Post-
Fukushima
accident

Sweden

Peer review country report

Stress tests performed on European nuclear power plants

ENSREG
European Nuclear Safety Regulators Group
Stress Test Peer Review Board

1 GENERAL QUALITY OF NATIONAL REPORT AND NATIONAL ASSESSMENTS

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

Country review reports are one of the specific deliverables of the EU stress tests peer review process. They provide information based on the present situation with respect to the topics covered by the stress tests. They contain specific recommendations to the participating Member States for their consideration or good practices that may have been identified, and to some extend information specific to each country and installation. Draft country review reports were initiated during the topical reviews based on discussions with the country involved in the three topics and on the generic discussions within each of the three topical reviews. Issues identified for each country during the topical reviews, due to only limited time available for each country, have required follow-up discussions in more detail, both between the topical reviews and the country reviews, and during the country reviews.

The current Country Report was finalized at the end of the Country Review, after final discussion with the reviewed country and visit of NPP. It is a part of the Final Report combining the results of the Topical Reviews and Country Reviews.

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

The Swedish report complies well with the guidance provided in the ENSREG stress tests specifications. However, the structure of the report is not consistent in all parts. The content and scope of the information provided for the three reactor sites is sometimes different. Nevertheless, conclusions and recommendations provided by the plant operators and the Swedish Radiation Safety Authority (SSM) are well structured and comprehensive.

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

The information given in the report is largely consistent with the guidance provided by the ENSREG. Detailed information on design basis of specific safety systems is not provided in the Swedish national report, being considered as security sensitive. However, this information was available during the country visit.

There are several parts of the Swedish national report where measures proposed to cope with cliff edge effects are presented. However, the details of the sequences of events leading to cliff edge effects (when core damage is unavoidable) are not included. According to the SSM, the time frame for the stress tests only allowed for simplified methods to be used, which limited the details available (such as information about the sequences of events leading to cliff edge effects).

The Swedish national report and further clarifications during country visit provides the information necessary for the assessing the general arrangements in place for the management of severe accident. It provides information about the organisational arrangements for accident management and emergency planning, hardware measures to address severe accident challenges (e.g. fuel damage, depressurization, hydrogen management, corium retention, etc), as well as procedural arrangements in case of severe accidents.

During country visit it was also clarified that all Swedish requirements including requirements regarding the licensees' emergency preparedness with procedures, competence, personnel resources, etc, are subject of reviews and re-evaluations.

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

Regulatory requirements regarding resistance of the plants against extreme external hazards have been developed over the years.

The report provides satisfactory evidence that the newest reactors Oskarshamn 3 and Forsmark 3 fulfil the updated requirements regarding earthquake, and the other units will in 2013. Regarding flooding and extreme weather conditions all Swedish reactors have to be in compliance with the updated requirements in 2013.

There is no explicit statement provided in the national report related to the adequacy of the assessment of compliance with the current licensing basis for the events of loss of electrical power and loss of ultimate heat sink (UHS). However, at the topical peer review meeting Swedish representatives clearly explained that all NPPs in the country are in compliance with their currently valid licences.

The requirements regarding the accident management and emergency preparedness are in general given in the current design basis of Sweden. The regulations SSMFS 2008:1 and SSMFS 2008:17 specify measures needed for preventing and mitigating radiological accidents, requirements on the main control room (MCR) and the emergency control room (ECR), and other requirements. The information provided in the national report shows that at the moment, not all regulations established in SSMFS 2008:17 regarding emergency preparedness and accident management are already implemented by the licensees and that the implementation of some of the identified measures and modifications is ongoing in accordance with decisions taken by SSM.

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

The safety margins beyond design basis (BDB) for earthquakes, flooding and other extreme weather conditions are adequately assessed in the report.

Similarly, the peer review team concludes that the assessment of the robustness of the Swedish plants against loss of electrical power and loss of the UHS is adequate. The assessment has been performed mostly on the basis of engineering judgement and simplified (e.g. bounding) methods. Only the most limiting cases are presented in the national report. The review team found this approach as acceptable.

The peer review team also concludes that the assessment of the robustness of the Swedish NPPs regarding severe accident management (SAM) and emergency preparedness is adequate. In addition, more detailed studies are envisaged by the licensees for potential improvements to the robustness of the NPPs regarding issues associated with the survivability in case of severe accidents, applying mitigation strategies under severe accident conditions during long-term events, the capability to handle more than one affected unit, the analysis of possible destruction of infrastructure both on the site and more widely, as well as damage to safety systems and barriers, etc.

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

On 25 May 2011, SSM ordered the licensees to conduct renewed analyses of their facilities' resilience against different kinds of natural phenomena. They were also asked to analyse how the facilities would be capable of dealing with a prolonged loss of electrical power and ultimate heat sink and combinations thereof, regardless of cause.

On 31 October, the plant operators reported on their stress tests results to SSM. Based on these reports, SSM has drawn the conclusion that the stress tests carried out by the Swedish plant operators are adequate. The scope and depth of these analyses and assessments are essentially in accordance with ENSREG's definition of "a comprehensive assessment of risk and safety". The stress tests show that

Swedish NPPs are able to cope with challenges beyond their original design levels, though the stress tests also identify a number of opportunities to further strengthen the NPPs' robustness.
The report provides evidence that the regulatory body was fully engaged in the stress tests. The regulator endorses the commitments and measures identified by the licensees, and enhances further investigations.
The national report does not give detailed information on whether additional regulatory inspections were carried out after the Fukushima accident related to SAM. However, SSM confirmed during the country visit that no urgent safety issues related to SAM were identified for the Swedish plants after the Fukushima accident, and therefore no additional inspections were deemed necessary.
An implementation schedule for the identified measures has not been presented in the national report. During the country visit it was clarified that SSM has already requested the licensees to present actions plans for additional improvements in spring 2012, which will be afterwards reviewed by SSM taking into account the outcome of the stress tests.

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

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

2.1.1 DBE (Design Basis Earthquake)

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

The regulatory approach by SSM is process oriented in accordance with general regulations. The supervisory role of the regulator includes issuing general advices, which are not legally binding. The SSM regulation SSMFS 2008:17 specifies the treatment of natural hazards including earthquakes: "The nuclear reactor shall be dimensioned to withstand natural phenomena … which can lead to a nuclear accident. In case of such natural phenomena and events, dimensioning values shall be established". The regulatory approach in Sweden is based on issuing goal oriented regulations and the licensees are required to implement applicable international standards and state of the art methods in order to fulfil the requirements. SSM then assesses and eventually approves the definition or specification of the values proposed by the licensees to fulfil these goals.
SSM's regulation concerning the design and construction of nuclear power reactors, SKIFS 2004:2, entered into force in 2005. Operators need to fully comply with these regulations (now termed SSMFS 2008:17) until the year 2013.
Evaluation of the national report suggests that SSM has not defined occurrence probabilities for the levels of ground motion hazard Seismic Levels , SL-1and SL-2 (or DBE), which are uniformly applied to all Swedish NPPs.

2.1.1.2 Derivation of DBE

In Sweden, only the two newest reactors, Oskarshamn 3 and Forsmark 3, were originally designed to withstand earthquakes. The other Swedish reactors became subject to general requirements for resilience against earthquakes when the Swedish Nuclear Power Inspectorate's regulations concerning the design and construction of nuclear power reactors, SKIFS 2004:2, entered into force in 2005. However, it should be noted in this context that the licensees also previously took resilience against earthquakes into consideration, primarily in terms improvements of mechanical plant in connection with modernization work and plant modifications.

Site specific investigations have subsequently been performed for the Swedish sites by the licensees.

The mitigation systems, installed during the 1980s in accordance with a government decision, were designed according to US NRC Regulatory Guide 1.60 scaled to peak ground acceleration (PGA) values of 0.15 g horizontal and 0.1 g vertical. The national report states that the "Swedish 10^{-5} earthquake" corresponds to intensity VI of the modified Mercalli scale (MMI VI).

It is understood from the national report that SSM has not issued a legally binding definition of the occurrence probabilities for the DBE. Instead, it is described that "Licensees apply a dimensioning earthquake within a radius of twenty kilometres of a strength corresponding to a magnitude of approximately 6.0 on the Richter scale and with a probability of once per 100,000 years (10^{-5})".

The DBEs are given as follows:

– Fosmark 1&2 (Swedish 10^{-5})	PGAH=0.092g for safe shutdown (Peak Ground Acceleration, Horizontal)
	PGAH=0.15g for severe accident mitigation system (Peak Ground Acceleration, Vertical)
– Fosrmark 3 and Oskarshamn 3	
(RG 1.60 scaled)	PGAH=0.15g and PGAV=0.11g
– Oskarsham 1&2 (Swedish 10^{-5})	PGAH=0.11g and PGAV=0.09g.

For Ringhals NPP the National Report refers to two different DBEs based on RG 1.60 and DBE based on the Swedish 10^{-5} earthquake, respectively.

2.1.1.3 Main requirements applied to this specific area

According to current Swedish practice only an evaluation of level SL-2 is applied, also this is not strictly required by the national regulations. However, according to the SSM it has been estimated that an Operational Basis Earthquake (OBE) (frequency of 10^{-2} per year) should cause a maximum ground acceleration of about 0,007 g and the effect of such an earthquake was considered to be negligible.

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

The assessment of the DBE ("dimensioning earthquake") uses a probabilistic approach based on a so-called "average Fennoscandian seismicity function" accounting for site conditions of hard rock. Consideration of site effects leads to compute peak ground accelerations for the "dimensioning earthquake" by the reduction of the Peak Ground Acceleration related to the "Swedish 10^{-5} earthquake" by 15% to account for the favourable site conditions as all plants are sited on solid rock.
DBE values, which are applied to severe accident systems, are based on RG1.60 (US NRC Regulatory Guide 1.60).
Seismic Margin Assessment (SMA) conducted to Forsmark 1 and 2 and Oskarshamn 2. The Safety Analysis Report addresses external hazards, including seismicity.

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

The national report does not give specific information on Periodic Safety Reviews (PSRs) in the section of earthquakes. However, it was clarified during the peer review, that PSRs are conducted in every ten years. There has not been a reassessment of the seismicity level of the sites in the recent PSR. Reassessment of the seismicity levels of the plants is included in the plans for 2014.

2.1.1.6 Conclusions on adequacy of design basis

SSM states that seismic hazard has been assessed according to the national requirements and that DBE levels are adequate.
It appears, that the values of the DBE's listed for the different sites are close to IAEA's suggested minimum values at the background of the active deformation of Fennoscandia, which is proved by geodetic and paleoseismologic data (see 2.1.3).

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

The reactors originally designed for seismic loads i.e. Forsmark 3 and Oskarshamn 3 are in compliance with current regulations. The full compliance of the reactors, originally not designed to

withstand seismic loads, is expected in 2013 after the implementation of modifications (e.g. anchoring of mechanical components, emergency power supply) in accordance with the current requirements on seismic safety, in force in 2005.
According to SSM, the plant currently complies with its licensing basis.

2.1.2 Assessment of robustness of plants beyond the design basis

2.1.2.1 Approach used for safety margins assessment

SMAs have been conducted for the units Forsmark 1 and 2, and Oskarshamn 2.
These assessments included partly structural analysis, calculations (piping systems), tests (e.g. electrical equipment) and other method's including walk downs for identification of failure risk to safety systems from non-seismically verified equipment. The beyond DBE analysis is emphasized to evaluate ability of the mitigation systems to perform their function.
The integrity assessments of the reactor containment, scrubber building and spent fuel pools (SFPs) are based on approximate calculation methods and engineering judgment on a best estimate basis due to the limited time available for this study.

2.1.2.2 Main results on safety margins and cliff edge effects

The integrity of reactor containments, SFPs and other important buildings are estimated to be preserved in case of the 10^{-7} – earthquake. However, there is a need for refined analyses and further investigations before definite conclusions are possible.
As the Swedish national report stated, further investigations are to be performed to evaluate the margins of structures, systems and components against ground motions exceeding DBE. Such investigations should emphasize evaluating margins to reach a safe shutdown condition.
Some measures to improve the situation during and after an earthquake have been identified, such as alternate ways to cool the SFPs.

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

Seismicity for the sites in Sweden is low and in general it can be stated that some margins beyond the DBE exist.
However, further investigations are envisaged to be performed to evaluate the margins of structures, systems and components against ground motions exceeding DBE. Such investigations should emphasize evaluating margins to reach safe shutdown conditions.
According to the licensees the Swedish plants are able to achieve a safe shutdown conditions in case of a DBE, provided that the deficiencies identified in some plants have been remedied (2013).
The mitigation systems for severe accidents are judged to be able to fulfill their function in case of the Swedish 10^{-7} earthquake in accordance with the relevant regulation.
Some measures to improve the situation during and after an earthquake have been identified, such as alternate ways to cool the SFPs.

2.1.2.4 Possible measures to increase robustness

Possible recommendations identified by the licensees:
Forsmark:
- The most important measures for Forsmark 1 and 2 to strengthen the robustness is to remedy the shortcomings identified in SMA-validation.

Oskarshamn:
- Installation of new pipes to provide fire water to the SFP,
- Further investigations regarding the structural integrity of the reactor containment, scrubber building and fuel storage pools.
- Further investigations to evaluate the margins of structures, systems and components against ground motions exceeding DBE.

- The Screening Evaluation Work Sheet (SEWS) applied in the Seismic Qualification Utility Group (SQUG) assessments does not explicitly consider aspects of seismic induced fire. This should be addressed.

Ringhals:

- The most important measure for Ringhals to strengthen the robustness is to remedy the shortcomings identified in SMA-validation. Studies to determine the complementary measures are still ongoing.

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

The regulator has required the utilities to develop detailed programmes including information on how and when the:

- identified deficiencies will be addressed,
- detailed analyses and investigations should be performed,
- identified measures that have been judged to improve the situation during and after an earthquake should be carried through,
- measures needed to prevent the threshold values.

2.1.3 Peer review conclusions and recommendations specific to this area

Although the methodology used for seismic hazard assessment (SHA) is not fully described in the national report, it was clarified during the country visit that additional documents state that the applied methods were state of the art at the time of the SHA. They appear to be widely compliant with current international standards and research results as requested in the ENSREG specifications.

According to SSM, the Swedish earthquake is based on observations and historical accounts of earthquakes in Fennoscandia for about 500 years as well as comparisons with the occurrence of earthquakes in other low seismic regions in the world.

Based on these facts, SSM estimated that fairly reliable predictions can be performed concerning the earthquakes that are likely to occur in Scandinavia in a short geological time scale. However, this could be questioned as a restriction due to the fact that geodetic and paleoseismologic data which according to some researchers indicates continuous active uplift and deformation of Fennoscandia. Also, the IAEA (SSG-9) explicitly suggests the use of such data in low-seismicity intraplate regions. Based on the discussions during the country visit, SSM agreed to reconsider the existing approach by taking into account the geodetic and paleosesimologic data.

SSM is recommended to consider in timely manner the fulfilment of assessments of licensees and the implementation of identified back fitting measures.

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

2.2.1 DBF (Design Basis Flood)

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

The regulatory approach is goal and process oriented with general advice provided to licensees. Since 2005 the new regulation SSMFS 2008:17 is in force.

2.2.1.2 Derivation of DBF

At the time of the construction of all Swedish NPPs in terms of flooding there were only conventional building codes in force. Only flooding from high sea water level has been considered by the licensees. In 2005 before mentioned regulation SSMFS 2008:17 came in force with the result that licensees have to meet sufficient provisions against flooding in 2013 at the latest. The licensees have interpreted this provision that their plants have to withstand flood with a frequency of less than 10^{-4} to 10^{-6} per year. SSM states that the only source of flooding considered in Swedish units is from high sea water level, because no Swedish units are located in close proximity to any other water source. Tsunamis are considered to be irrelevant or insignificant. Seiches and other phenomena are considered to be covered by high sea water levels.

DBF values are (above normal sea water level):

- Forsmark + 3.0 m
- Oskarsham + 2.02 m
- Ringhals + 2.65 m.

The basis for the DBF is the observed registrations in the vicinity of NPP sites by the Swedish Meteorological and Hydrological Institute (SMHI):

- Forsmark: observations from 30 years' period, max. 1.44 m above sea water level (2007)
- Oskarsham: observations from 45 years' period
- Ringhals: registrations from 1887 to 2006.

The frequency of an increase of the sea water level above the DBF is estimated to be 10^{-5} annually at the sites of Oskarshamn and Ringhals; and at Forsmark 10^{-6} annually.

2.2.1.3 Main requirements applied to this specific area

The regulation SSMFS 2008:17 applies to this area. In addition, the licensees have identified further actions in response to the recommendations issued by World Association of Nuclear Operators (WANO) after the Fukushima accident.

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

The issue of flooding together with other external hazards is addressed in the Safety Analysis Report. Similarly, all external hazards (excluding earthquakes) are included in Probabilistic safety Analysis (PSA) level 1 and 2 for all plants.

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

PSRs are regularly conducted and address the issues of external hazards.

2.2.1.6 Conclusions on adequacy of design basis

The national report states that the DBF is adequate for all Swedish NPP units covering the known and experienced phenomena. However, the detailed methodology for the definition of high sea level is identified as an open issue by SSM.

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

According to SSM all sites fulfil the DBF regulatory requirements.

2.2.2 Assessment of robustness of plants beyond the design basis

2.2.2.1 Approach used for safety margins assessment

The water entering paths are roughly assessed considering issues such plant layout, location and levels of watertight rooms, location of equipment for safe shutdown and safety functions. It was clarified during the country visit that all plant operating states in all sites have been considered, but only the most limited cases are presented.

Forsmark: No detailed assessment was done. If an external flooding above ground level (a few decimeters over +3.0 m) due to high sea water levels occurs, the water level in the respective buildings rises to the same level. Equipment necessary for safety is not designed to withstand such a water level and therefore damage to core is likely if no manual action is taken.

Oskarshamn: The sea water level of 2.6 m corresponds the frequency of 10^{-7} annually (DBF: 2.02 m, 10^{-5}/a) extrapolated by SMHI. Since the phenomenon is slow, manually initiated scram and measures are credited. A spontaneous increase of ground water leakage through rock or broken barrier between

sea water cooling channel and the shaft are assumed in the units 1 and 3 (screened out from the unit 2). The critical level of sea water or ground water level is +1.35 m at unit 1 and no critical level at unit 3.
Ringhals: The consequences of see water levels above DBF to safety functions and mitigation systems are estimated in categories levels below 2.65 m, 2.65 – 3.0 m, 3.0 – 3.3 m; 3.3 – 4.0 m and over 4.0 m.

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

Forsmark: The frequency of the design basis sea water level is 10^{-6} per year corresponding to a sea water level of +3 m. With higher water levels, and if no action is taken, core damage cannot be excluded .

Oskarshamn: As the national report states, one identified cliff edge effect is a sea water level higher than +3.0 m at which level cooling of Oskarshamn 3 cannot be ensured (this level has been determined conservatively). For Oskarshamn unit 1 and 2, the core cooling is judged to be ensured up to a sea water level slightly above ground level +6.0 m (considering pump foundations etc.), since residual heat removal can be accomplished with the mitigation system, which does not require any electrical power supply and is not affected by flooding up to ground level (+6.0 m).

Ringhals: The cooling water channels can withstand the water pressure from a water level of +3.4 m. In case of high sea level, the power of the plant has to be reduced. In this case, the water level stays below +3.4 m at the outlet as well as the inlet. The cooling water channels will hence not be damaged and no water will enter any Ringhals unit at the sea water level between 2.65 – 3.0 m. Large amounts of water will enter the Ringhals units through various openings when sea level is between 3.3 – 4.0 m. According to the report the Ringhals units are assumed to be significantly affected by the flood, but the severity of consequential, potential fuel damages depend on a number of factors such as what rooms are flooded and the duration of the flooding. According to the national report, above 4.0 m the sea water reaches the level where the doors break. At all Ringhals units doors will break at sea water level of +4.0 m and water will instantly flood all Ringhals units up to the sea water level and fuel damage will occur.

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

In case of failure of the drainage function it is assumed that flooding will take many hours before any severe damage will occur to the plants so manual action is likely to be successfully performed. The water and pressure resistance of buildings, gates or exterior doors as well as flow paths that could be subject to back-flow might pose a weak point regarding flooding above +3.0 m.

2.2.2.4 *Possible measures to increase robustness*

The licensees have identified the following recommendations on possible measures:

- Enhance communication between SMHI and NPPs regarding warnings of extreme weather
- Study on how water would spread inside the plants during external flooding should be conducted in all NPPs
- In addition to the above mentioned items, lists with technical and procedural improvements exist for all Swedish NPPs.

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

The above mentioned lists are under approval of the regulator. It is considered to implement the improvements in timely manner.

2.2.3 Peer review conclusions and recommendations specific to this area

Reviewers' appreciate that the licensees compile a list of improvements for each NPP and recommend SSM to consider approving and implementing the possible improvements in a timely manner. They further judge to consider carrying out more detailed flooding risk analysis including cliff edge analysis. In order to identify plant vulnerability against flooding, implementation of a refined external flooding PSA could be suggested to be introduced for Swedish NPPs.

It is also recommended for the Forsmark and the Ringhals sites, to consider studying the combination of high sea water level and other external phenomena such as swell, strong wind and organic materials.

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

2.3.1 DB Extreme Weather

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

Design basis for all Swedish NPPs have been the conventional rules and guides in force for rain, wind, low sea water level, outdoor temperature, seawater temperature and lightning. Since 2005 the new regulation SSMFS 2008:17 is in force.

2.3.1.2 Derivation of extreme weather loads

The regulation SSMFS 2008:17 addresses extreme weather but without quantification of the loads. The extreme weater loads are specified by the licensees, assessed and then approved by SSM.

2.3.1.3 Main requirements applied to this specific area

Besides regulation SSMFS 2008 :17, there are no additional requirements for extreme weather conditions.

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

The issue of extreme weather conditions and other external hazards is addressed in the Safety Analysis Report. Similarly, all external hazards are included in PSA level 1 and 2 for all plants.

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

PSRs are regularly conducted in Sweden to assess licensee compliance with current regulations. During the country review it was clarified that extreme weather hazards are addressed in the PSR.

2.3.1.6 Conclusions on adequacy of design basis

Initial design basis for extreme external phenomena is basically considered adequate, but acceptance criteria or combinations of loads to be taken into account for addressing current extreme external hazards could be further specified.

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

At present there are no detailed requirements for extreme weather. All Swedish plants have to fulfil new requirements regarding extreme external hazards in 2013.

2.3.2 Assessment of robustness of plants beyond the design basis

2.3.2.1 Approach used for safety margins assessment

As the national report states the safety margin assessments for extreme weather conditions are limited and should be further evaluated. Licensees have analysed to some extent the margins of their plants in respect to extreme weather aspects by engineering judgement.

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

Some cliff edge effects were identified in the national report. Safety margins are considered by the licensees to be adequate. However SSM has requested the licensees to perform further analysis in this area.

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

Some improvements are identified in the national report (like improving the resistance of some buildings against tornado induced missiles), but it is expected that the further analysis mentioned in the previous section will identify additional measures against extreme weather (ice storms are of particular interest).

2.3.2.4 *Possible measures to increase robustness*

Regarding external hazards, safety also relies on the quality of early warning systems, which are not in place for all sites. Peer reviewers consider that such systems, as well as relevant operating procedures in case of extreme weather conditions, should be implemented at all sites.
The licensees identified measures to improve the safety in respect to extreme weather hazards for all Swedish NPPs.

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

It has been stated in the national report that the licensees have identified a number of potential improvements, some of which are already being implemented. SSM agrees with this list, and has identified additional measures to be considered, eg evaluate how the extreme weather can affect the access to the site of personnel and equipment, capability of equipment to perform safety functions, administrative measures to cope with extreme weather conditions, etc.

2.3.3 Peer review conclusions and recommendations specific to this area

As the Swedish national report states, there is limited information available on extreme weather conditions and the evaluation of the respective hazard. Reviewers' appreciate that the licensees compiled a list of improvements for each NPP and recommend SSM to consider approving and implementing the possible improvements in a timely manner. They further recommend considering carrying out more detailed external hazard analysis on the basis of the state of the art requirements.

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

3.1 Description of present situation of plants in country

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

There is a short, but for the purpose of stress tests, sufficient overview of Swedish regulatory system in the report; SSM's goal oriented regulatory approach is briefly explained. Swedish requirements on design of NPPs are derived from U.S. NRC General Design Criteria; this set of criteria has been supplemented by more specific requirements. The regulations are based on Swedish and international operating experience, recent safety analyses, results from research and development projects and the development of IAEA safety standards and industrial standards that were applied in the construction of the facilities.
On 1 January 2005, the former supervisory authority, the Swedish Nuclear Power Inspectorate (SKI), put into force new regulations concerning the design and construction of nuclear power reactors, now designated as SSMFS 2008:17. When they entered into force, the regulations contained transitional

provisions providing the basis for SKI's decision concerning reactor-specific modernisation programmes, including a timetable for implementation of these programmes. The regulations impose requirements on increased resilience against internal and external events, for example through more separation and diversification of equipment and systems in facilities. (The regulations also impose requirements on the facilities' resilience against natural phenomena and other events, such as earthquakes, flooding, extreme winds, extreme temperatures and extreme icing.).

3.1.2 Main requirement applied to this specific area

Basic safety requirements relating to the plant's power supply are formulated in the SSM regulations SSMFS 2008:1 and SSMFS 2008:17. When designing and building the electrical power system, the following general conditions have been followed: the safety systems including the power systems are divided in separate and redundant divisions to be able to secure the safety functions in a reliable manner, the divisions of diesel generators and batteries used as power supply sources, should therefore be physically and functionally separated, and, as far as reasonable achievable, independent of one other.

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

Well arranged description of technical background for requirements set up by SSM for safety of NPPs is provided. It is evident from the report, that deterministic approach is complemented with PSAs studies and models. Operational experience feedback is systematically analyzed and results of analyses are used as one of inputs for improvement of regulatory requirements/guidance.

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

The PSR process is briefly mentioned in the section 1.9 of the national report. It is evident that a continuous review and improvement process is ongoing in Swedish NPPs. Exhaustive list of safety improvements implemented in Swedish NPPs gives clear understanding of the quality of the safety review process.

3.1.5 Compliance of plants with current requirements

At the topical review meeting Swedish representatives clearly explained that all NPPs in the country are in compliance with their currently valid licences.

3.2 Assessment of robustness of plants

3.2.1 Approach used for safety margins assessment

The general approach adopted in assessing the safety margins with respect to the loss of electrical power and loss of heat sink aspects of the stress test requirements is to identify associated level of redundancy and diversity, as well as the timescales by which various safety functions need to be implemented in order to prevent significant fuel damage. For all reactor designs, fuel damage is postulated to be unavoidable when the water level reaches the top of the fuel. It was explained at the topical review meeting that bounding approach was used when performing the analyses and only the most critical situation are described in the national report.

3.2.2 Main results on safety margins and cliff edge effects

- **Loss of off-site power (LOOP)**

Swedish NPPs have a robust design of power supply to cope with LOOP: no fuel damage or release of radioactivity should occur in this situation.
There are at least 2 off-site power sources. If the connection to the main external grid is lost, load reduction to house load operation is implemented in all Swedish NPPs. It is clearly explained in the

report that this capability is viewed as related to the defence in depth, but this function is not credited in the deterministic analysis.
If load reduction to house load algorithm fails, a switch-over to the alternative grid is attempted. If it fails, there are Emergency Diesel Generators (EDGs) available at all sites, with sufficient redundancy and sufficient diesel fuel volume, i.e., the plants safety buses are powered from the EDGs and batteries for the time period exceeding the ENSREG stress tests specifications requirement (24/72 hours). Reassessment of pipes and equipment needed for EDGs refuelling considering all natural phenomena and other events was identified by SSM as an issue related to LOOP.
SSM considers further evaluations and reassessments of the EDGs lubricating oil supply as potential measures to increase robustness of the plants, at one boiling water reactor (BWR) external delivery of lubricating oil might be necessary within 72 hours. There are no additional plant specific peer review findings.

- *Loss of off-site power and loss of the ordinary back-up AC power sources*

To cope with the situation in which all EDGs failure to supply safety buses, gas turbines (GTs) are installed for each nuclear power station as alternate AC power sources with the exception of Oskarshamn 2, where the gas turbines at present serve as primary electricity back up. Four new diverse EDGs with robust I&C are planned to be installed in 2013 for Oskarshamn 2. This will compensate for this difference, and allow the gas turbines to become an alternate power source for the whole power station. GTs are able to provide AC power for at least 4 days without external support.
These alternate AC power sources are in most cases not fully qualified against external hazards. At the country visit it was clarified that the alternate Alternating Current (AC) power sources i.e. GTs, are originally graded as non-safety and therefore the level of qualification will differ between the sites. Some licensees have adopted US NRC RG 1.155 which puts certain requirements, e.g. quality and reliability, on equipment like GTs, which are credited to function as an alternate power source in a Station Blackout (SBO) situation.

The assessments indicate however, that the performance and the units' connection to the alternate back-up AC powers supply might not be robust in all situations especially when all units at one site are affected. Further evaluations and reassessments of the alternate back-up AC power supply will be considered as potential measures to increase robustness of the plants according to the Swedish national report.

- *Station blackout*

In the event of a LOOP, failed house load operation, in addition loss of ordinary and alternative auxiliary power, what remains operational then is a battery-backed uninterruptible AC and Direct Current (DC) power supply for essential services loads of minor consumption. Design basis for battery capacity is 1-4 hours according to the safety analysis reports, but supporting documents and experience indicates that battery capacity can be extended. Lists of expected battery capacities are not included in the national report but are included in the licensee stress test reports which were available during the country visit.
Additionally, as was stated in the national report, a potential measure to increase robustness of plant could be to consider shedding of nonessential loads since this may further increase the battery depletion times.
Various mobile units can be used, such as diesel-powered pumps and generators. As stated in the Swedish national report, the analysis, indicates that the capacity and number of mobile units are insufficient during beyond design basis event when several reactors are affected simultaneously. Further evaluations and reassessments of mobile units are viewed as potential measures to increase robustness of the plants.
Some units have steam or gravity driven core cooling functions (R1-4 and O1), and Instrumentation and Control (I&C) related to these systems are dependent on battery backed power. The national report concludes that the relatively short depletion time of related batteries will limit the usability of these systems in a situation where all AC power including the alternate AC power is unavailable (i.e. only battery power remains). There is a strong dependence of electrical power in Swedish BWR and if

only battery backed up power is assumed to be available fuel damage might occur within one hour for units without steam or gravity driven systems.

The release of activity is mitigated at severe accidents by means of the Multi Venturi Scrubber System (MVSS– description of this system is provided in the national report) function. However, power is not needed initially for the MVSS filter function, only for monitoring. The MVSS is designed to be able to filter the releases even if power is unavailable (including battery back- up). Each MVSS filter has its own set of batteries with a much longer depletion time (normally 24 hours) than the ordinary station batteries.

Plant specific review findings – Forsmark

For the Forsmark units, damage to the fuel is calculated to be unavoidable after 35 – 60 minutes depending on the unit.

If no manual actions to cool the SFPs have been successfully completed, damage to fuel will be unavoidable after about 1 day for the most limiting case when all the fuel is located in the fuel storage pool during refueling and neither alternate makeup with firewater nor mobile equipment is available in all units. Availability of firewater eliminates any cliff edge effect.

Plant specific review findings - Oskarshamn:

For Oskarshamn 1, and if the emergency condenser is assumed to be available, damage to the fuel is calculated to begin within 3 hours. This assumes that the emergency condenser return valves are opened before batteries are depleted (2 hours). However, if earthquake is considered, i.e. the emergency condenser is assumed to be unavailable, damage to the fuel is calculated to begin within 1 hour.

For Oskarshamn 2 damage to the fuel is calculated to begin after approximately 2 hours, and for Oskarshamn 3, damage to the fuel is calculated to begin after approximately 1 hour.

As it was clarified during the country visit, in the event of a SBO (only batteries available) at Oskarshamn, without taking any action, the available time before the onset of boiling in the SFPs is 18 hours for Oskarshamn 1, 40 hours for Oskarshamn 2 and 21 hours for Oskarshamn 3. There are about 91 hours for Oskarshamn 1, 6 days for Oskarshamn 2 and 74 hours for Oskarshamn 3 before the pool level reaches 2 m above the top of the spent fuel.

It is identified in the Swedish national report that if all units are affected simultaneously, both powering of pumping of water from the MVSSs and powering emergency response centre require the same site mobile diesel generator. An additional site mobile diesel generator is needed to cope with this situation.

Plant specific review findings - Ringhals:

If the mobile unit is assumed to be connected:

a) For Ringhals 1, no detailed analysis is found for this scenario. However, the scenario is assumed to initially be equivalent to a scenario with mobile unit is assumed to be unavailable and it is likely that the mobile unit would improve the time before damage to fuel becomes unavoidable.

b) For Ringhals 2, Ringhals 3 and Ringhals 4, it will take approximately 70 hours before fuel damage may occur.

If the mobile unit is assumed to be unavailable:

a) For Ringhals 1, fuel damaged becomes unavoidable after approximately 16 hours

b) For Ringhals 2, Ringhals 3 and Ringhals 4, fuel damaged becomes unavoidable after approximately 9 hours.

There was no information in the national report about Reactor Coolant Pumps (RCPs) seals leakage during SBO. It was clarified by the licensee during the country visit that a certain leakage was considered, and that the ongoing analysis will be presented to SSM for evaluation.

The peer review team supports the SSM requirement that Ringhals NPP licensee devotes adequate attention to this issue for the Transitional Provisions for Regulation SSMFS 2008:17.

It was clarified by SSM during the country visit that for Ringhals 1, the time from loss of cooling of the SFPs to the onset of boiling is, without taking any action, around 14 hours, and to a loss of shielding, around 91 hours. For Ringhals 2, 3 and 4, the available time from a loss of SFP cooling to the start of boiling is around 9 - 10 hours and to a loss of shielding, is around 50 hours.

- *Loss of ultimate heat sink*

The water which is taken directly from the sea is the UHS for Swedish NPPs. A brief explanation on pumping stations at Oskarshamn and at Ringhals is provided. For the Forsmark NPP information was provided during the plant visit.
All NPPs are designed to withstand a blockage of the sea-water inlet following any natural phenomena and other events that could arise outside the plants. In a blockage of the cooling water intake, all plants will be able to safely shut down and maintain safe shut down conditions. For Ringhals 3 and Ringhals 4, demonstrations of design basis have not been fully verified. The national report concludes that additional need for verification will be further evaluated.
The assessments show that blockage in both intakes and outlets could lead to significantly more challenging situations for the plants, and will require high operational performance and advanced manual actions. For the ASEA BWR designs licensees have described that the severe accident mitigation systems could be used for maintaining a safe state in these situations, i.e., for removing the residual heat from the reactors, if some method to inject water into the reactor pressure vessel can be established. However, this has not been considered in the design for these systems and it is therefore stated in the national report that this function will be considered for further evaluations and reassessments.
The licensee assessments of loss of UHS also show that the available time before damage to fuel being unavoidable is highly dependent on available water volumes (in storage tanks). It is stated in the national report that further evaluations and reassessments of the minimum acceptance values for levels in storage tanks and also the priority of water volumes in storage between units will be considered as a potential measure to increase robustness of the plants.
To secure SFP cooling the licensee assessments shows that manual actions are required for all Swedish NPPs. It is stated in the national report that further evaluations and reassessments of SFP cooling capabilities (including accessibility, availability, capacity, installation, operation, etc) will be considered as a potential measure to increase robustness of the plants.

- <u>*Loss of primary UHS*</u>

<u>*Plant specific review findings - Forsmark*</u>

In case of loss of primary UHS all units are shut down and maintained in a safe shut down conditions without any damage to the fuel in the reactor core or in the SFPs. Additionally, off-site power was assumed to be lost in the analysis of this scenario. Since seawater is needed to cool the EDGs, loss of the primary ultimate heat sink with a simultaneous loss of offsite power means that the power to the safety systems needs to be supplied by the GTs.
For all units, damage to the fuel in the reactor core is not anticipated to occur as long as the high pressure safety injection system is available and the residual heat in the reactor core can be removed via the suppression pool and transferred to the atmosphere through the MVSS.
For all units, damage to fuel in the SFPs will not occur as long as make-up water from the fire-water system can be manually provided. If make-up water for the SFPs is not available, fuel in the SFPs is anticipated to be uncovered within 23 hours. Only the case where one unit at a time is affected is within the design basis. However, the Swedish national report states that engineering judgements indicates that if the event affects all units at the site at the same time the situation can be handled without requiring any external water source.

<u>*Plant specific review findings - Oskarshamn:*</u>

In case of total blockage of sea-water intake, all units can be shut down and maintained in a safe shut down conditions without any damage to the fuel in the reactor cores or in the SFPs. If both sea-water intake and outlet is assumed to be blocked, core cooling and residual heat removal will be maintained, and all units will be shut down and maintained in a safe state.
In the following paragraphs, Loss of UHS in combination with LOOP and further electrical power is analysed for potential cliff edge effects.
For Oskarshamn 1, the residual heat is removed through the emergency condenser. No cliff edge effects have been identified as long as the emergency condenser together with the air-cooled EDGs is operational.
For Oskarshamn 2, the core inventory is maintained with the auxiliary feedwater system, and residual heat is transferred by blowing steam to the condensation pool. No cliff edge effects have been identified as long as the GTs and the alternate suppression pool cooling system are available.

For Oskarshamn 3, the residual heat removal is performed similarly to Oskarshamn 2. There will be no fuel damage in the reactor core identified as long as one train of the high pressure injection system is operational and the connection between Oskarshamn 3 and the GTs will be manually accomplished within 1 hour. For Oskarshamn 3, this situation requires also that the residual heat from the reactor core will be transferred to the atmosphere via the suppression pool, and the MVSS.

Only the case where one unit at a time is affected is within the design basis. Engineering judgement by the licensee indicates that if the event affects all units at the site at the same time the situation can be handled without requiring any external water source. This will be further assessed by SSM.

For the SFPs, the make-up water capacities in the fire-water systems is enough to prevent fuel damage in the SFPs for at least 90-250 days for Oskarshamn 1 and Oskarshamn 2, and 18-66 days for Oskarshamn 3, depending on when the event occurs.

Plant specific review findings - Ringhals:

At Ringhals 1 it takes at least 25 days before any damage to the fuel in the reactor core occurs, provided the water volumes in available tanks are close to maximal.

For Ringhals 2, Ringhals 3 and Ringhals 4 it is assumed that the auxiliary feedwater system is in function, supplied by water from the condensate storage tank. The relief valves of the steam generators are used to remove the residual heat from the reactor. It is assumed that there is no leakage from the sealing of the reactor coolant pumps due to the fact that the off-site power is available and water for seal injection is available via the refueling water system tank (RWST). The limiting factor to withstand fuel damage is therefore the amount of water available for the auxiliary feedwater systems, if water volumes in available tanks are maximal, the fuel damage will occur after 17 days at Ringhals 2 and after 11 days at Ringhals 3,4.

If water volumes in available tanks are minimal, fuel damage becomes unavoidable at Ringhals 1 after 35 hours, at Ringhals 2 after 11 hours, and Ringhals 3 and Ringhals 4 after 8 hours.

For the spent fuel pools, if all units at the site are affected simultaneously fuel damage becomes unavoidable after 8-9 days and loss of adequate shielding radiation occurs after about 7 days.

- *Loss of primary UHS and alternate UHS*

Plant specific review results – Forsmark:

No alternate UHS exists for any unit at the Forsmark site. The MVSS function is designed to operate during core melt scenarios. However, engineering judgement indicates that the MVSS functions can mitigate the effect of loss of UHS and has therefore been credited in the Swedish stress tests for the BWR designs.

Plant specific review findings – Oskarshamn:

For Oskarshamn 1, the loss of the emergency condenser as the alternative heat sink will turn the situation similar to the loss of UHS scenario at Oskarshamn 2 and 3. For Oskarshamn 3, no alternative UHS is considered to exist. The MVSS function is designed to operate during core melt scenarios. Similarly as in the case of Forsmark the engineering judgement indicates that the MVSS functions can mitigate the effect of loss of UHS and has therefore been credited in the Swedish stress tests for the BWR designs.

If water injection to the core is lost, the situation is from the core point of view identical to total SBO. Oskarshamn 2 has an alternative heat sink, using an alternate suppression pool cooling arrangement to transfer heat from the core to the atmosphere.

Plant specific review findings - Ringhals:

Calculations indicate that water inventory will be enough to provide make-up water for approximately more than 35 hours at Ringhals 1, 13-18 hours at Ringhals 2, and approximately 14-20 hours at Ringhals 3 and Ringhals 4. If manual actions are delayed, damage to fuel will be unavoidable within 2 hours, after the steam generator inventory has been depleted.

- *Loss of ultimate heat sink with SBO*

Reference is made to sections of national report dealing with SBO. It was explained by the SSM representatives at the topical review meeting that bounding approach was used when analysis was performed and combination of loss of UHS and SBO is included in the analysis of SBO. There are no plant specific review findings related to this topic.

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

Capability to withstand loss of UHS scenario for long time periods if water volumes in various tanks are close to maximal is considered by the peer review team to be a strong feature of majority of Swedish NPPs.
A total loss of electrical power or loss of UHS (failed cooling) leads to an accident scenario with serious core damage. In order to mitigate the consequences of these kinds of accident scenarios, all Swedish NPPs are fitted with consequence mitigating systems in which filters of the venting system and the independent containment spray system are key features. The stress tests demonstrate the strength of these systems in connection with station blackout and a loss of heat sink, or a combination of both these events. The function of consequence-mitigating systems should according to the national report be investigated further from the perspective of an extended accident sequence. Also for the BWRs, the national report states that engineering judgement indicates that the MVSS function can mitigate the effect of loss of UHS and has therefore been credited in the Swedish stress tests during these events. However, this function has not been considered in the design for these systems and it is therefore stated in the Swedish national report that this function will be considered for further evaluations and reassessments.

3.2.4 Possible measures to increase robustness

A number of plant specific measures to increase robustness of the operating NPP is planned to be implemented. As Swedish representatives informed at the topical peer review meeting, the following items have been identified by the SSM review in addition to the measures identified by the licensees during the licensee assessments of protection against loss of electrical power, and will be considered as potential measures to increase robustness of the plants:

- pipes and equipment needed for EDG refuelling will be evaluated and re-assessed considering all natural phenomena and other events that could arise outside or inside the facility
- evaluate further needs of additional diversified equipment within the important instrumentation and control functions (including power supply) needed in accident conditions
- evaluate further need of standardised mobile diesel generators and standardise well protected connection arrangements the units/sites
- evaluate the accessibility of the important areas at the site and inside the plants (including all areas where access is need for successful execution of manual actions) during accident scenarios, especially following natural phenomena and other events that could arise outside or inside the facility.

The following items have been identified by SSM in addition to the measures identified by the licensees during the licensee assessments of protection against loss of UHS, and will be considered as potential measures to increase robustness of the plants:

- re-evaluation of emergency operating procedures (EOPs) and implementation of possible updates regarding all alternate cooling capabilities available at site
- re-evaluation of EOPs and implementation of possible updates regarding manual hydrogen venting
- further evaluation of a simultaneous event at all units are needed for the Forsmark site.

For SFPs at NPPs, the following information on further actions is provided in the national report:

- look into possibilities of introducing a way to cool and feed the SFPs from outside the building, including fixed external connections
- verify the pool integrity for boiling conditions
- review the level and temperature instrumentation
- develop strategies to priory different actions when several reactors and the SFPs are affected at the same time
- develop strategies and procedures to reach a stable safe state
- evaluate the risk of criticality, during boron dilution under boiling conditions (for PWR reactors)
- look into ways of venting steam from the building
- review possible ways of protecting the SFPs buildings from effects of severe fuel damage in the spent fuel pools, e.g. hydrogen explosions.

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

It was clarified in the peer review that no urgent measures have been identified. However, there are a number of less urgent actions and specific investigations that will be be implemented in the near future. Some of these actions are already in progress.

3.3 Peer review conclusions and recommendations specific to this area

The Swedish licensees have performed assessments of protection against loss of electrical power and loss of UHS in accordance with the ENSREG stress tests specifications. The SSM confirmed that the overall intention of the stress tests has been fulfilled. Identified deviations from the ENSREG stress tests specifications have been explained and justified.

With respect to electrical supplies, LOOP situation is within the design basis of all Swedish NPPs. EDGs (normal back-up power sources) are designed to be in operation for at least 7 days. For situations including loss of off-site power and loss of the ordinary back-up AC power sources, gas turbines are at all sites capable to supply power for 4 – 7 days without external support. If off-site power, ordinary back-up AC power sources, and permanently installed diverse back-up AC power sources are all lost (SBO), fuel damage is unavoidable. At some plant units, the fuel damages occur quite rapidly, whereas in some units, it is possible to keep the plant in a safe state for several hours even in a complete SBO.

- There are various measures proposed to be implemented in the area of power supply at all levels of defense in depth. The review team concluded that measures identified are appropriate and considers as the most important the following ones:Reducing risks of common cause failures in EDGs.
- Analysis of robustness of gas turbines as alternate AC power sources robustness.
- Improving possibilities to refill the diesel tanks at diesel units by ensuring that valves and pumps are fed by power from safety classed equipment .
- Performing analysis to verify that it is possible to use lubricating oil from other units in case of emergency without jeopardizing the operation.
- Investigation of the possibilities to use diesel engines which today are used for the physical protection systems (security functions).
- Increasing the number of mobile diesel generators at site (each facility should get its own mobile diesel unit with prepared connection points).
- Increasing the discharge time of the batteries (disconnecting of some less important loads).
- At Ringhals an alternative cooling system for EDGs is prepared that might be an alternative at other units.

If primary UHS is lost, at some plants no damage to fuel occurs, at other plants fuel damage can occur, as a minimum within 11 hours, as a maximum within 25 days, depending on the level in the fresh water supply tanks systems.

- There are various measures proposed in the area of UHS. The review team concluded that measures identified are appropriate and considers as the most important the following ones:Maintaining the level in available water storage tanks close to maximal.
- Installation of pipelines to provide fire water to spent fuel pools.
- Verification of the spent fuel pools integrity for boiling conditions.
- Re-evaluation of emergency procedures and implementation of possible updates all alternate cooling capabilities at site and implementation of possible modifications regarding manual hydrogen venting.

4 PLANT(S) ASSESSMENT RELATIVE TO SEVERE ACCIDENT MANAGEMENT

4.1 Description of present situation of plants in Country

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

SSM's regulatory approach is high level, focussing on the processes required rather than specifying detailed requirements. This means that the regulations are general, with a focus on the required licensee processes and the types of outcomes expected from these processes. SSM does not specify details on how these processes have to be performed.

In addition to the regulations themselves, general advice on the interpretation of most of the safety regulations is given. Measures should be taken according to the general advice or, alternatively, methods identified that are justified to be equal from the safety point of view must be implemented.

According to the national report, general requirements for the management of severe accidents and emergency preparedness are included in the Swedish regulations. Specifically, they are given in SSM 2008:1 (The Radiation Safety Authority Regulation for Safety and Security in Nuclear Facilities), SSM 2008:17 (The Radiation Safety Authority Regulation for Design and Construction of Nuclear Power Plants) and SSM 2008:15 (The Radiation Safety Authority Regulation for Emergency Preparedness at Nuclear Facilities).

Low level requirements and guides, i.e. more detailed guidelines are based on IAEA Safety Requirements and Safety Guides, US NRC General Design Criteria, Regulatory Guides and Standard Review Plans, American Nuclear Society (ANS) Nuclear Safety Criteria and American Society of Mechanical Engineers (ASME) Nuclear Safety Criteria.

4.1.2 Main requirements applied to this specific area

Requirements for nuclear facilities in the context of emergency preparedness are given in regulations SSM 2008:1 and SSM 2008:15.

Authority decisions based on governmental decisions in 1981 and 1986, and Regulation SSM 2008:17 describe requirements regarding the design and construction for Swedish NPPs:

- Filtered containment venting through an inerted, MVSS with a decontamination factor of at least 500
- Independent containment spray water supply (mobile units and/or firefighting system)
- Automatic filling of lower drywell with water (for some units)
- Containment relief in event of a loss of coolant accident (LOCA) and a large leakage between the drywell and wetwell (BWR)
- All mitigating systems to be designed for seismic loads
- A comprehensive set of Severe Accident management Guidelines (SAMGs)
- Organization to handle severe accidents.
- Requirements concerning the design in case of severe accidents cover the following scenarios:No electric power available except battery and battery back-up power;
- No turbine-driven equipment available and no other passive core cooling means;
- Core melt including vessel melt through;
- High pressure in containment with a damaged core is not acceptable for long periods of time;
- A stable end state with a water-covered core/core melt and residual heat removal shall be achieved

As general conditions for severe accidents, the following has to be considered:

- Manual measures should not be needed for the first 8 hours.
- The manual measures that may be needed after 8 hours should be well-prepared and controlled by procedures.
- Other measures, which are not prepared, should not be needed until after 24 hours.

- Release of Cs-137 and Cs-134 and other ground contaminating isotopes should not exceed the absolute value of 0.1 % of the core inventory corresponding to a 1800 MWth reactor.
- There should be no immediate fatalities as a consequence of a severe accident.
- The non-acceptable releases frecuency should not be higher than 10^{-7}.

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

SAM in Sweden has been developed based on the decisions issued by the Swedish Government in 1981 and 1986. Decision from 1986 required that SAM measures shall be implemented at the power plants that are in operation today by the end of 1988.
The implementation of safety improvements, including severe accident mitigation provisions, was initiated in accordance with the general approach applied in the nuclear industry, taking into account lessons learned from previous accidents (e.g. the Three Mile Island (TMI) accident, Barsebäck 'strainer incident').

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

The approach to PSRs with regard to SAM is not detailed in the national report, but during the country visit it was clarified that PSRs are regularly conducted in Sweden to assess licensee compliance with current requirements incl. compliance with requirements related to SAM. SAM at the NPPs is also evaluated through regulatory inspections at the NNPs.

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

The compliance of the Swedish NPPs with current national requirements is stated in the national report. This compliance is based on the general advice given in regulations SSM 2008:1, SSM 2008:17 and SSM 2008:15.
Nevertheless it should be noted that it has not been a part of the stress tests to verify that the present SAM arrangements can meet new demands. For example, for the containment filtered venting systems, one of the design requirements is their passive operation for at least 24 hours. However, these systems are not designed for accident scenarios with longer duration, nor for the aggravated conditions experienced during the Fukushima accident. Thus, an evaluation of the system for long-term operation of more than 24 hours needs to be performed.
The issue of compliance with WENRA Reference Levels for SAM is not explicitly addressed in the report, however, during the country visit it was clarified that Western European Nuclear Regulators' Association (WENRA) RL within SAM area are implemented in SSMs Regulatory Code and at the NPPs.

4.2 Assessment of robustness of plants

4.2.1 Adequacy of present organizations, operational and design provisions

4.2.1.1 Organization and arrangements of the licensee to manage accidents

The emergency organization at Swedish NPPs is described in an Emergency Preparedness Plan. The Emergency Preparedness Organisation (EPO) consists partly of a common on-site emergency control centre (KC) and partly of a unit-related section (unit preparedness). It was observed during the plant visit that the centre is bunkered, adequately equipped with information systems, EDG, filtered ventilation, etc. There is also an off-site emergency centre similarly equipped. The main tasks of the EPO in case of accidents are to:
- Restore/maintain the facility to ensure a stable and safe state.
- Take appropriate protective measures for the personnel and facility.
- Minimize impacts to the environment as far as possible in case the incident poses a threat to environmental safety.

- Notify/alert the authorities that have the responsibility for third parties, continually report on the status of, and give a prognosis on, developments to these authorities.

The County Administrative Boards in the local counties conduct, at intervals of a few years, a major training exercise to test and drill the Emergency Preparedness Plans. The counties take turns in arranging these exercises, which mainly focus on testing the preparedness for an emergency situation at the NPP in question. The training is planned in collaboration with the neighbouring counties, other counties with NPPs and the relevant authorities and other parties.Staff training is conducted for all functions involved in the management of the emergency organization (BL) and the security contractor's Central Check Point (BS). The training aims to improve internal and external collaboration for incidents leading to the calling-in of the EPO, and the handling of applicable procedures and technical equipment in the common on-site emergency control centre. The training is carried out in the form of a role-play, with a target group, a counterpart acting group and a reference group, and may include collaboration with other organizations, such as the rescue services.
All Swedish NPPs have access to off-site technical support for accident and protection management. In case of a severe accident at the plant, the EPO management may ask for help from other Swedish NPPs, or from an emergency group coordinating the international response. For example, the Forsmark NPP and the Ringhals NPP EPOs could contact the emergency group at the Vattenfall BU Nuclear Crisis Management Team; Oskarshamn NPP accordingly may ask for help from the E.ON Group. The Ringhals NPP EPO has the option to contact the European office of Westinghouse in Brussels for technical consultations for the Pressurised Water Reactor (PWR) units and for Ringhals 1, the Westinghouse BWR-office at Västerås, Sweden. These contacts are available on a 24/7 basis.
All NPPs are equiped with an ECR in addition to the MCR. Habitability of Main and Emergency Control Rooms following filtered venting has been summarized during the country visit as follows:
Forsmark:
For units 1 and 2, ECR isolation is automatically triggered by a SBO. For unit 3, the ECR isolation function requires the availability of the emergency diesels. If there is the risk of radioactive releases, the emergency ventilation system is started as well. The system contains carbon filters to remove halogens and aerosols (for all units, the emergency diesels are required to perform this function).
The filtered venting is passive, however, if needed, related valves can be manually operated from a shielded, easily accessible local control station. The placement of the local control stations is specifically chosen in such a way to minimize personnel exposure due to releases following filtered venting.
Oskarshamn:
Controlled filtered venting via MVSS gives the opportunity to control the exposure to all personnel on site. Before filtered venting is conducted, communications to all MCRs on site are established and, in case of unfavorable wind direction, the MCRs are temporarily abandoned. The filtered venting is passive, however, if needed, related valves can be manually operated from a shielded, easily accessible local control station.
Ringhals:
Several conditions (Safety Injection signal, high radiation, manual actuation) will trigger "Recirculation Mode" of the Control Room Ventilation will be activated during a use of Containment Filtered Vent (CFV).
A successful CFV sequence with no other bypass is supposed to give an outdoor dose of less than 1 Sv/24 hr "at the fence". The shielding and ventilation of the MCR is supposed to give a much lower dose.
Establishment of a remote emergency rescue centre is being considered.

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

Although no plant-specific details are provided in the national report, there is a general description of the licensees' procedures and guidelines for accident management.
The report reflects the different approaches of the SAM organizations, as well the different sets of EOPs and SAM documentation:

- Forsmark have symptom-based EOPs that cover also the SAM but less prescriptively. A "knowledge based manual" for SAM is also available to guide the plant manager to select the appropriate strategies during the accident development.
- Oskarshamn have symptom-based EOPs/SAMGs that integrate the SAM strategies.
- Ringhals 1 has event-based EOPs. For symptom-oriented accident management, procedures called "Generalen" are used. During shutdown states additional guidance is found in "Korporalen".
- Ringhals 2, 3 and 4 utilise Westinghouse Owners Group approach, with transition between symptom based EOPs and SAMGs.

During the plant visit it was verified that the procedures covered also plant shutdown states and events occurring in the SFPs. It was also verified that training in the use of SAMG is conducted periodically. Also, a general exercise on emergency preparedness, with all relevant sections of the plants involved, takes place every three years. It is suggested that SSM considers further enhancing of SAMG training.

4.2.1.3 Hardware provisions for severe accident management

After the Three Mile Island accident, the Swedish government decided that all Swedish NPPs should be capable of withstanding a core melt accident without any casualties or ground contamination of importance to the population. This resulted in an extensive backfitting for all Swedish NPPs, including:

- Filtered containment venting through an inerted MVSS with a decontamination factor of at least 500.
- Independent containment spray water supply (mobile units and/or firefighting system)
- Passive Autocatalytic hydrogen Recombiners (PWR)
- Flooded lower drywell in BWR aiming to stabilize ex vessel molten corium.

All Swedish BWR containments are inerted with nitrogen since their original design to avoid hydrogen risks.

The Filtered Containment Venting Function (FCVF) protects the containment from overpressure in case of severe accidents. Filtered containment venting is installed to reduce release to less than 0.1 % of caesium-134 and caesium-137 and other ground contaminating isotopes in the events of severe accidents for an equivalent of a 1800 MWth reactor. The passive operation of the filtered venting system (that activates close to the design pressure through a burst disc) is possible for at least 24 h. No manual action is needed during the first 8 h for filtered venting system operation. The possibility to manually open and close the filtered venting system line also exists.

In the event of a severe accident, the residual heat removal function could be performed using the ordinary containment sprinkler system in recirculation mode. In case this fails, the containment sprinkler system can be supplied with firewater by a mobile external supply and the steam can be released through the MVSS, thus providing an UHS.

The hardware provisions for SAM are qualified against DBE and other external hazards. This should be also ensured for mobile equipment and its storage.

4.2.1.4 Accident management for events in the spent fuel pools

The strategies for accident management in the SFPs are based on maintaining sufficient coolant inventory so that severe accidents can be effectively eliminated. Make-up of the pools is possible with the use of fire fighting water. This action must be performed before the onset of harsh conditions (humidity, temperature, radiation) in the spent fuel area.

A conservative loss of cooling scenario has been analyzed for Forsmark 1, 2 and 3. In cases of lost cooling, with a full power un-decayed reactor core loaded into the spent fuel pool, the required 2 m water coverage for radiation shielding will not be lost until at least 23 hours.

In the event of a SBO at Oskarshamn 1, 2 or 3, there is currently no permanent system that can be used for cooling the SFPss. A conservative calculation of the available time shows that there are about 18 hours available for Oskarshamn 1, 40 hours for Oskarshamn 2 and 21 hours for Oskarshamn 3 before the pool temperature reaches 100°C. Taking into account adequate radiation protection (i.e. 2 m of water above the fuel) there are about 91 hours for Oskarshamn 1, 6 days for Oskarshamn 2 and 74 hours for Oskarshamn 3 available to take measures.

For the SFPs at Ringhals NPP, there are in general several possibilities for cooling, but most of them require that the SFPs buildings are habitable. For Ringhals 1, the time from loss of cooling of the SFPs to the onset of boiling is, conservatively during refueling, 5 h (14 h under realistic assumptions), and to a loss of shielding, conservatively 41 h (91 h under realistic assumptions). For Ringhals 2, 3 and 4, the available time from a loss of SFP cooling to the start of boiling is, conservatively during refuellin, around 2 hours (9 h under realistic assumptions) and to a loss of shielding, conservatively around 16 hours (48 h under realistic assumptions) . Once water levels in the SFPs have decreased through boiling, or because of structural failure e.g. after an earthquake, and caused a loss of shielding, there are only a few SAM measures available.

For all Swedish NPPs the time to boiling, loss of shielding and fuel uncovering is highly dependent on whether the plant is in normal operation with limited amounts of fuel in the storage pools, or in an outage for refuelling with often higher nuclear inventories of recently discharged fuel. During outages, adequate shielding could be lost within 16 hours (Ringhals 1) – 144 hours (Oskarshamn 2), while the times are extended to one week or more for a plant in normal operation.

Generally, the measures for handling a loss of SFP cooling when the SFP-building is habitable are robust and adequate. Once the SFP-building is no longer habitable there are very limited possibilities to re-establish SFP cooling. Monitoring equipment is not qualified for 'hot and wet' conditions. There are no planned mitigation measures in place in case of fuel damage.

It has to be noted, that the national report does not consider leakage of the borated PWR SFPs as it is stated that considered events including seismic events would not damage the SFPs integrity. This also means that there is no further discussion in the national report concerning sub-criticality in the PWR SFPs as boron is retained in the water phase during feed-and-boil off, allowing unborated make-up water to be used as long as the water level is kept below the brim (to avoid dilution). It was clarified during the country visit that heavy load dropping in the SFPs has been analyzed in the Safety Analysis Report and this event does not represent an unresolved issue.

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

Factors that may impede accident management at Swedish NPPs have been identified in the report and presented in an essentially satisfactory way for each area, but are in many cases common for several areas. The more important areas are summarized:

- In the case where it has not been possible to establish an EPO or if it is impossible to arrange for relieving staff within a reasonable period due to demolished infrastructure, the decision-making hierarchy will evidently will be affected.
- EPO are written for handling a severe accidents affecting one unit at a time. The accessibility of the affected site could be impaired due to radioactive releases and high dose rates resulting from multiple unit accidents. Also manual severe accident mitigation operations might be affected.
- There are procedures in place for assembly points, abandoning and establishing of EPOs, turnover, evacuation, etc. These procedures do currently not take into account high radiation levels and demolished/damaged buildings.
- Some of the functions included in the EPOs have so few personnel allocated that after a few days it could be difficult to sustain shift operation on a 24 h basis, especially if more than one unit is affected.
- Food supplies are available in emergency control centre but they only cover the requirements for a few days.
- Supply of oil for diesel generators and supply of nitrogen could be a problem in the longer perspective, if the infrastructure is and remains damaged.
- In the long-term, the radiological effect on the environment will be highly dependent on the plant's ability to handle large amounts of radioactive contaminated water.
- Problems with communication tools and lighting might make control and management difficult

These factors will be reflected in the enhancement of the emergency arrangements.

4.2.2 Margins, cliff edge effects and areas for improvements

4.2.2.1 Strong points, good practices

After the TMI accident, the Swedish government decided that all Swedish NPPs should be capable of withstanding a core melt accident without any casualties or ground contamination of importance to the population. This resulted in an extensive backfitting for all Swedish NPPs. It was assumed during design that the environmental protection requirements can be met if containment integrity is maintained during the accident sequence (core melt-scenario) and that the releases and leakage from the containment can be controlled and treated. For the most part, the SAM systems and procedures currently in place were developed during the 1980s and are part of the design bases of the plants (see chapter 4.2.1.3).

Also, the national report highlights that the communication solution RAKEL chosen by Oskarshamn NPP was noted as a "Good practice" at the latest IAEA Operational Safety Team (OSART) review.

The regulators overall assessment is that questions specified in the ENSREG document have essentially been answered by the Swedish licensees in an acceptable way and that the assessment and presentation of the NPPs' ability to cope with the specified challenges beyond the design basis have been described in a satisfactory manner at the present stage of the ongoing evaluations.

4.2.2.2 Weak points, deficiencies (areas for improvements)

The SAM fulfils design requirements as specified in the national regulations. For the containment filtered venting systems, the design requirement is passive operation for at least 24 hours. However, the containment filtered venting systems are not designed for accident scenarios with prolonged duration. The national report concludes that re-evaluation of the system for the long-term operation of more than 24 hours is needed.

.According to the national report in the event of a SBO including loss of alternate AC power, there are currently no permanent systems that can be used for cooling the SFPs. The national report also concludes that make-up of the pools is possible with use of fire water, but it has not been verified that existing accident management procedures fully cover all manual actions needed or consider all possible situations that could arise, for instance if the shielding is lost due to a low water level in the SFPs, it may be problematic to establish this make-up. Results from the Swedish stress tests shows that depending on residual heat generated by the spent fuel in the storage pools, adequate radiation shielding could be lost at some Swedish NPPs' after 16 hours.

The cliff-edge effects have been addressed and presented by the licensee in an essentially satisfactory way. However, as it is stated in the national report the presentation could have been more complete with regard to the time before a specific cliff-edge is reached and the linkage between identified cliff-edge effects and recommended potential improvements. Concerning cliff-edge effects for the emergency preparedness organization, the regulatory body has found that these are specified explicitly in the text only for Oskarshamn site. This should be addressed for the other sites as well.

4.2.3 Possible measures to increase robustness

4.2.3.1 Upgrading of the plants since the original design

The upgrading of the Swedish NPPs since their original design has been mostly done following the Three Mile Island accident (see chapter 4.2.1.3).

Also, the implementation of safety improvements, including severe accident mitigation provisions, was performed in accordance with the SSM regulations SSM 2008:17. According to these requirements SAM systems were installed at the Swedish NPPs. The related upgrades are plant-specific. The list of installed hardware provisions is provided in the national report.

4.2.3.2 Ongoing upgrading programmes in the area of accident management

As noted in the previous section the implementation of safety improvements, including severe accident mitigation provisions was performed in accordance with the regulation SSM 2008:17. Additional improvements were identified in the stress tests. While some of these improvements have been completed, others are ongoing or have only recently been completed:

- Additional assessment of the containment integrity in the event of a severe accident, including measures if necessary (all reactors: 2012).
- Strategy for long term cooling of a severely damaged core, including physical measures if necessary (all reactors: 2012, some measures before 2012) .
- Independent emergency core cooling system. (All reactors, studies ongoing).
- Change to two phase flow relief valves (Ringhals 1: 2011, Oskarshamn 2: 2013) .
- Measures to vent incondensable gases from the reactor vessel (Ringhals 1: 2012) .
- Analysis of the adequacy of emergency control, including upgrade measures, if necessary (Oskarshamn 3: 2012, Ringhals 3,4: 2012) .
- Installation of a new emergency control (Forsmark 1: 2011, Forsmark 2: 2012, Oskarshamn 2: 2013).

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

4.2.4.1 Upgrading programmes initiated/accelerated after Fukushima

The assessments done by the licensees and the review carried out by the regulator in the area of SAM has resulted in conclusions and recommendations for further analyses, which should be considered as potential measures to increase the robustness of the plants.

A summary of the conclusions that the licensees have proposed can be found below. It should be noted, that not all conclusions have been addressed by all licensees and they are not relevant for all units.

- The enhancement of the SAM system has to be considered in all aspects. The existing accident managing system is neither designed nor analysed to work independently from support off-site and without power supplies for safety systems for a longer period of time. The stress test has identified several areas where problems could occur, regarding equipment, staff supplies and operating procedures.
- Capability to handle more than one affected unit: In principle the emergency response organization is designed to handle a severe accident with core melt at only one unit at a time. If two or more reactors are subjected to a severe accident, the current staffing levels and shift-rotation could lead to difficulties in carrying out all required accident management measures due to the limited human resources available. At present, all simulator trainings and emergency trainings are performed with the assumption that only one unit is affected. However the containment filtered venting is individual for each unit, except for Oskarshamn unit one and two who share filter which could affect its endurance. A severe accident at multiple units would thus still result in limited doses to the public, as long as the containment barrier is intact.
- Capability to cool the spent fuel pool: In the event of a total loss of power, there is currently no system that can be used for cooling the spent fuel pools, however, in this case, make-up of the pools is possible with use of fire fighting water. If the shielding is lost due to a low water level in the spent fuel pools, it may be a problem to establish this make-up due to high radiation levels.
- Introduce/enhance alternative back-up power sources and systems to inject water to the reactor vessel to handle SBO: All existing systems for injecting water to the reactor vessel are dependent on external power supplies or diesel back-up (supported also by gas turbine). In the event SBO there is no possibility of injecting water into the reactor vessel. For the PWRs, cooling the core via the steam generators is still possible with emergency feed water as long as there is battery power.
- Enhance management of hydrogen in the containment (in the long term) and reactor building: The current emergency preparedness has not considered the possibility of hydrogen leaking out and accumulating in the reactor building.
- Enhancement of radiation monitoring.
- Communication system and call-in system: The present system to call-in personnel may not be reliable enough in all foreseen situations.

- Managing loss of containment integrity: SAM strategies are focusing on using the dedicated systems and procedures, which are all aimed to maintain the containment integrity with the use of independent containment spray and containment filtered venting systems. A loss of containment integrity with larger releases of radioactive material is not included in the considerations.
- Off-site located emergency control centre: Evaluation of the need for an alternative off-site emergency control centre, considering advantages as well as disadvantages, should be carried out.

An implementation plan for measures identified by the licensees or others is not included in the Swedish national report. At this stage there are no decisions on measures to be taken and therefore there is no time schedule for the potentially improvements. SSM will request the licensees to present actions plans for additional improvements in spring 2012, which will be afterwards reviewed by SSM taking into account the outcome of the stress tests.

4.2.4.2 Further studies envisaged

The licensees have also identified the following recommendations for further evaluations and reassessments. It should be noted that not all these recommendations have been identified by all licensees and not all are relevant to all units:

- The enhancement of the SAM system in all aspects: The question on how to enhance existing accident management system to achieve a robust system capable to handle Fukushima-like conditions must be further investigated.
- Capability to handle more than one affected unit: A thoroughly developed plan for managing several, simultaneously affected units should be made, including mobile equipment for supply of water and power, staffing and procedures.
- Capability to cool the spent fuel pool: The following improvements should be considered: Permanent filling pipes from a protected location to the spent fuel pools in units that do not have them yet. Robust/simple level measurement in the fuel pools that can be read from a radiation protected location. Analyses of the conditions with a boiling fuel pool with respect to high temperatures, radiation, pathways for water and steam, and procedures.
- Introduce/enhance alternative power back-up sources and systems to inject water to the reactor vessel to handle SBO: The need for independent core cooling systems and mobile diesel back-up units should be further investigated. Also the need for diesel back-up generators for the charging of batteries and to power the emergency control centre should be included.
- Enhance management of hydrogen in the containment and reactor building: The possibility of accumulating hydrogen in the reactor building should be analysed and possible countermeasures implemented. Decision support for handling hydrogen in a lengthy sequence, both in the reactor building and containment, should be improved.
- Managing re-criticality: A need has been identified for updating of the strategies for handling re-criticality, both for detection and countermeasures.
- Measuring radiation levels: There is a proposal to introduce more dose rate monitors in the reactor building to support accident management.
- Communication system and call-in system: To ensure the call-in of personnel, the need for new call-in methods should be investigated. Alternatives to be used are e.g. satellite phones, RAKEL (radio) etc.
- Managing loss of containment integrity: Strategies for handling cases with lost containment integrity should be developed.
- Off-site located emergency control centre: Evaluation of the proposed advantages and disadvantages of replacing the existing substitute command centre with a suitable facility outside the plant area to avoid both being lost to a common-cause event.

The regulator's assessment of the above list is that the conclusions and recommendations for potential improvements proposed by licensees are relevant and reasonable. However, in addition to measures identified by the licensees during the assessment of SAM, the regulatory body has identified the following issues which should also be considered by the licensees as potential measures to increase the robustness of the plants:

- Guidelines for emergency response organization for handling long-term accidents.

- Long-term handling of the containment chemistry (for a year or more).
- The functioning of the containment filtered venting system in the long-term (more than 24 hours).
- The performance of the common system for filtered containment venting at Oskarshamm 1 and 2.
- Analysis of the possible destruction of infrastructure as well as destruction on-site and of safety systems and barriers, must be carried out with regard to a wider set of scenarios and not just the accident scenarios identified in the stress tests.

The regulator's conclusion regarding the emergency response organization is that all licensees have a good description of strategies, instructions and equipment. Weak areas and suggestions for improvements as a result of the stress test are shown. However, the regulator is of the opinion that the following areas need further and deeper evaluation:

- Emergency planning should comprise severe emergency situations involving all units at the site.
- Accessibility and functionality of the ordinary on-site emergency control centre and the alternative emergency control centre should be secured with regard to location, protection, robust communications systems and power supply.
- Personal safety issues have to be re-assessed. The difficulties that will be encountered due to rapid changes of radiation and contamination levels during execution of accident management measures needs to be considered. Routines for the emergency response organization should be further developed regarding the protection of the personnel in severe accident environments. Access to protective equipment, dosimetry and management, as well as working procedures need to be clarified.
- The need for common resources available at the site for assisting with multi unit severe accidents should be evaluated since the currently available resources may not be sufficient if all units at the site are affected (even in the short term).
- Action plans should be set up where the need for external resources, both human and material, should be identified along with the information from where and how they can be obtained, as well as the time for their transport to the site.
- Areas critical for accident management in the long-term should be identified. These can include for example the need for external resources, routines for access to the site and means to manage the larger quantities of radioactive water.

The regulator intends to carry out deeper analyses of all issues raised in the stress test and the licensees' suggested solutions for these issues. Based on the licensees' reports the regulator will take decisions on actions, which will include:

- issues raised in the stress test by the licensees
- issues raised by the authority's review of the stress test
- issues outside the scope of the stress test, which should be dealt with in connection to the stress test issues.

The issues will be prioritized for short term and long term actions. New demands might trigger a later revision of regulations.

4.2.4.3 Decisions regarding future operation of plants

The regulator has reviewed the stress tests carried out by Swedish licensees and drawn the conclusion that they were largely performed in accordance with the specification given within the EU. The scope and depth of these analyses and assessments are essentially in accordance with ENSREG's definition of 'a comprehensive assessment of risk and safety'. The stress tests show that Swedish facilities, organisations and procedures are robust, but they also identified a number of possibilities to further strengthen this robustness. In a number of cases, the stress tests indicate deficiencies or deviations from safety requirements. In these cases, the regulator will require the licensees to make improvements so that the facilities fulfil relevant requirements. SSM nevertheless assesses that none of the deficiencies currently identified, nor the measures needed, are of such a nature that the continued operation of the facilities needs to be put into question.

4.3 Peer review conclusions and recommendations specific to this area

The overall conclusion is that questions specified in the ENSREG document have been answered in an acceptable way and that the assessment and presentation of Swedish NPPs' ability to cope with the demands beyond the design basis have been described in a satisfactory way. Important measures for SAM were already introduced in Swedish NPP in the eighties, well before the Fukushima accidents. SAM measures are being enhanced in line with new knowledge.

The assessments done by the licensees and the review made by the authority in the area of SAM indicated several areas for safety improvements at the Swedish NNPs:

- consideration of multiple unit events including long term effects
- long term performance of the filtered venting system (> 24 hours)
- consideration of natural disasters leading to loss of infrastructure
- concepts to manage large volumes of contaminated water
- accumulation of hydrogen in rooms or buildings outside the containment.

After the implementation of the proposed improvements, the robustness of Swedish NPPs will be further increased for SAM and emergency response.

In additional, to recommendations for potential improvements identified by the licensees and authority during the assessment of SAM and emergency preparedness (see chapter 4.2.4.2), following items could also be considered as potential measures to increase the robustness of the Swedish NPPs:

- Instrumentation for measurement of necessary parameters in the spent fuel storage (water level, temperature) in the event of severe accident as well the resistance of the equipment from harmful environment conditions;
- Enhancement of the accident management programmes (SAMGs, EOPs) for all plant states including spent fuel pools and multi-units events;
- EPO training and drills for extended scope of the accident management such as consideration of multiunit accidents under conditions of infrastructure degradation with the need to coordinate all parties at the state level.

List of acronyms

AC	Alternating Current
CFV	Containment Filtered Vent
BDB	Beyond Design Basis
BWR	Boiling Water Reactor
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DC	Direct Current
DG	Diesel Generator
ECR	Emergency Control Room
EDG	Emergency Diesel Generator
ENSREG	European Nuclear Safety Regulator Group
EOP	Emergency Operating Procedure
EPO	Emergency Preparedness Organisation
IAEA	International Atomic Energy Agency
GT	Gas Turbines
HCLPF	High Confidence Low Probability of Failure
I & C	Instrumentation and Control
KC	Emergency Control Centre
LOCA	Loss-Of-Coolant Accident
LOOP	Loss Of Offsite Power
MCR	Main Control Room
MVSS	Multi Venturi Scrubber System
NPP	Nuclear Power Plant
OBE	Operational Basis Earthquake
PAR	Passive Autocatalytic Recombiner
PGA	Peak Ground Acceleration
PSR	Periodic Safety Review
PSA	Probabilistic Safety Analysis
PWR	Pressurised Water Reactor
RWST	refueling water system tank
SAM(G)	Severe Accident Management (Guidelines)
SBO	Station Blackout
SEWS	Screening Evaluation Work Sheet
SFP	Spent Fuel Pool
SG	Steam Generator
SHA	Seismic Hazard Assessment
SL	Seismic Level
SMA	Seismic Margin Assessment
SMHI	Swedish Meteorological and Hydrological Institute
SSCs	Structures, Systems and Components
SSM	Swedish Radiation Safety Authority
SQUG	Seismic Qualification Utility Group
UHS	Ultimate Heat Sink
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators' Association