements of seismic P and S wave velocities according to cross-hole methodology up to 100 m in depth, refractional seismic measurements of P and S wave velocities, and gamma-gamma measurements of material density and geoelectrical sounding of the terrain. In addition to the above mentioned investigation, six trial pits to 4 m in depth were excavated for relative density determination.

The most recent stage of investigations began in 1991 when the question of seismic hazard at the Krško NPP site was posed in the Slovenian parliament. To answer this question, an "ad hoc" commission was formed in 1992. The commission's conclusion was that additional investigations in the vicinity of the Krško NPP were needed.

The Probabilistic Seismic Hazard Analysis (PSHA) made in 1994 increased PGA to 0.42 g while the 2004 revised PSHA study has further increased the seismic hazard to PGA of 0.56 g. The Seismic Probabilistic Safety Analyses (SPSA) finished in 1996 and 2004 were used to evaluate the plant's vulnerabilities to seismic events. The NPP Krško Seismic Category I structures (e.g. containment vessel, shield building, interior concrete structures, control building, auxiliary building, intermediate building, essential service water intake and pump-house structure, diesel generator building and component cooling building) are dynamically analyzed for SSE (US NRC RG 1.29) earthquake conditions using a modal analysis time history method.

As part of the seismic PSA investigation, Individual Plant Examination for External Events (IPEEE) analysis for the seismic part was performed in the nineties (besides an Individual Plant Evaluation, IPE). That included a detailed walk-down of the plant to identify seismic vulnerabilities. The conclusion was that the plant had been well designed and constructed for a seismic event and no serious seismic issues were observed in containment. Also in the nineties a walk-down outside containment was performed, covering all components which were identified in the IPE as essential components for accident mitigation and safe shutdown of the plant. For all identified observations the Krško NPP performed appropriate corrective actions or design changes and resolved all deviations. In May and December 2003, a walk-down was conducted to assess new equipment added or replaced since 1996.

The SPSA studies have shown that the greatest risk comes from earthquakes two to three times the SSE. It was determined that earthquakes below about two times the SSE would result in very low probability of failure of individual equipment. That is why it was decided that the structural response analysis, including Soil Structure Interaction (SSI), should be conducted at this level. The probabilistic SSI analysis was carried out at an earthquake level equal to twice the design earthquake level (0.6 g). In a probabilistic response analysis, the characteristics of the free-field ground motion is defined by the shape of the median uniform hazard spectrum corresponding to return period of interest (10,000 years). To perform the probabilistic analysis, an ensemble of 30 earthquakes (3 components each), was developed to capture the randomness of the seismic input. Since the uniform hazard spectrum was developed for the site, it is assumed to characterize the motion at the surface of the soil profile. To account for the effects of deconvolution in the SSI analysis of the main complex (e.g. reactor containment base), the motion at the embedment depth of this structure was determined by deconvolution were compatible with the properties used for developing the foundation impedances for each simulation. 30 deterministic SSI analyses were performed using free-field ground motions. For each analysis, key structure and soil parameters were randomly sampled from assumed lognormal distribution.

When comparing the resulted median centered in-structure response spectra against the original Final Safety Analysis Report (FSAR) results it can be observed, that the main difference between the FSAR and median centered spectra is the frequency at which the spectral peaks occur, since they occur at lower frequencies when compared to the FSAR results, while peak amplitudes are roughly the same. This finding suggests that the reactor building in Krško NPP can accommodate a ground motion of much higher intensity than it was designed for.

The first periodic safety review represented a significant review process, where seismic issues were identified, evaluated, and new actions were set up for plant seismic improvements. One of the most important resulting improvements is the installation of a third seismically classified emergency diesel generator, which is to be completed in 2012.

2.1.2 Safety Margin Evaluation

2.1.2.1 Range of earthquake leading to severe fuel consequences

Seismic margins with weak points and cliff edge effects are evaluated first by means of identifying success paths from the safety analysis report and safety studies, then by mapping each critical safety function in every success path to the specific system, structure and component (SSC) with determining their seismic margins. The seismic margin for each critical safety function must be also determined. Critical functions for which the corresponding seismic margin was exceeded are assumed unavailable. In this manner all relevant cliff edges are identified. A success path becomes disabled when first of the required critical functions becomes unavailable. With increasing seismic severity a number of success paths decreases. The point (seismic level) at which the last success path is disabled can be considered as the "seismic margin" for the whole plant. Evaluation of seismic core damage margin, seismic margin for containment and spent fuel pool integrity and cliff edge effects are presented.

Regarding the identification of success paths it can also be said that if none of the Loss-of-Cooling-Accident (LOCA) categories is induced, but there is a total loss of Essential Service Water system (ESW), the required critical functions would be reactor scram, secondary heat sink (by means of Auxiliary Feedwater Turbine Driven Pump (AFW TDP)) and Reactor Coolant System (RCS) inventory/Reactor Coolant Pump (RCP) seal integrity. If none of the above categories is induced, but there is a Steam Line Break (SLB), the required critical functions would be reactor scram, High Pressure Safety Injection (HPSI)/recirculation and secondary heat sink (by means of motor driven AFW pumps). If none of the above is induced, but there is a seismically induced failure to insert control rods (i.e. seismically induced Anticipated Transient without Scram (ATWS)), the required critical functions would be secondary heat sink (AFW), pressurizer relief and long term shutdown. If none of the above initiators is induced, the Loss-of-offsite-power (LOOP) should be considered. In such a case, the required critical functions would be onsite power (by means of Emergency Diesel Generators (EDG)), secondary heat sink (AFW) and RCP seal injection (by means of Chemical and Volume Control System (CVCS) charging pumps or Positive Displacement Pump (PDP)). Finally, it is pointed out that all the above success paths additionally require success of the following two functions: Integrity of large structures (e.g. buildings); and Integrity of large primary system components (e.g. reactor vessel, steam generators (SG), etc.). Failure of any of these two would lead to beyond design basis conditions for which no success path can be considered.

According to the above described approach, the plant level seismic margin is assessed by evaluating the availability of success paths following a postulated seismic event, with increasing severity. The evaluation is based on consideration of controlling seismic failure modes for the relevant SSCs, including necessary support systems. Based on the plant specific seismic fragility analyses the expected plant response would be as follows from core damage standpoint:

- *Earthquakes in the range below the Operating Basis Earthquake (OBE) (PGA < 0.15 g):*
  At earthquake levels approaching OBE value, the 400 kV switchyard (High Confidence of Low Probability of Failure, HCLPF = 0.093 g) would fail with probability close to 10%. However, a failure of 110 kV is considered low probability event (HCLPF = 0.15 g, Median Capacity = 0.29 g; therefore, failure probability of 1% at most) at this seismicity level. Therefore, a complete LOOP is not considered likely. (Failure probability is considered bounded at 0.1 × 0.01 = 1E-03 per event.) Failures of any safety related SSC are considered unlikely (as the upper end of the considered interval is well below the HCLPF values for the relevant SSCs).

- *Earthquakes in the range between the OBE and Safe Shutdown Earthquake (SSE) (0.15 g < PGA < 0.30 g):*
  Toward the upper end of this seismic interval a LOOP can be expected. (Median capacity of 110 kV offsite power is around 0.30 g and, hence, failure probability would approach 50 %.). the expected sequence in the range of 0.15 g to 0.30 g can be bounded by a LOOP without additional failures of safety related SSCs. At lower part of the interval, the expected sequence is reactor trip with, at worst, 110 kV offsite power available.

- *Earthquakes in the range between the SSE and 0.45 g (0.30 g < PGA < 0.45 g):*
  The expected sequence in this range is considered to be a LOOP without additional failures of safety related SSCs. Median capacity of 110 kV offsite power is around 0.30 g. Failure probabilities of safety related SSCs are below 1%.

- *Earthquakes in the range of 0.45 g < PGA < 0.60 g:*
  None of the discussed success paths is still considered to be affected in this seismic range. The expected sequence in the range is still a LOOP with possible, although not likely, additional failure of condensate storage tanks (CST) and/or Refueling Water Storage Tank (RWST) (probability < 6%). Success path for LOOP (in the absence of any other initiator) would apply. Suction to the AFW pumps would be provided from the CST (if not failed) or from the ESW. The RCP seal injection would be provided by the CVCS pumps taking suction from the volume control tank. Power would be provided by the EDGs.

- *Earthquakes in the range of 0.60 g < PGA < 0.75 g:*
  With earthquakes in this range, structural failure of CST and/or RWST is a credible consequence. (At the upper end, failure probability is 17% for the CST.) Failure of RWST is not considered a concern, as far as induced LOCAs /SLB are considered, due to their high HCLPF values. The RWST is also alternative source for CVCS pumps to perform RCP seal injection. This function (suction to CVCS pumps) can, however, be achieved by alternative means described in the Emergency Operating Procedure (EOP) ECA-0.0 Appendices. Failure of EDGs (due to electrical periphery) is also not considered likely in this interval (Median Capacity is 1.45 g. Failure

probability < 6%). Assuming the failure of CST, alternate suction would be established for the AFW pumps by realignment to ESW.

- *Earthquakes in the range of 0.75 g < PGA < 1.0 g:*
  At this interval, seismic failure of EDGs is considered likely (at 0.85 g, probability < 10%). This means that alternative means will be needed to ensure secondary heat sink and the RCP seals. Additionally, at the upper part of the interval, failure of control rods insertion cannot be excluded. (At the upper end, probability of failure for the fuel assembly geometry is less than 10%.) The loss of ESW pump house is still relatively unlikely. (Failure probability at the upper end is < 5 %.) Loss of ESW, however, would not have the additional impact, as EDGs would, likely, be also lost at this level. Therefore, critical functions would be those associated with seismic ATWS sequence integrity.

- *Earthquakes in the range of PGA > 1.0 g:*
  At seismic levels of, approximately, 1 g, a number of SSCs are expected to fail, including CST, RWST, EDGs and ESW. Certain degradation of fuel assemblies' geometry in the core is also expected, which can prevent the control rods to drop in the core, causing the reactor scram failure. At seismic levels exceeding 1 g, failures of other safety systems, as well as larger structures are expected to fail.

Based on the seismic margin evaluation, taking into account the alternative means described in the EOPs and Severe Accident Management Guidelines (SAMG), it is considered that seismic levels at which core damage would be likely are at PGA range of 0.8 g or higher. At these seismic levels, the critical induced sequence is seismic ATWS with Station Black-Out (SBO) conditions. Seismic ATWS could, at seismic events of such a severity, be caused by a failure of control rods insertion due to degradation of fuel assemblies' geometry. Although the long term shutdown (sub-criticality) can still be achieved (boric acid transfer system), the critical function is ensuring the secondary heat sink in time. Following the seismic failure of CST, together with conditions of induced SBO and/or loss of ESW, the secondary heat sink would have to be provided by alternative means specified in the EOP ECA-0.0 Appendices. It is questionable, however, whether this can be implemented in time, considering the ATWS condition. Also, the liquefaction cannot be excluded which would potentially fail buried structures and/or equipment. Seismic capacities of structures related to primary or secondary pipe breaks (i.e. LOCAs or SLBs) are fairly above these levels.

At the end, it needs to be pointed out that seismic events with PGA higher than 0.8 g were estimated to be very rare events at the Krško NPP site. Based on the revised PSHA and SPSA, the return period for such an event is considered to be larger than 50,000 years. The seismic events at which early radioactivity releases into the environment would be likely to occur are considered to be of PGA significantly exceeding 1 g. At these seismic levels, the collapse of shield building cannot be excluded. Under such circumstances, the integrity of containment isolation paths cannot be credited.

2.1.2.2 Loss of containment integrity

For evaluating seismic margin for the containment integrity, an analogous approach was taken which was applied to reactor core damage margin. For early releases, one success path is defined: success of containment isolation. In terms of seismic response this refers to the function and integrity of isolation valves and containment penetrations. Additional requirement for success, which is assumed implicitly, is success of containment structure to remain intact following an earthquake. This success path (i.e. containment isolation) applies to all initiator categories considered for seismically induced core damage (i.e. LOCAs, Loss of ESW, and others) with addition of beyond design basis reactor vessel failure. Also, additional success path, which is assumed implicitly, is prevention of core damage. Accordingly, an early radioactivity release (following a seismic event) is prevented if core damage is avoided or if containment structure integrity remains intact and containment isolation is performed successfully. For late releases, two success paths are defined. The first one is successful operation of Reactor Containment Fan Coolers (RCFC). The second one is successful operation of Containment Spray (CI) Recirculation in combination with Residual Heat Removal system (RHR) recirculation through heat exchangers.

As with core damage margin, the margin for the containment integrity function is assessed by evaluating the availability of all success paths following a postulated seismic event, with increasing severity. Based on the plant specific seismic fragility analyses, the expected containment response would be as follows:

- *Earthquakes in the range of PGA < 0.45 g:*
  The expected sequence in this seismic range can be bounded by a LOOP without additional failures of safety related SSCs. Success path for early releases is not challenged as seismic capacities for containment structure and containment isolation are both above 1 g, with high confidence. Also, neither of the two success paths for late releases is challenged in this range.

- *Earthquakes in the range of 0.45 < PGA < 0.60 g:*
  Containment structure or isolation function is not challenged in this range (i.e. early release is considered a low probability event). The expected sequence in the range is a LOOP with possible, although not likely, additional failure of CST and / or RWST (failure probability at the upper end < 5%).

- *Earthquakes in the range of 0.60 g < PGA < 0.75 g:*
  Containment structure or isolation function is not challenged in this range (i.e. early release is considered a low probability event). Seismic failure of RWST, however, cannot be excluded. In the case of RWST failure, the transfer of cold water inventory to the containment sump can be performed by some of alternative means described in SAG-6. The EDG (electrical periphery) is a controlling seismic failure mode for both success paths for late releases. Based on its seismic capacity, the failure of EDG is not considered likely in this range (failure probability at the upper end < 6%).

- *Earthquakes in the range of 0.75 g < PGA < 1.0 g:*
  Containment structure or isolation function is still not challenged. At this interval, however, the seismic failure of EDGs is considered likely (at 0.85 g, probability < 10%). Assuming the failure of EDGs, both CI and low pressure emergency core cooling system would be unavailable (and so would the success paths regarding late releases). Failure of ESW Pump House structure would not have an additional impact (assuming the EDGs failure). Thus, at lower end of the seismic range, the expected sequence is seismic SBO with unavailable CST and RWST. Toward the upper end of the range, there is increased possibility of seismic ATWS with SBO conditions.

- *Earthquakes in the range of PGA > 1.0 g:*
  At seismic levels of, approximately, 1 g, a number of SSCs is expected to fail, including CST, RWST, EDGs and ESW. Certain degradation of fuel assemblies' geometry in the core is also expected, which can prevent the control rods to drop in the core, causing the reactor scram failure. Core damage is considered unavoidable.

The conclusion is that the seismic events at which late radioactivity releases into the environment would be likely to occur are considered to be of PGA in the range of 0.8 g or higher. This estimate is dictated by the fact that core damage is considered likely at this range of seismic events. It would occur under conditions where neither EDGs nor ESW/CCW would be available. Seismic events at which early radioactivity releases into the environment would be likely to occur are considered to be of PGA significantly exceeding 1 g. At these seismic levels, the collapse of shield building cannot be excluded. Under such circumstances, the integrity of containment isolation paths cannot be credited.

2.1.2.3 Spent Fuel Pool

- *Earthquakes in the range below the OBE (PGA < 0.15 g):*
  Complete LOOP is considered of low probability even at the upper end. Power supply would be transferred to 110 kV. The SFP cooling system is expected to continue normal operation. Success path is not considered to be challenged.

- *Earthquakes in the range between the OBE and SSE (0.15 g < PGA < 0.30 g):*
  In the upper part of the range, normal operation of SFP cooling system cannot be credited. However, the alternative strategies described in the EOP Appendix 33 would be implemented to provide the makeup water for the maintenance of SFP water inventory. The SFP integrity is not challenged.

- *Earthquakes in the range between the SSE (0.30 g) and around 0.9 g:*
  Normal SFP cooling system operation cannot be credited. According to the EOP ECA-0.0 Appendix 33, the time to uncover fuel assemblies is 76 hours. It is expected that during this time the alternative strategies for SFP water inventory makeup, described in the ECA-0.0 App. 33 and in SAMGs would be implemented, which would enable long term cooling of the SFP.

- *Earthquakes in the range of PGA > 0.9 g*
  In this range gross structural failures of SFP can not be excluded. Fuel damage can be expected.

Therefore, for earthquake levels up to, approximately, 0.9 g, it is considered that the SFP integrity would not be challenged. Alternative strategies from ECA-0.0 and SAMGs are credited to provide the makeup water for the SFP inventory and, thus, prevent the fuel assemblies from overheating in the case of the small leakages or loss of inventory during evaporation. Accordingly, for earthquakes in the range of PGA exceeding 0.9 g, gross structural failures of SFP cannot be excluded. For earthquakes of such intensity it can be expected that fuel uncover in the SFP would occur.

2.1.2.4 Earthquake and potential consequent flooding exceeding Design Basis Flood

For the consideration of seismically induced floods, hydro power plant (HPP) dams at the Sava river are relevant. Additionally, potential formation of a natural dam (and its subsequent failure) following a catastrophic earthquake needs to be considered. A number of studies have been performed related to the failures of dams upstream of NPP, with different scenarios considered. When developing the scenarios, the requirements from the standard ANSI/ANS-2.8-1992 were considered.

HPPs at Sava river, which are relevant for NPP due to potential flooding safety implications, are divided into two groups: there is a group of operating HPPs at the upper Sava river and, at the lower Sava river, there is group of hydro plants which are in different stages of operation, construction and planning. Plant specific analyses included postulated damage of all three HPP dams at upper river Sava, with assumed initial presence of 25-yr flow along the whole river. The resulting flood wave would, at the region of lower river Sava, have a peak in the range from 100-yr flow and 1000-yr flow. It would cause, downstream of HPP Boštanj, considerable flooding, mostly in the area of Dolenji Boštanj and Sevnica, but also in the area downstream of NPP. However, from the description of flooded condition, it can be seen the considered flood would not have a safety impact on the NPP.

For the group of HPP dams at lower Sava, a number of scenarios were developed and analyzed. None of the scenarios was found which would threaten the safety of the NPP. (Actually, at the current status, only the HPPs Vrhovo and Boštanj are relevant for the NPP.) With assumed 25-yr flow as initial conditions, all the scenarios were found to be less severe than the scenario with failure of all three dams at upper Sava.
Additionally, the scenario with failure of all gates at the HPP Vrhovo with simultaneous opening of all gates at the HPP Boštanj was analyzed. The results of calculation showed the flood wave with peak at 2257 m^3/s and duration of 8 h. As the peak of the flood wave is below the 100-yr flow, it can be concluded that assumed scenario would not threaten NPP or its surroundings.

It is necessary to consider what can be said about the maximum (peak) discharge that happens immediately downstream of the damming. The maximum discharge decreases with the distance from the damming into the downstream direction due to the flattening of the dam-break flood wave. A scenario for the forming of a large lake (behind the natural dam) is only possible during a very strong earthquake that would trigger a large debris flow, a landslide or a rock fall. This would, according to the plant specific study, require an earthquake that is of the 9th or 10th grade on the European Macroseismic Scale (EMS) scale, or an earthquake with the magnitude well above 6. In terms of PGA, this would mean an earthquake in the range of 0.6 g or higher. The study evaluated potential consequences of a large debris flow, a landslide or a rock fall resulting from such an earthquake. Regarding the first, it was estimated that the critical events that would be a consequence of a debris flow pose no threat to the Krško NPP, especially due to its location in a safe distance from a potential debris-flow source area. As for the induced landslides, the examination of the regional geological setting showed that critical events as a consequence of a landslide would not threaten the Krško NPP. Looking at a critical event which could be triggered by a rock fall, it was determined that in the area before the Sava river enters the Krško-Brežice Basin, small rock falls from steep slopes are possible, but they cannot dam the Sava river.

2.2 FLOODING

This subchapter consists of three parts. In the "Current Licensing Basis" the terms as Design basis flood (DBF) and Probable maximum flood (PMF) are defined, as well as the impact of Flood wave caused by dam failures located upstream and heavy rain. The "Revision of hydrological and hydraulical analyses" was performed mainly in the last decade and the results of analyses are presented in 2.2.2 and the evaluation of safety margins against flooding is in 2.2.3.

2.2.1 Current Licensing Basis

2.2.1.1 Design basis flood (DBF) – 10,000-year flood

Design basis flood (DBF) is the 10,000-year flood and was determined as flow of 4790 m³/s and corresponds to the 155.35 meters above Adriatic Sea level. The time series of maximum annual Sava river flows in Krško, originating from the period 1926 – 2000, represent a statistical flood population sample that should be described by a theoretical distribution functions. Six theoretical distribution functions have been applied to the data of Sava river flow in Krško for evaluation of flood occurrence probability. By considering the statistical criteria and the trend of data of floods with return periods of 5 years and more, Gamma distribution was the most qualitative one with the result of 10,000-year flow of the Sava river at Krško as 4431 m³/s. The Log Normal distribution would give the 10,000-year flow of about 4700 m³/s. The national value for 10,000-year flood was calculated by the Institute for Water of the Republic of Slovenia using Log Pearson III distribution and the result is the flow of 4790 m³/s. Krško NPP conservatively chose the flow of 4790 m³/s as the value of 10,000-year design flood.

2.2.1.2 Probable maximum flood (PMF)

The probable maximum flood (PMF) represents the hypothetical flood that is considered to be the most severe reasonably possible, based on application of probable maximum precipitation and other hydrologic factors favorable for maximum flood runoff such as sequential storms and snowmelt. To determine PMF a range of precipitation and snowmelt scenarios were considered according to the methodology of World Meteorological Organization (WMO) and ANSI/ANS-2.8-1992 standard. The probable maximum precipitation (PMP) and runoff were determined from climatic and hydrological data. A new model of the Sava river was applied and calibrated on actual Sava river flow data. The model was validated using the data on flood events from 1990, 1998 and 2007. Riverbed profiles and ground elevation data were used for development of hydraulic models that were validated using data from flood events from 1990 and 1998. The PMF flow was determined as 7081 m³/s and it corresponds to the 156.41 meters above Adriatic Sea level water level at the dike including the effect of the waves due to wind activity.

2.2.1.3 Flood wave caused by dam failures

For the upstream hydro power plants the analysis supposes that the breaking of dams is instantaneous and complete caused by earthquake, and that this happens at the moment when the upstream storages are full, while the Sava flow corresponds to the occurrence of 25-year flood. There are three hydro power plants on the upper Sava river and four hydro power plants on the lower Sava river upstream of the Krško NPP. The region of upper Sava and the region of lower Sava are different seismic regions and it is not considered that a single seismic event could have a damaging impact on both groups. The failures of dams upstream of NPP evaluated different scenarios according to the standard ANSI/ANS-2.8-1992. Plant specific analyses included postulated damage of all three HPP dams at upper Sava river, with assumed initial presence of 25-yr flow along the whole river. The resulting flood wave would have a peak of 3700 m³/s. The flood waves due to different combinations of lower Sava river dams failures are all below 3000 m³/s. The flood due to dam failures results in a lower flow and level than the DBF.

This subject including damming is considered also in the subchapter 2.1.2.4, which deals with eartquakes.

2.2.1.4 Local heavy rainstorm

Flash floods due to local heavy rainstorms are determined by comparison of the runoff of the water from the site with the maximum hourly intensity of rainfall in the local area. The extreme value distribution was fitted to maximum hourly rainfalls near Krško NPP from 1970 to 1986. The runoff coefficient takes into account the type of soil. The height of the standing water left after the first hour that would not evaporate, transpire or seep into the soil was determined as 29.25 mm. As average rainfall intensity over periods longer than one hour is lower, the height of standing water will decrease after the first hour.

2.2.1.5 Adequacy of protection against external flooding

Plant building entrances and openings are constructed above the elevation of the 10,000-year flood. So the plant is safe for the occurrence of the DBF. Plant is also protected against the PMF with the appropriate design of the Sava river interface structures, the evacuation of greater quantities of water via the Sava river right bank inundation (the NPP is located at the left Sava river bank) and with the protection dikes for protection of plant site against PMF with additional waving due to winds. Dikes around the NPP plain are at 157.10 meters above Adriatic Sea level, while the PMF flood level including additional waving is 156.41 meters. To take into account nature phenomena changes with the time, the adequacy must be reevaluated every decade (periodic safety review interval), which is the regular practice in Krško NPP. Flood wave caused by hydropower plants dam failures is not a threat to the Krško NPP since maximum flood wave would reach only the flow of 3700 m^3/s what is much less than the design flood wave. Heavy local rainstorm does not jeopardize the safety of the plant as NPP Krško site is located on higher ground elevation than surrounding area, which provides the capabilities for natural water drainage, by gravity.

2.2.2 Revision of hydrological and hydraulical analyses

During the history of Krško NPP operation there were four significant floods in the area in the years 1990, 1998, 2007 and 2010. The latest one took place after the recent hydrological analyses were finished and has therefore not been taken into account yet. Several new hydro power plants on the river Sava are in the various stages of construction, design and planning. These new facts led to performance of a number of studies and analyses related to external flooding hazard for the Krško NPP following the plant’s first periodic review in 2003:

- The DBF was revised in 2005 using new Sava river flow data and new riverbed profiles data for hydraulic models.
- The PMF was revised in 2010 using new climatic and hydrological data, new Sava river model, new PMF methodology according to the ANSI/ANS-2.8-1992 standard and new riverbed profiles data for hydraulic models.
- The dam failure flood wave was revised in 2008 considering new hydro power plant dams on the river Sava, the methodology according to the ANSI/ANS-2.8-1992 standard and new hydraulic models.
- The flood due to local heavy rainstorms was first included in the Updated Safety Analysis Report (USAR) in 2009.

- The new hydraulic models to determine the flood protection adequacy were developed and validated in 2010. The upgrade of flood protection by dikes was performed in 2011 and 2012.

Upgraded dikes upstream of the plant are capable of protecting the plant against the flood flows beyond the PMF flood of 7081 m³/s. Figure 1 below shows the conditions at the beyond design flood flow of 10,000 m³/s with estimated frequency of one in 1 million years.

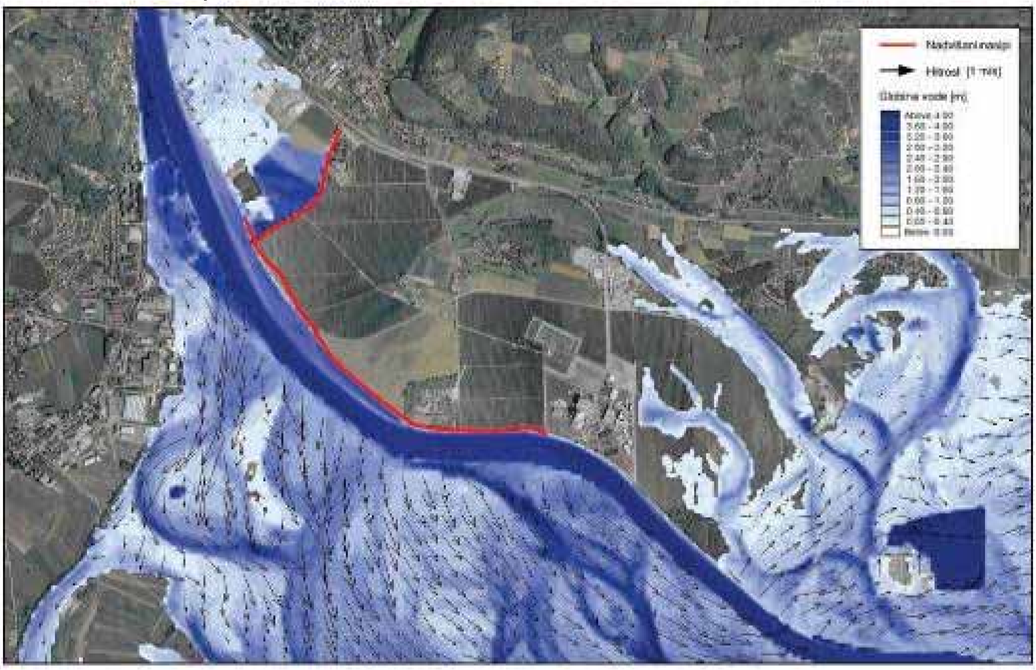

Figure 1: Flood protection of the Krško NPP for beyond basis flood (10,000 m^3/s)

2.2.3 Evaluation of Safety Margins Against Flooding

According to the ENSREG Stress test requirements the evaluation of weak points and cliff edge effects was performed and was presented in the Slovenian national report.

The extreme flood would be one that would exceed the PMF. The conclusion from the PMF analysis shows from the flood wave shape that the flooding event would be relatively slow in progression with over 20 hours needed for the development of the maximum flow. The duration of the high flows is 24 hours or less, while the discharge time of high water levels in the flooded area is considerably longer. This time is sufficient to allow normal plant shutdown and implementation of alternative methods for ensuring critical safety functions of the plant.

2.2.3.1 Methodology for evaluation of external flooding margins

The evaluation of external flooding margins at NPP was performed by identification of “success paths” for a range of flooding events. A “success path” is defined as a minimum set of functions required for avoiding reactor core damage state following a flooding event. Each success path identified is specified in terms of required critical safety functions. The availability of all success paths was evaluated following a postulated flooding event with increasing severity, starting with the lowest flooding event and gradually increasing the severity in terms of a maximum river flow. The maximum river flow at which the last success path is disabled can be considered an "external flooding margin" for the whole plant.

Based on the hydraulic analyses it can be concluded that if NPP plain is to be flooded, it would not happen from the river side, i.e. by water overflowing the dike. The incoming water would split and the NPP plain would form an island, which would be protected from the river side by the dike. The difference in elevations between the dike and the NPP plain buildings openings is 1.60 m. Flooding of NPP plain would come from behind.

Flooding of the NPP site would start at about 11,000 m^3/s and could lead to core damage. The return period for such flood is more than 1 million years. This flow causing cliff edge effect is about 1.6 times higher than the PMF flow. The same margin analysis was performed for the containment integrity and the cliff edge effect was determined at the same flood of 11,000 m^3/s.

2.3 EXTREME WEATHER

Regarding the extreme weather phenomena no additional new analyses were done after the Fukushima accident. These phenomena are very well analyzed and described in the plant's USAR as well as in the plant PSA. Local meteorology is well known and taken into account in the design of the plant. The following extreme weather phenomena were taken into account:

- Severe winds and tornadoes
- Drought and low river flow
- Extreme river temperatures
- High and low air temperatures
- Snow and ice
- Rain
- Storm

Plus the following combinations of events

- Severe winds combined with snow, extreme temperatures and accident conditions
- High air temperature with high water temperature and low Sava river flow
- Low air temperature with low water temperature and low Sava river flow
- Low Sava river flow with pollution of Sava river

2.3.1 Single Events

2.3.1.1 Severe winds and tornadoes

As a design basis for Category I structures a wind speed of 140 km/h multiplied with a factor of 1.7 was used (combined with other loads, e.g., snow, extreme temperatures, accident conditions). The highest measured instant wind speed recorded in the vicinity of the Krško NPP is 102 km/h (an estimated 10,000 year wind speed is 134 km/h), while no hurricanes or tornadoes were ever reported in the region.

Likewise a state-of-the-art PSA analysis was performed in 2007 for both Level 1 and Level 2. Wind hazard frequency curves were developed using site specific data fitted into reverse Weilbull distribution (Type III). Plant specific fragility analysis was developed, which considers wind force fragility, as well as potential wind generated missile impact. Wind hazard frequency curves were then combined with plant fragility analysis in the plant specific PSA model. CDF caused by high winds is estimated at 2E-6 /yr.

For the estimation of hazard presented by tornadoes the approach described in NUREG/CR-4461 "Tornado Climatology of the Contiguous United States" was used. The tornado characteristics of the western region of US were considered applicable for the Krško NPP site. Taking into account plant specific fragility analysis the CDF contribution of tornadoes is conservatively estimated to be on the order of 2.5E-6 /yr, thus total CDF due to extreme winds and tornadoes is estimated at 4.5E-6 /yr.

2.3.1.2 Drought and low river flow

Main provision for drought and low river flow represents a pool of river water (>450,000 m^3) that is formed before the plant's dam (which is SSE qualified). This pool (in concordance with RG 1.27 "Ultimate Heat Sink for Nuclear Plants") provides a minimum of 30-day cooling water supply to safety-related equipment (even in the case of large Loss-Of-Cooling-Accident, LOCA) without exceeding design basis temperature even with zero river flow.

On the other hand low river flow can be a challenge for the normal operation of the plant, since the Sava river water (combined with cooling towers) is used for cooling the condensers. When the river flow drops below 40 m^3/s power reduction is necessary and in the worst case the plant must be shutdown. A 1,000-year low river flow is estimated to be 31.4 m^3/s, while mean annual minimum flow is 64.8 m^3/s.

2.3.1.3 Extreme river temperatures

The Technical Specification limit for the SW intake water temperature is 26.7 °C. With higher temperature, the plant must shutdown.

During the cold weather season when the river water temperature may be near freezing, warm water is diverted from the SW to the inlet of the intake structure for de-icing purposes. With such configuration the water can be prevented from freezing until -28.9 °C (-20 °F) of outside temperature. In worst case reactor shutdown would be necessary.

2.3.1.4 High and low air temperatures

Design bases external temperatures are bounded by design basis minimum temperature for SW intake structure, -28.9 °C, and design basis maximum temperature for diesel generator building cooling systems, 40 °C.

10,000-year low and high temperatures are estimated at -33 °C and 44 °C respectively.

Several ways of heating are available for equipment and buildings exposed to low temperatures, like water heating for tanks and heat tracing for pipes. For the case of a SBO several mobile gas powered heaters are available that can be used to heat equipment and even whole buildings if necessary.

2.3.1.5 Snow and ice

Plant structures are designed to withstand snow and ice load of at least 150 kg/m^2, which corresponds to 1.5 meter of fresh snowfall. In case of excess snowfall, snow would be removed as regular inspections are provided in seasons with low temperatures.

2.3.1.6 Rain

Plant is located on higher ground elevation as surrounding area, so any eventual excess of water will runoff the plant area to the lower surrounding area. Extreme rainfall is also described in detail in the "Flooding" section.

2.3.1.7 Storm

Lightning protection is assured with network of lightning rods and grounding connections which form grounding island for the plant. All electrical and metal structures are properly connected on grounding island. Possible consequences of lightning (e.g., loss of offsite power, induced reactor trip, local fire due to lightning, loss of automated fire protection system, various possible overvoltage protection actuation causing induced loss of power or safety equipment actuation) are already addressed and taken into account, and can be mitigated with safety and additional mobile equipment already analyzed in appropriate chapters.

2.3.2 Combinations

2.3.2.1 High air temperature with high water temperature and low Sava river flow

In case of extreme high temperatures, maximum SW intake water temperature of 26.7 °C can be reached. In that case the reactor would be shutdown. The safety margin still exists as cooling is still sufficient till 29.2 °C with higher SW flow (considering the event of large LOCA).

2.3.2.2 Low air temperature with low water temperature and low Sava river flow

Low air temperature and low water temperature are regularly occurring. With additional low Sava river flow, return of heated water into SW intake structure prevents freezing and loss of function of this part of SW at extremely low external temperatures of up to -28.9 °C. If operational cooling, the circulating water system would be inoperable or only partially operable due to ice formation, shutdown of plant would be necessary.

2.3.2.3 Low Sava river flow with pollution of Sava river

Dam maintains minimum water level of 150.00 m (absolute height above sea level) which presumes 3 meters higher level than necessary for the safe pumps operation. At the same time such a solution prevents the intake of accidentally spilled flammable liquid in the upstream flow of river Sava. The impact of possible upstream corrosion substances into river Sava is small. In case of spilled 30 m^3 of corrosion substances maximum concentration in water at the SW intake is 36 ppm for the period of 6 hours.

2.3.3 Conclusions for Extreme Weather Conditions

For extreme weather conditions most of the design bases are based on at least 1,000 year period value or higher. With conditions exceeding design bases values the plant would shutdown but remain safe.

All described events in this chapter can cause the SBO and Loss of UHS events (see chapter 3). Thus same as for SBO and Loss of UHS the onsite available alternative equipment can be used (e.g. mobile diesel generators, gas heaters, etc.) if needed.

Still a plan for future improvements has been made by the operator (described in detail in subchapter 1.1.2). According to the plan all new safety improvements will be designed for extended design basis outside temperatures, namely -33 °C and +45 °C for extremely low and high outside temperatures respectively (these represent extreme outside temperatures with a 10,000 year return period). Likewise the flood protection of equipment will be additionally improved by upgraded dikes and additional flood protection of newly installed equipment as well as the nuclear island buildings.

3. DESIGN ISSUES

3.1 DESCRIPTION OF ELECTRICAL AND WATER SUPPLY SYSTEMS

3.1 Description of the electrical power supply solutions

The Krško NPP is a one unit plant with one generator rated at 730 MWe. Generator is connected to two 400 kV switchyard busses via generator load breaker, two step-up transformers 21 kV/400 kV and substation breaker. The 400 kV switchyard is connected to the 400 kV grid with three high voltage transmission lines. The switchyard 400 kV bus is also extended to transformer distribution station (TDS) Krško and connected to 110 kV switchyard via 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 (see Figure 2).

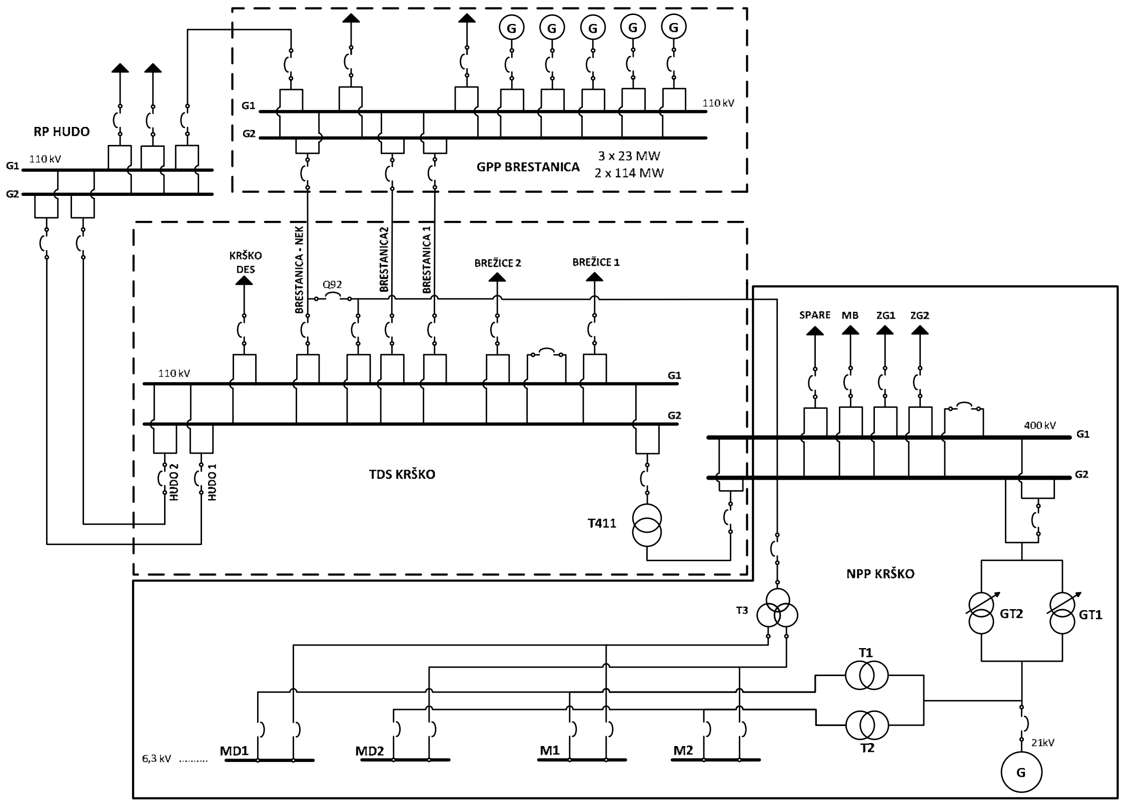

Figure 2: The Krško NPP electrical connections to the grid

All four busses can also be energized from the station auxiliary transformer powered through direct underground cable from transformer distribution station Krško or directly from gas-steam power plant (GPP) Brestanica, which is located 7 km from the Krško NPP. GPP Brestanica is equipped with three gas-powered units of 23 MW capable of cold 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, supplying power to the Krško NPP only.

3.1.2 Description of the water supply solutions for cooling

The emergency service water system (ESW) provides cooling water to the component cooling system (CCW) and boron thermal regeneration system (BTR) to transfer the plant heat loads from these systems to the ultimate heat sink, the Sava river. The system also serves as a backup safety related source of water for feeding the steam generators 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 plant normal or accident condition and during a 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 river Sava is used to maintain the water level at a nominal elevation. Dam threshold is designed to continue with its function in case of SSE and to form a pool of capacity 450,000 m^3 from which ESW is provided by water together with the bank river protection with the same design basis. The loss of upstream Sava river flow will not disturb ESW cooling function. The highest water temperature rise in this pool, in the case of loss of river flow, is expected to be expected 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 is 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 LOSS OF ELECTRICAL SUPPLY

3.2.1 Loss of Offsite Power (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 diesel generators. These emergency diesel generators are cooled by air therefore in case of the additional loss of heat sinks, they can still operate. With the available fuel at the site, at least 7 days of emergency diesel generator operation is possible. The time of operation of emergency diesel generators can be prolonged by stopping one emergency diesel generator. For shutdown of the plant and for maintaining the safe shutdown conditions only one train of safety equipment is needed, one emergency bus and one diesel generator. If one emergency diesel generator is inoperable, then fuel can be transferred from one underground reservoir to another by portable air driven pump. In addition, fuel for emergency diesel generator(s) can be obtained from any other diesel fuel storage on the site.

A third emergency diesel generator will also be installed in 2012 in order to reduce the CDF for events initiated by the LOOP. The third emergency diesel generator 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.

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 have sufficient capacity per design to cope with the SBO for 4 hours, to ensure safe shutdown of the unit.

There are also several portable and mobile diesel generators. Establishing alternative power supply to the DC distribution panel and to the instrumentation distribution panels from portable diesel generators assures the long time 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 would be supplied from offsite). For long-term operation, external support would be needed for diesel and gasoline supply to run the portable alternative equipment.

Spent fuel pool cooling pumps are powered from the safety-related 400 V busses. In the event of a LOOP the safety-related emergency buses can be powered either from the 110 kV switchyard TDS Krško through station auxiliary transformer or from emergency diesel generators. If diesel generators are started and blackout appears or safety injection (SI) 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.

3.2.2 Station Black-Out (SBO)

The SBO scenario considers the LOOP and loss of the ordinary back-up AC power sources. The following features are considered to cope with the SBO, in order to ensure the safety functions fulfilment:

- Establishing alternative power supply to the bus LD11 and to battery chargers from one of the two portable Diesel Generators (DGs) assures the long time 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 could provide a much longer availability of essential instrumentation.
- The batteries have capacity per design to cope with a 4-hour SBO, to provide 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 steam generators (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 turbine driven pump (TDP) and the power operated relief valves (PORV) for releasing steam from steam generators.
- In the worst case scenarios considering unavailability of the AFW TDP, if temporary steam generator injection equipment are deployed and made functional in 1 hour, enough margins exist to prevent core damage.
- Safety batteries capacity ensure 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 minimized.

To mitigate deterioration of 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 steam generators with AFW TDP which can be controlled from control room (if power from batteries is still available) or locally.
- Minimize the primary system inventory loss by isolating letdown lines.
- Restore power to any AC emergency buses by starting at least one emergency DG or by establishing offsite power supply.
- Depressurize primary system by depressurizing steam generators.
- Enhance the equipment cooling by opening certain doors.
- Initiate spent fuel pool makeup using alternative equipment (SAME).
- If needed initiate flooding of containment sump by gravity drain from the RWST.

<u>For the spent fuel pool:</u>
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 water in SFP would 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 in such case established by water boiling and evaporation in the SFP. For maintaining the constant water level in the SFP it is required to deliver water flow at least at 14.1 m^3/h.

Alternative means for establishing spent fuel pool makeup:

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

3.3 LOSS OF ULTIMATE HEAT SINK (UHS)

If the loss of UHS event occurs for states where the heat removal can be performed by the steam generators:

- The plant will be put in a "hot shutdown".
- The loss of primary system coolant due to RCP seal leakage is compensated with positive displacement pump (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 steam generators, steaming with SG PORVs, natural circulation of reactor coolant is maintained.
- Condensate storage tanks (CST) makeup from available water sources: demineralized water storage tanks, fire protection tank, condenser, circulating water tunnel, river Sava and potable water from city of Krško.

Additional features:

- In case of inoperable CSTs and operable AFW pumps, water can be delivered to the suction of AFW pumps with 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 outside organization 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 not to be limiting given the reduced residual heat. Water makeup will be done from the RWST. This is also possible in case of SBO (manual valves to open – gravitational make-up). Procedure and training exist for this case.

For the spent fuel pool:

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

3.4 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 onsite 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 steam generators. 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 ensured 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. Decay heat removal (in first phase) is independent of heat sink and component cooling media. The speed of steam driven pump can be controlled manually as well as release of the steam from steam generators to control the decay heat removal. If the steam generator relief valves cannot be operated by remote control, they may also be operated locally, using compressed air from portable diesel compressor and local pressure regulators or manually. The Main Steam Safety Valves (MSSV) can be used for depressurization of steam generators as an alternative to the SG PORVs. With stabilization of the reactor temperature at above 130 °C to have enough driving steam for 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 primary system leak is minimized and controlled by depressurization 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 from diesel or gasoline engines, with enough storage capacity for 72 hours at rated load (with the assumption that EDGs 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 the safety beyond 4 hours, the use of one of the two alternative diesel generators as alternative power supply is proposed. These generators can provide electrical power to parts of the 400 V system. This way also power for necessary lighting, the 220 V DC charger can be provided. Also the positive displacement charging pump (PDP), which doesn't need cooling and can provide charging flow from the RWST and/or boric acid tanks to the primary circuit, can be powered this way. The PDP 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 establish power from 400 V to recharge the batteries, using a method which is described in system operating procedures and is used in regular outage as temporary modification. Power to the instrumentation distribution panels 2 and 4 can be established also by energizing a motor control center with one of the three 150 kVA portable diesel generators. If power to a 118 V instrumentation system cannot be established or, in case of loss of control room, operators can establish alternative power to a shutdown panel, with two 220 V petrol driven generators and transformation to 118 V thus securing essential instrumentation.

Water sources considered for this scenario are CSTs, demineralized water storage tanks, potable water, well water and also the Sava river. External support can also be provided by enough water capacity from Krško potable water source or any other available water source.

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

Spent fuel pool heat-up is the same as in case of SBO; actions are similar or the same. Heat removal from the spent fuel pool can be achieved through its heat exchanger, through evaporation of water, or combination of both. In the case that the operation of heat exchanger cannot be achieved, the only way is through evaporation of water with boiling. In this situation boron remains in the SFP and there is no concern about criticality. Enough amount of water needs to be provided to replace the evaporated water. Several water sources can be used for SFP cooling (e.g., 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 SFP water surface) using portable diesel driven fire pumps.

3.5 SAFETY MARGINS FOR DESIGN ISSUES

3.5.1 LOOP and SBO

No cliff edge effects have been identified in case of LOOP. This accident is a design basis accident, analyzed in the Safety Analysis Report (SAR) for licensing.

Likewise no cliff edge effects have been identified in case of LOOP and loss of onsite backup power sources for a period longer than 7 days because usage 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 onsite fuel and oil resources, when external delivery is necessary.

Autonomy of alternative DGs used to supply electrical power is 72 hours, with the fuel available onsite (not taking into account the fuel in the emergency diesel tanks, which are DBE qualified).

The batteries autonomy is 4 hours by the design. With the use of mobile diesel generators provisioned to charge the batteries (and supported by available equipment and procedures), this time can be extended to 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 extend to more than 13 hours (procedures are prepared and available).

The SFP instrumentation has dedicated batteries with a minimum capacity for 30 hours of continuous measurements.

At SFP, if no water is delivered into 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 beginning of uncovery of the spent fuel elements if no water were added to the SFP.

3.5.2 Loss of UHS

No cliff edge effects have been identified in case of loss of UHS for a period more than 7 days because usage of alternative equipment assures reactor coolant inventory control and decay heat removal.

The Krško NPP does not have an alternative ultimate heat sink. The construction of a seismically qualified cooling tower is planed as an alternative UHS (see chapter 1.1.2).

3.5.3 Loss of UHS with SBO

The SBO for the NPP site with 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 usage of alternative equipment assures reactor coolant inventory control and decay heat removal. From the assessment of this scenario, the following are the results.

3.6 CONCLUSIONS FOR DESIGN ISSUES

The Krško NPP has sufficient power generation sources (permanent, mobile or portable), as well as equipment for delivering enough quantities of cooling water to steam generators, reactor, containment and spent fuel pool available onsite. The alternative equipment is supported by sufficient fuel supplies providing at least 3 days of independency from offsite (not taking into account the fuel stored for emergency diesel generators). All alternative equipment is part of the plant and its configuration control so equipment is periodically tested and maintained on the regular basis. In place are also procedures (EOPs, SAMGs, equipment manuals) that provide instructions on when and how the equipment is to be used. It is also incorporated into the normal training process so the use of the equipment is regularly trained.

Together with new analyses prepared by the operator and supported by independent reviews and calculations of the Technical Support Organizations (TSO), this provides enough confidence that the plant can withstand even most challenging events like combined event of a SBO and Loss of UHS for several days without any offsite support.

4. SEVERE ACCIDENT MANAGEMENT AND RECOVERY (ON-SITE)

4.1. ON-SITE EMERGENCY PREPAREDNESS AND RESPONSE

4.1.1 On-site Emergency Organization

The emergency preparedness and response in Slovenia in case of accidents at Krško NPP is conducted on a plant, local, regional and state level.

The accident response at plant level is covered by the Krško NPP Radiological Emergency Response Plan (RERP). It includes the Emergency Response Organization (ERO) covering the Main Control Room (MCR) and shift organization, a Technical Support Centre (TSC) and Operational Support Centre (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 case of an emergency he acts as Emergency director.

The on-site emergency response organization consists of different organizational structures which are activated depending on the emergency level and are located in the Emergency Response Facilities (ERF). Until the technical support centre is operable, the management and coordination of the emergency response is organized within the main control room shift organization. The technical support centre is organized to perform plant status evaluation, Severe Accident Management (SAM) strategy evaluation and determination and to provide operational support to plant operators. When the transition from Emergency Operating Procedure (EOP) to Severe Accident Management is in place, responsibility of decisions is transferred from main control room to technical support centre.

The Operational Support Centre (OSC) is organized to deploy the intervention teams on the site and carry out intervention measures determined in the TSC. The Emergency director directs and coordinates on-site emergency response. The Emergency director also assumes, in case of site or general emergency, the functions of Emergency Operations Facility director until this position is established.

The off-site structure of Emergency Response Organization, activated in case of a site or general emergency, consists of the Emergency operations facility and is located in Ljubljana. The Emergency Operations Facility is organized, equipped and located to carry out overall direction and co-ordination of the Krško NPP’s emergency response, support to the TSC and intervention personnel, coordination with involved authorities, evaluation of offsite radiological consequences and recommendations of urgent protective measures for the population, public information. EOF has manpower and possibilities to take over some TSC’s functions. Additional support is provided on a contractual basis by external organizations.

4.1.2 Measures to enable optimum personnel intervention

Emergency response measures are determined in the Krško NPP's Emergency Response Plan and specified in plant procedures. Competences and responsibilities are determined in the ERO which are specified for decision making, initiation, coordination, preparation, control and implementation of individual emergency response measures.

The ERO intervention teams (including operators and security guards) are man-powered for shift turnovers during the interventions and for long-term emergency response. At all times, the Krško NPP has 6 shift crews of licensed operators, sufficient number of licensed shift engineers and other personnel with operations knowledge not directly working in the main control room. Intervention personnel is educated, trained and prepared for their emergency tasks. Emergency response responsibilities are delegated in the area of personnel’s expertise.

Protection of intervention personnel during the emergency, the exposure and contamination control and dosimetry are considered as one of the most important parts of the emergency preparedness. The line of responsibility for decision making regarding the exposure control is specified. The Emergency Director is competent to approve exceeding normal operating dose limits when necessary to protect public and prevent event escalation.

During the accident, the intervention staff is located in the emergency response facilities (MCR, TSC and OSC), which are structured, equipped and organized to enable long-term habitability. Adequate protection of intervention teams is one of the check points in the procedure dealing with direction to interventions.

In accident conditions the MCR is automatically isolated and cleanup system is started to keep the area habitable. MCR systems are redundant, safety related, seismically qualified and energized from independent safety power buses. Breathing apparatus with compressed air tanks are also available. In case of evacuation of the MCR, 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.

4.1.3 Extensive destruction of infrastructure

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 severe accident management measures may depend on the availability of mobile power sources and pumps present on the site.

Mobile severe accident management equipment is stored at least 100 m away from the reactor building. New building for severe accident management equipment is designed according to extended design requirement (PGA=0.6 g) and will be ready in 2012. Many dedicated hardware connections are provided in plant systems in order to perform relevant functions (e.g. decay heat removal from steam generators and from reactor cooling system via feed and bleed, containment flooding, spent fuel pool filling up and cooling).

There are various and redundant communication means inside the plant and between the plant, EOF and other external organizations involved in the emergency response (telephone, wireless VHF, plant paging…). They are powered with different uninterruptible power supplies. For the extreme case when all communication links are broken, satellite phones are available.

The plant operating staff excluding security (there are 15 technical individuals available all the time onsite) is able to implement the plant EOPs and other required actions from the site RERP by itself without additional support for at least 24 hours. All equipment to be used during a serious event is present onsite with the following supplies:

- Emergency diesel generators: Fuel oil supply for 7 days of operation
- Additional portable emergency equipment: Fuel supply for 72 hours of operation

However, in accordance with the RERP the time to activate and to achieve the operability of the plant emergency support centres (TSC and OSC) is 1 hour and 2 hours for the EOF. The number of the OSC staff is sufficient to support the implementation of all the needed corrective maintenance. On the other hand, operating staff is trained and capable of operating all prescribed emergency equipment or by the support of the fire fighters permanently present onsite (3 persons).

In an accident situation, support to the NPP Krško 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 Radiological emergency response plan. This type of support could include additional heavy mobile equipment (i.e. diesel generators, 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 is also provided.

4.2 ACCIDENT MANAGEMENT

4.2.1 Procedures and guidelines for accident management

Accident management and corrective measures, individual emergency response actions and the activities for maintaining emergency preparedness are dealt with in detail in different types of Krško NPP procedures. The intervention staff is regularly trained on the use of procedures and informed about procedure revisions. Responsibilities in the ERO are clearly defined as regards the procedure use and emergency response actions in them.

The main sets of procedures dealing with accident and emergency response are:

- abnormal operating procedures (AOPs),
- emergency operating procedures (EOPs),
- severe accident management guidelines (SAMGs),
- fire response procedures (FRPs),
- radiation protection procedures,
- security plan procedures,
- emergency implementing procedures (EIPs).

AOPs and EOPs are used by operators in the MCR to carry out operations actions on plant components and systems in case of abnormal or emergency operational conditions of the plant corresponding to design basis accidents (DBA) and beyond design basis accidents (BDBA) not involving core damage. Operation crew in the MCR is competent to take operational actions by EOPs.

The plant status evaluation team in TSC evaluates overall operational and safety status of the plant during an accident and supports the MCR crew as regards particular operations measures.

The EOPs aim at preventing core damage. In case of a severe accident when the EOP's are no more effective in preventing core damage the transition from EOP's to SAMG's is performed. Shift supervisor in the MCR makes a decision on the transition from EOPs to SAMG's based on transition criteria. The overall objective of the SAMGs is to terminate the severe accident condition so that three primary goals associated with SAMG's are achieved:

- to return the core to a controlled stable state;
- to maintain or return the containment to a controlled stable state;
- to terminate any fission product releases from the plant.

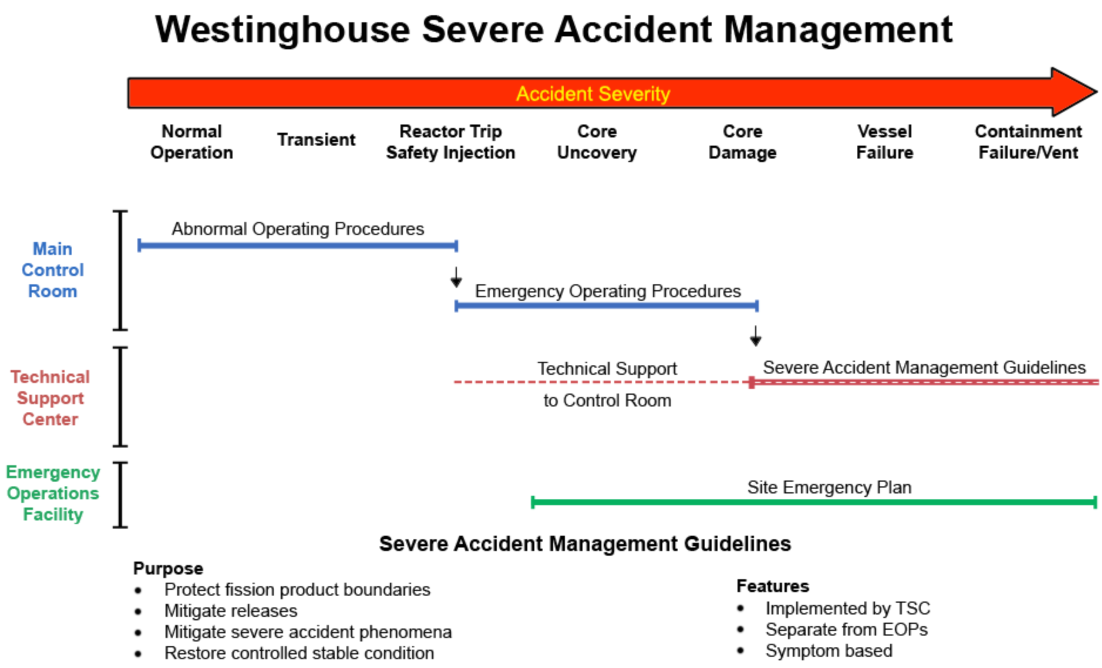

Figure 3: Graphic structure of Krško NPP procedures and guidelines in case accident scenario is leading to core damage

The plant status evaluation team in the TSC evaluates SAMG's and recommends severe accident management strategies to the emergency director. The emergency director makes final decisions on the implementation of particular severe accident management strategies. The SAMG decision making support group in the TSC (SAMG DMSG) supports the emergency director in making decisions about implementation of SAMG strategies. The following positions in the TSC are assumed within the SAMG DMSG: operations coordinator, technical support and engineering coordinator, maintenance coordinator and radiation protection coordinator. The plant status evaluation team monitors the effectiveness and positive and negative impacts of the implemented strategies and suggests appropriate corrective measures to the emergency director.

The EIPs are a set of procedures that have been written to effectively and efficiently implement a response to an emergency situation or conditions in accordance with RERP. The EIPs consist of six general categories of procedures that address classification of the accident, general response guidance, protective actions recommendations, emergency response facilities activation, emergency support activities and group support.

For the low power and shutdown states, there are some AOPs specifically addressing such operating conditions. Those AOPs that are used in case of degradation of SSC conditions, equipment malfunctions, and abnormal operation are e.g.:

- Shutdown LOCA,
- Loss of RHR cooling,
- Loss of RHR during refueling.

The SAMGs are plant specific and validated with a full scope simulator as well as with emergency exercises. They are not dependent on power states. The Krško NPP SAMGs include eight severe accident guidelines (SAGs):

- Inject into the Steam Generators (SAG-1),
- Depressurize the RCS (SAG-2),
- Inject into the RCS (SAG-3),
- Inject into Containment (SAG-4),
- Reduce Fission Product Releases (SAG-5),
- Control Containment Conditions (SAG-6),
- Reduce Containment Hydrogen (SAG-7),
- Flood Containment (SAG-8),

as well as four severe challenge guidelines (SCGs):

- Mitigate Fission Product Releases (SCG-1),
- Depressurize Containment (SCG-2),
- Control Hydrogen Flammability (SCG-3),
- Control Containment Vacuum (SCG-4).

Spent fuel pool scenarios are also covered by SAMGs.

4.2.2 Equipment availability

All included alternative equipment, which is listed in the EOPs and SAMGs, is located onsite. This includes fire fighting equipment, health physics and contamination control equipment, protective, rescue and first aid equipment, respiratory equipment, maintenance tools and instrumentation and other equipment

The Severe Accident Management Equipment (SAME) is placed on safe locations to avoid impairments due to accidental conditions (earthquake, floods, fire, etc.). Fuel is stored onsite for mobile equipment in the quantities for at least first 72 hours. The mechanical connections, power supplies, connection tools and other arrangements are prepared in advance on locations and on components of systems where SAME should be connected or applied to implement required severe accident management strategies. This enables preparation and implementation of severe accident management strategies only with shift crews under accident conditions in an effective manner after making a decision to implement the strategy.

The SAME is included in Krško NPP equipment data base as an Accident Equipment system and is regularly tested and maintained in accordance to plant maintenance procedures. Regular training and drills for shift personnel and other personnel in

ERO responsible for implementing the severe accident strategies and handling with the SAM equipment are conducted on an annual basis.

4.2.3 Design characteristics and 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.

High pressure core melt scenarios are prevented through the use of the RCS depressurization system. In extended SBO sequences in which the batteries or air supply is depleted prior to the onset of core damage, two onsite portable air compressors which could restore instrument air to PORVs, and portable generators for providing the necessary power to the valves are available.

Protecting the containment from overpressure is provided 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 hydrogen concentration consists of two redundant electric recombiners which have been designed for design bases accidents (LOCA case) and are meant to be used as a hydrogen ignition system in severe accident conditions. Planned upgrading measures envisage that electric recombiners will be replaced in 2013 by passive autocatalytic recombiners covering DBAs and BDBAs (see chapter 1.1.2).

Flooding of the reactor cavity is identified as a means to avoid molten core-concrete interaction (MCCI) if the reactor pressure vessel 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 is sourced from the RWST and two boric acid tanks. The tanks can be refilled with portable fire fighting equipment.

Radioactivity inside the containment in case of a severe accident can be assessed by high-range radiation monitors (PARM) and by a post-accident sampling system (PASS) of gases in the containment atmosphere.

4.2.4 Accident management for events in the spent fuel pool

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 to 25 μSv/h for the personnel. 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 an 18-months cycle.

High temperature (close to boiling) or a low level of SFP water would require the use of guidelines. The high diversity of cooling methods guarantee with sufficient confidence, that 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.

4.3 TRAINING AND EXERCISES

Training program is based on systematic approach to training process. It consists of classroom, on the job training, drills and exercise. Emergency response training activities are planned on annual basis within overall Krško NPP annual training plan.

Krško NPP employees and contractors' personnel become familiar with the RERP and emergency protective measures within performing of regular general employee training program.

The licensed operators are regularly trained in accordance to the licensed operator training program. It consists of four segments of training per year and includes operational management of plant abnormal and emergency conditions according to AOP's and EOP's on the plant's full-scope simulator. The scenario regularly includes accidents with the use of respiratory equipment in simulator control room and evacuation of simulator control room.

The intervention personnel assigned to the Krško NPP ERO and intervention personnel of off-site emergency response support organization receive additional emergency response training for their respective assignments.

Krško NPP regularly conducts different types of drills and exercises to verify the status of emergency preparedness of ERO and participating support organizations, allow the participants to be familiar with their duties and responsibilities, develop and maintain skills, verify the adequacy of methods described in the emergency response procedures, check the availability and operability of emergency supplies and equipment, and to identify and correct erroneous performance. Adequate personnel with responsibilities for different tasks participate in drills, for example operators, fire fighters, security guards, RP technicians participate in fire-fighting drills, all onsite personnel participate in onsite evacuation drills, etc.

The elements of drills are included in integrated emergency response exercises. An integrated emergency response exercise is carried out annually to evaluate overall emergency response readiness of the Krško NPP and participating organizations. The scenario of exercise is varied from year to year so that all major emergency response elements of the RERP are included in the exercise objectives and tested within a 5-year period. An exercise is carried out based on the scenario which in its final phase results in general emergency level, severe accident conditions and release of radioactive material to the environment, so that emergency response is needed in the plant vicinity as well. In a 5-year period the integrated national exercise is carried out with participation of local, regional and state emergency responders.

The full-scope real time Krško NPP's simulator serves as an exercise's scenario simulation tool for accidents (including severe accidents). The simulator is also used for the real MCR simulation.

4.4 CONCLUSIONS AND WAY FORWARD

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 has implemented additional safety upgrades (see chapter 1.1.2).

The plant has triggered 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 the accident. It is estimated 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 also 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 be accessed or even should be accessed for the reason of 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.

The accident management organization is well structured and adequate to cope with different levels of severity in case of accident including severe core damage. EOPs together with plant specific SAMGs are in place with all necessary equipment safely stored onsite.

Severe accident management scenarios (together with the use of SAM equipment) are regularly trained and exercised with the plant's full-scope simulator, which also enables regular validation of the plant's SAMGs.

5. NATIONAL ORGANIZATION

Based on Slovenian legislation (the Ionizing Radiation Protection and Nuclear Safety Act – »2002 Act«) the competencies in nuclear and radiation safety are mainly divided among two regulatory bodies, namely the **Slovenian Nuclear Safety Administration** (SNSA) and the Radiation Protection Administration (SRPA). Slovenian Nuclear Safety Administration (SNSA - which is, based on the new governmental structure, from beginning of this year part on the Ministry of Agriculture and Environment), performs specialized technical and developmental administrative tasks and tasks of inspection in the following areas: radiation and nuclear safety; carrying out of practices involving radiation and the use of radiation sources, except in medicine and veterinary medicine; protection of the environment against ionizing radiation; physical protection of nuclear materials and facilities; non-proliferation of nuclear materials and safeguards; radiation monitoring; and liability for nuclear damage. Slovenian Radiation Protection Administration (SRPA), an agency within the Ministry of Health, performs specialized technical, administrative and developmental tasks and tasks of inspection related to carrying out practices involving radiation and the use of radiation sources in medicine and veterinary medicine, protection of public health against the harmful effects of ionizing radiation, systematic survey of exposure at workplaces and in the living environment due to the exposure of humans to natural ionizing radiation sources, monitoring of radioactive contamination of foodstuffs and drinking water, restriction, reduction and prevention of health problems resulting from non-ionizing radiation, and auditing and approval of radiation protection experts.

Besides this general division, there are some parts of the legislative and regulatory framework which are entrusted to other institutions, i.e. the **Administration for Civil Protection and Disaster** Relief of the Ministry of Defence, which is accountable for emergency preparedness and planning, while the **Ministry of Interior** is responsible for physical protection.

The national reports, prepared under the Convention on Nuclear Safety also explains in detail the role, functions and interactions of various expert and/or advisory bodies. The SNSA obtains expert advices from the **Expert Council for Radiation and Nuclear Safety** in the field of radiation and nuclear safety, physical protection of nuclear materials and facilities, safeguards, radioactivity in the environment, radiation protection of the environment, intervention measures and mitigation of the consequences of emergencies and use of radiation sources other than those used in health and veterinary care. For last mentioned areas the SRPA established its own **Expert Council for Ionizing Radiation Protection.**

Through our national reports we have explained several times that there are numerous Expert Organizations (TSOs) which are authorised in accordance with the 2002 Act; the scope of their work, methods of authorisation and their role and importance in the administrative procedure (licensing process) have been also explained in details several times Among them the most important in the area of nuclear safety are authorized experts for radiation and nuclear safety.

In light of the TEPCO-Fukushima Dai-ichi accident SNSA has reviewed the national responsibilities as well as aforementioned arrangements between the SNSA, several advisory bodies (commissions) and TSO's and did not reveal any issue stemming from needing immediate action. SNSA is committed to address any relevant implications and lessons learned from the TEPCO-Fukushima Dai-ichi accident for further improvement of its regulatory process. The activities of SNSA are clearly separated from those organisations and bodies that may have responsibilities in the operation of nuclear facilities or any role in the promotion of nuclear energy. SNSA is able to exercise its authority and to take timely decisions in order to prevent any radiation or nuclear risk or in handling a nuclear emergency situation.

6. EMERGENCY PREPAREDNESS AND RESPONSE AND POST-ACCIDENT MANAGEMENT (OFF-SITE)

The arrangements for emergency response, both within and outside facilities, are regulated by The Act on Protection against Natural and Other Disasters (2006) and by the Ionizing Radiation Protection and Nuclear Safety Act (2002).

The National Emergency Response Plan for Nuclear and Radiological Accidents, Version 3.0, was adopted by the Government of the Republic of Slovenia in July 2010. It was prepared by the Administration for Civil Protection and Disaster Relief in close cooperation with the Slovenian Nuclear Safety Administration (SNSA). The plan gives the SNSA the responsibility to lead a special inter-ministerial committee appointed by the Government in order to plan, coordinate, monitor and evaluate the implementation of the plan. Committee members are ministry representatives (Ministry of Defence, Ministry of Agriculture and Environment, Ministry of Health, Ministry of Interior, etc.). After the Fukushima events the committee needs did initiate and speed up some activities like distribution of Iodine pills (see below) and elaborated planning on local levels.

In 2009, the SNSA started a campaign to solve the iodine prophylaxis issue. There was a regulation in force, which was not operational enough to assure effective iodine prophylaxis as a protective measure during a nuclear emergency. Along side with the plan, a new regulation based upon best international practices was drafted. The regulation was later adopted by the Government in July 2010.

The principal novelty is that the iodide pills are going to be pre-distributed in 10 km radius around the Krško NPP. This has not been implemented yet. Latest information is that this will be done by mid 2012. The regulation changed stockpiling from centralized to regional. The old stock from central storage was distributed to local hospitals, whereas for 10 km around the NPP new pills were purchased.

Direct result of the Fukushima accident concerning off-site emergency preparedness and response is the SNSA decision issued for the Krško NPP to analyze fundamental assumptions for emergency planning, on which the national plan is based, in particular the threat assessment and consequently the radius of emergency planning zones around the NPP (see chapter 1.2 "Activities Performed by the Regulator"). The deadline is end of 2012.

7. INTERNATIONAL COOPERATION

In spite the fact that Slovenia operates a relatively small nuclear power programme, it developed a broad spectrum of international co-operation. For instance, Slovenia is a party to numerous multilateral conventions as well as Slovenia concluded a significant number of bilateral agreements. In the multilateral arena the domestic legislation gives the authority to the Slovenian Nuclear Safety Administration for the implementation of a set of agreements and conventions, while some multilateral instruments were put in force by succession of the agreements ratified by the former Socialist Federal Republic of Yugoslavia.

The bilateral agreements on early notification in case of a radiological emergency were concluded with all four neighbouring countries on a state level except with Italy, where the agreement was between the regulatory authorities. There are also bilateral agreements between the regulatory authorities on exchange of information with the USA, Slovakia, France, Korea and Canada. Slovenia is a party to the most important multilateral agreements and conventions, notably the Convention on Nuclear Safety, Joint Convention (radioactive waste and spent fuel), on third party liability (Paris Convention and Brussels Protocol, Joint Protocol), Conventions on Early Notification and Assistance (emergencies), Convention on Physical Protection of Nuclear Material (also to the Amendment to the Convention), as well as Non-Proliferation Treaty and the Treaty Banning Nuclear Weapon Tests.

Slovenia is a member of the IAEA since 1992. The Slovenian Nuclear Safety Administration is regularly represented in the meetings of WENRA and is active in its working groups on Reactor Harmonisation and on Waste and Decommissioning. In 2011 Slovenia reached compliance of its legislation with the WENRA reference levels.

Director of the SNSA Mr. Andrej Stritar was elected as the first Chairman of the ENSREG (Group of high-level representatives of the nuclear safety and/or radioactive waste competent authorities of the EU) for the second term in 2009 and he had his term of office extended to mid 2012.

Since May 2011 Slovenia is a member of the OECD/NEA and its Data Bank. Slovenian delegates received observer status in all NEA technical standing committees in 2002. Slovenia renewed this status several times until its admission to the NEA.

In the Slovenian Nuclear Safety Administration the IAEA standards are widely used in the preparation of secondary legislation, as well as to formulating the law requirements. However, one should bear in mind, that the law changes are not so frequently compared to the secondary legislation (the Rules). Different IAEA standards in the areas of radiation protection, nuclear power plant and research reactor safety, quality management, transport safety, radioactive waste management, physical protection and emergency preparedness are utilized for drafting the Rules.

Considering the accident at the Fukushima nuclear power plant in Japan, the Council of the European Union declared that “the safety of all EU nuclear plants should be reviewed, on the basis of a comprehensive and transparent risk assessment (“stress tests”). During their plenary meeting on the 22nd and 23rd of March 2011, WENRA members decided to provide “an independent regulatory technical definition of a “stress test” and how it should be applied to nuclear facilities across Europe”. Slovenian experts in WENRA played important role in designing “Stress tests” specifications.

The Slovenian delegation participated at the IAEA Ministerial Conference on Nuclear Safety which took place in Vienna from 20 to 24 June 2011. The Conference was called to identify lessons learned from the nuclear accident at the Fukushima Dai-ichi NPP. The Conference adopted a Ministerial Declaration that called for improvements in global nuclear safety. The Ministers asked the Director General to prepare a draft Action Plan to address issues related to nuclear safety, emergency preparedness and response and radiation protection of people and the environment, as well as the international legal framework.

At the eleventh Biennial General Meeting of WANO (World Association of Nuclear Operators) held in Shenzhen in October 2011 the WANO acknowledged the outstanding contribution made by eight nuclear professionals to promote excellence in the safe operation of commercial nuclear power. One of the 2011 award recipients was Mr. Stane Rožman, President of the Managing Board of the Krško NPP. These honorary awards were established in 2003 to recognize individuals who have made extraordinary contributions to excellence in the operation of nuclear power plants, or the infrastructure that supports the nuclear power enterprise, or through WANO. Potential award recipients undergo a rigorous nomination and selection process before being approved.

7.1 IRRS Mission 2011

The Integrated Regulatory Review Service (IRRS) mission to Slovenia was conducted from 25 September to 4 October, mainly in Ljubljana. The team also visited several nuclear and radiation facilities, including the nuclear power plant, the research reactor and the country's emergency response centres.

The IRRS reviewed the following regulatory areas: responsibilities and functions of the government; the global nuclear safety regime; responsibilities and functions of the regulatory body; the management system of the regulatory body; the activities of the regulatory body, emergency preparedness and response; radioactive waste management; decommissioning; public and environmental exposure control; and transport. SNSA’s actions in response to the TEPCO Fukushima Dai-ichi accident were also addressed. In addition, the IRRS mission included policy discussions on long-term operation of nuclear power plant and radioactive waste management.

In general the IRRS team found legal system adequate and praised Slovenian response to Fukushima:

- Through its legal framework, the Slovenian government has appointed SNSA to regulate its nuclear safety program and SNSA has in place an effective process for carrying out this responsibility; and
- Slovenia’s response to the accident at the Fukushima Daiichi power plant has been prompt and effective. Communications with the public, development of actions for improvement within the Slovenian nuclear industry and coordination with international stakeholders was considered effective. Further lessons learned will also need to be adequately addressed.

The IRRS team emphasized among the good practices in the SNSA: the management system, which is ISO 9001 certified, and the integrated information management system.

The IRRS Review Team also identified certain issues warranting attention or in need of improvement. It believes that consideration of these would enhance the overall performance of the future regulatory system:

- Slovenia should develop a national policy and strategy for nuclear safety which would be supported by a national co-ordinated plan to ensure the appropriate national infrastructure is in place;
- Consideration should be given to possible alternative methods of financing SNSA to provide it with the flexibility to meet its regulatory responsibilities while also ensuring it operates effectively. This should include provision for research and development;
- SNSA should develop and implement a process for carrying out a systematic review of the organisational structure, competencies and resource needed for it to effectively discharge its current and future responsibilities; and
- The Government should make the necessary provision for the Low and Intermediate Level Waste Repository to ensure radioactive waste can be disposed at the appropriate time.

7.2 Other International Peer Reviews

Other international peer reviews conducted in Slovenia were mainly organized by the IAEA:

- RAMP – Review of Accident Management Programmes (2001)
- OSART – Operational SAfety Review Team - the last mission was in 2003, and the previous missions were in 1984 and 1993,
- ORPAS – Occupational Radiation Protection Appraisal Service (2001)
- TransSAS – Transport Safety Appraisal Service (1999)
- IPPAS International Physical Protection Advisory Service (2010)
- INSARR – INtegrated Safety Assessment of Research Reactors (1992)

Slovenia volunteered to host pilot RANET evaluation review mission in 2012.

7.3. Transparency and Effectiveness of Communication

There is no dedicated public relations service in the SNSA, but this does not limit the SNSA to reach the broadest audience by the following means:

- the SNSA website,
- press releases and media events,
- taking part in the TV or radio programmes.

During two months after the Fukushima Dai-ichi accident the SNSA daily reported to domestic public not only about the event itself, but also about the improvements made in the Krško NPP, measurements of iodine in Slovenia, as well as about regulatory decisions issued to the Krško NPP.

In the SNSA website is a tab, called Information Center, which contains publication "News from Nuclear Slovenia", published twice per year, which is aimed to inform about the main achievements in the area of regulations, operation of nuclear facilities, radiation safety, emergency preparedness and international cooperation. This site contains also reports about International Peer Reviews conducted in Slovenia in the past years.

All bilateral agreements with the neighbouring countries contain obligations for early notification in case of a nuclear and radiation emergency, which are commensurate with the provisions of the Convention on Early Notification in Case of a Nuclear Accident or a Radiological Emergency, but are not limited to that. All these agreements are aimed also at regular exchange of information, which is mostly done at the annual meetings of the contracting parties, but also more frequent information exchange via requests for technical or other information is encouraged.

7.4 Foreign Operational Experience

The Slovenian Nuclear Safety Administration’s (SNSA) operating experience feedback system is based upon IAEA approach (A System for the Feedback of Experience from Events in Nuclear Installations, IAEA Safety Guide No. NS-G-2.11). The information about operating experience from the nuclear facilities throughout the world is being collected and screened for applicability for domestic nuclear facilities. Besides operating experiences from nuclear facilities, the SNSA also receives and processes requests and requirements of foreign regulatory bodies about safety assessments, modifications or upgrades to be taken, as well as new insights gained through international research activities.

ACRONYMS AND ABBREVIATIONS

AC	Alternate Current
AFW	Auxiliary Feedwater System
AFW TDP	AFW Turbine Driven Pump
ANS	American Nuclear Society
AOP	Abnormal Operating Procedure
ASME	American Society of Mechanical Engineers
ATWS	Anticipated Transient Without Scram
BDBA	Beyond Design Basis Accident
BTR	Boron Thermal Regeneration System
CCW	Component Cooling Water System
CDF	Core Damage Frequency
CI	Containment Spray System
CST	Condensate Storage Tank
CVCS	Chemical and Volume Control System
CVCS PDP	Positive Displacement Pump of the CVCS system
CY	Condensate System
DBF	Design Basis Flood
DC	Direct Current
DMSG	Decision Making Support Group
EDG	Emergency Diesel Generator
EIP	Emergency Implementation Procedures
EMS	European Macroseismic Scale
ENSREG	European Nuclear Safety Regulator Group
EOF	Emergency Operations Facility
EOP	Emergency Operating Procedures
ERF	Emergency Response Facility
ERO	Emergency Response Organization
ESW	Essential Service Water System
FRP	Fire Response Procedures
FSAR	Final Safety Analysis Report
GPP	Gas Power Plant
HCLPF	High Confidence of Low Probability of Failure
HPP	Hydro Power Plant
HPSI	High Pressure Safety Injection
IAEA	International Atomic Energy Agency
IPE	Individual Plant Evaluation
IPEEE	Individual Plant Examination for External Events
IRRS	Integrated Regulatory Review Service
LERF	Large Early Release Frequency
LOCA	Loss of Coolant Accident
LOOP	Loss of Offsite Power
MCCI	Molten Core-Concrete Interaction
MCR	Main Control Room
NPP	Nuclear Power Plant
NUREG	US Nuclear Regulatory Commission Regulation
OBE	Operating Basis Earthquake
OSC	Operating Support Center
PARM	Post-Accident Radiation Monitoring System
PASS	Post-Accident Sampling System

PGA	Peak Ground Acceleration
PMF	Probable Maximum Flood
PORV	Power Operated Relief Valve
PSA	Probabilistic Safety Assessment
PSHA	Probabilistic Seismic Hazard Analysis
PSR	Periodic Safety Review
RCFC	Reactor Containment Fan Coolers
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RERP	Radiological Emergency Response Plan
RG	Regulatory Guide
RHR	Residual Heat Removal System
TDS	Transformer Distribution Station
RWST	Refueling Water Storage Tank
SAG	Severe Accident Guideline
SAM	Severe Accident Management
SAME	Severe Accident Management Equipment
SAMG	Severe Accident Management Guidelines
SBO	Station Blackout
SCG	Severe Challenge Guideline
SFP	Spent Fuel Pool
SG	Steam Generators
SI	Safety Injection
SLB	Steam Line Break
SNSA	Slovenian Nuclear Safety Administration
SPSA	Seismic Probabilistic Safety Assessment
SSC	System, Structure and Component
SSE	Safe Shutdown Earthquake
TSC	Technical Support Center
UHS	Ultimate Heat Sink
USAR	Updated Safety Analysis Report
US NRC	United States Nuclear Regulatory Commission
WMO	World Meteorological Organization