Post-Fukushima accident

Finland

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 in Japan on 11th March 2011 triggered the need for a coordinated action at EU level to identify potential further improvements of Nuclear Power Plant (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 nuclear power plant. It is a part of the Final Report combining the results of the Topical Reviews and Country Reviews.

1.0 General plant data

The Finish National report (FI-NR) covers all the operating nuclear power plants (Loviisa 1 and 2, Olkiluoto 1 and 2) and the unit under construction (Olkiluoto 3). The intermediate storages of spent fuel in Loviisa and in Olkiluoto are included in the stress tests. The new NPP units to be constructed which do not yet have a construction license are not considered.

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

FI-NR has been prepared in accordance with the ENSREG specifications, and addresses the topics in the specifications. FI-NR summarizes the results of the regulatory review of the licensee reports. FI-NR meets the ENSREG Specifications. The required data and main characteristics of the nuclear units are presented at a level that allows overview of the plant response to the events specified in the report. The potential cliff-edge effects are also identified.

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

FI-NR sufficiently fulfilled in respect to design basis and generic issues, flooding, earthquakes and extreme weather conditions. The information to assess response of the nuclear unit as well as the identification of safety margins is consistent with the ENSREG methodology. The Partner Country provided comprehensive answers and clarifications to the written comments as well as to questions asked during the country presentation that completed the information provided in the FI-NR. The information in the Severe Accident Management (SAM) Chapter adequately reflects the issues that are required to be considered and corresponds to a certain degree to the ENSREG specifications.

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

The Partner Country stated that the NPP is in compliance with the current licensing basis represented by the Finish national standards, regulations on nuclear energy and radiation safety and YVL Guide (YVL (Ydinvoimalaitosohjeet)/Regulatory Guides on nuclear safety). The particular regulations applicable to the topics of the Stress Tests are given in the corresponding chapters of the FI-NR. The plants were designed, constructed and licensed to operate taking into account the requirements of nuclear codes and standards, as well as best practice procedures applicable to the seismic qualification of safety related structures, systems and components (SSC). Assessment against the current licensing/safety case appears adequate.

The legal basis introduced in Chapter SAM is very detailed regarding the severe accidents, and it is closely followed for the new plants. It contains also the statements regarding compliance of existing NPPs with YVL Guide on safety principle in NPP design issued in 1982, and updated version of Guide YVL 1.0 has been issued in 1996. The Guide is in compliance with the respective Western European Nuclear Regulators' Association (WENRA) reference levels (WENRA 2008) in general. However, from the report provided, and clarified during the country visit, Finnish acts and Government Decrees are applied to existing plants as such with some exemptions described in the Decree 733/2008.

Regarding compliance of Olkiluoto 3 (OL3) with national requirements Radiation and Nuclear Safety Authority (STUK) is reviewing the detailed design; the plant and system level design were reviewed during the construction license phase in 2004.

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

Comprehensive assessments of the current safety margins at the plants as well as measures which can be envisaged to increase robustness of the plants are made for all events that are considered in the ENSREG Specifications. These assessments involved the four units in operation, spent fuel pools (SFPs), and one unit under the construction.

The whole qualification process from external events hazards to approved equipment qualification criteria was reviewed in order to understand better the formation of external events design margins of NPPs. Station blackout (SBO) and loss of ultimate heat sink (UHS), as well as their combination was assessed for power as well as shut down modes. The SAM addresses all components, which are considered essential for management of severe accidents and which are to major extent already implemented in existing plants and fully covered in the NPP under construction. Current margins and degree of robustness for each plant are also mentioned and considered adequate but only a very few quantitative indicators are given in the FI-NR. It is however beyond the possibilities of the peer review to assess the quantitative level of robustness of such provisions.

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,…)

STUK has reviewed the licensee reports in terms of completeness, the adequate application of the ENSREG methodology and the correct categorization of the referenced documentation (if already done by the licensee). In summary, the adequate application of the ENSREG methodology was confirmed. FI-NR appears to be open and transparent. Various potential improvements identified. A well defined programme of work is expected in June 2012.

The regulatory treatment applied to the actions and conclusions presented by the utilities are described in adequate detail, such that the active role of the regulatory body in the whole process could be observed.

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

2.1.1.1 Regulatory basis for safety assessment and regulatory oversight

There is the Government Decree on the Safety of Nuclear Power Plants [733/2008] sets requirement for siting of a plant in Section 11: STUK has issued guides YVL 2.6 (1988, replaced by update 2002) and YVL 2.8 (1996, re-placed by update 2003) for giving general requirements for the design and demonstration of seismic resistance with corresponding nuclear safety as well as for the monitoring of earthquakes and their effects during the operation of the nuclear power plants. YVL 2.6 requires site and NPP specific design basis earthquake (DBE) criteria in order to ensure the safe shut-down including the cooling of the radioactive inventory. Those criteria are corresponding with IAEA NS-G-3.3 requirement 5.3 with footnote 1 [NS-G-3.3]. The goal has been to assure that seismic threats to safety remain extremely small.

2.1.1.2 Derivation of DBE

STUK has issued guides YVL 2.6 for giving general requirements for the design and demonstration of seismic resistance with corresponding nuclear safety as well as for the monitoring of earthquakes and their effects during the operation of the nuclear power plants. YVL 2.6 requires site and NPP specific DBE criteria in order to ensure the safe shut-down including the cooling of the radioactive inventory. Those criteria are corresponding with IAEA NS-G-3.3 requirement 5.3 with footnote 1 [NS-G-3.3].

2.1.1.3 Main requirements applied to this specific area

In Finland the DBE as site specific design criteria are defined so that, in the current geological circumstances, stronger earthquakes are anticipated not more often than once in a hundred thousand years (10^{-5}/a) on median confidence level. Current understanding is that the expected median frequency of DBE for Loviisa is less than 10^{-6}/a and for Olkiluoto less than $8 \cdot 10^{-6}$/a.

2.1.1.4 Technical background for requirement, safety assessment and regulatory oversight

The definition of DBE has been presented and justified based on statistic study of the area's seismic history, regional and local geology as well as tectonics. Due to the fact that there are no registered strong motion acceleration recordings of earthquakes in Finland, earth-quake recordings from Saguenay and Newcastle from Canada and Australia are taken as sources of initial data for the attenuation equations. The Saguenay and Newcastle regions have geological and tectonic similarity to Fennoscandia.

2.1.1.5 Periodic safety reviews

The Finland report provides good evidence that periodic safety reviews (PSR) are carried out regularly and have led to significant improvements.

2.1.1.6 Conclusions on adequacy of design basis

The Finland report provides sufficient information to enable the conclusion that the design basis is adequate in relation to international standards.

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

The Finland report identifies that the licensees have confirmed that their plant is compliant with national regulations and STUK guides and request following from the Fukushima event.

2.1.2 Assessment of robustness of plants beyond the design basis

2.1.2.1 Approach used for safety margins assessment

The report provides that the site specific structural design parameter is seismic ground response spectrum, where the zero period value is peak ground acceleration (PGA). Corresponding horizontal component of PGA is analysed for Loviisa 0.056 g and for Olkiluoto 0.082 g. Both sites' ground responses are covered with enveloping spectra. Finally the PGA value in Finland is set 0.1 g as the minimum level suggested by IAEA [NS-G-1.6, NS-G-3.3]. It is also claimed that justification is based on the seismic Probabilistic Safety Assessment (PSA). It is claimed that sound design provides approximately a high confidence of low probability of failure (HCLPF) point on representative fragility curves.

2.1.2.2 Main results on safety margins and cliff edge effects

In order to develop and verify seismic design of NPPs in Finland, research project SESA has been established at the end of 2010 for the Finnish Research Programme on NPP Safety 2010–2014. Safety design margins of NPPs are studied by assessing seismic hazards and the potential effect of earthquakes on plant safety requirements and design criteria for new installations. Therefore the whole seismic qualification process from seismic hazards to approved equipment qualification criteria will be reviewed in order to understand better the formation of seismic safety design margins of NPPs.

In the case of Loviisa 1&2, a seismic PSA has been completed for Loviisa 1 & 2 in 1991 and 2010 although at present it does not include the containment. No information presented regarding the cliff edge effects for the containment.

In case of Olkiluoto 1 & 2, due to the low seismicity of the site, no processes for ensuring seismic safety critical SSCs for achieving safe shutdown after earthquake, or limiting indirect effects are specified especially for earthquakes.

Common maintenance, testing and monitoring of SSCs is considered to include also preparedness against seismic events.

Earthquake was not demanded as a design basis for the plants currently in operation. Seismic requirements are taken into account in modifications and building of new systems and structures since 1997. Living seismic PSA is used to verify appropriate safety level for safe shut down after earthquake.

Containment's HCLPF seismic capacity is above 0.3 g; inner wall 0.33 g and outer wall 0.43 g.

In case of Olkiluoto NPP unit 3, HCLPF capacity against reactor containment integrity is 1.26 g.

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

The report claims that the confirmatory assessments have been conducted by the licensee in response to the Fukushima accident.

2.1.2.4 Possible measures to increase robustness

The report provides: e.g. a more detailed evaluation of the seismic stability of spent fuel pools and the fire fighting systems against earthquakes beyond the current DBE level at the NPPs site.

In case of Loviisa 1&2, certain plant modifications will decrease the seismic risk further. Additionally, the ongoing automation renewal includes replacement of plant equipment with new, seismically qualified equipment. This will further decrease the seismic risk. Licensee is studying seismic fragilities of pool structures in reactor containment and pools in spent fuel storages. Analyses cover PGA levels of 0.1g, 0.2g, 0.3g and 0.4g in order to research seismic capacity such structures on and beyond current DBE level combined with possible boiling of pool water. Also seismic fragility of fire water systems is under study.

In case of Olkiluoto 1&2, Steel racks for batteries are being modified according to the replacement schedule. Above mentioned modifications will decrease seismic Core Damage Frequency (CDF). Further improvement to seismic capacity has been done, especially for eliminating relay chatter: replacement of low voltage switchgears, one train in Olkiluoto 2 has been installed in 2011. Planned work in future are: 2012 Olkiluoto 1 two trains; 2013 Olkiluoto 2 two train; 2014 Olkiluoto 1 two remaining trains; 2015 Olkiluoto 2 one remaining train.

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

To respond to STUK's requirements after Fukushima accident, Licensees are studying seismic fragilities of those spent fuel pool structures, which were not originally designed against earthquake. Seismic capacity of fire water system will be completed to cover also the fragilities of piping and estimation of corresponding consequences.

In case of Olkiluoto 1 & 2, modification has been done for the anchoring improvement of relay cabinets to prevent relay chatter. Work is ongoing.

2.1.3 Peer review conclusions and recommendations specific to this area

The Design Basis has been explained and is considered to be acceptable in comparison with international standards. There is evidence that a PSR process has been applied. Measures on increasing of earthquake robustness are ongoing.

During the country visit, it was noted that the updated seismic PSA has been prepared for both Loviisa and Olkiluoto NPPs. STUK is currently performing the review. Based on review results, it will be possible to conclude on the qualification status of the critical SSC identified in the seismic PSA.

With this regard, STUK should consider additional assessment of critical SSC with respect of PGA = 0.1g (as recommended in the IAEA Safety Guide NS-G-3.3).

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

The approach is similar to that adopted for earthquake events.

More detailed requirements are set forth in guides YVL 1.0 (Safety criteria for design of NPPs), YVL 1.10 (Safety criteria for siting a NPP) and YVL 2.8 (Probabilistic safety analysis in safety management of NPPs).

The Finnish regulations do not include explicit quantitative requirements on the flood level which shall be considered in the design of NPPs. The design values shall be based on clarifications conducted or contracted by the licensee and reviewed by STUK in cooperation with the appropriate expert organizations, especially the Finnish Institute of Meteorology.

2.2.1.2 Derivation of DBF

For Loviisa NPP, the frequency estimate for the sea water level to rise above the critical 3 m is approximately $4 \cdot 10^{-7}$/a. During refuelling, the plant is more vulnerable to high seawater level. However, the annual refuelling outages are schedule for late summer - autumn when the seawater levels are lower than during winter.

Olkiluoto 1 and 2 NPP units have been designed against flooding up to the level +3.5 m in the N60 coordinate system. As the mean sea level is about –0.2 m in the N60 system, the units are protected against sea level rise to 3.7 m above mean water level. As stated during the country visit, the frequency of exceeding sea-water level +3.5 m (N60) is estimated to be less than less than $1 \cdot 10^{-8}$/a.

The characteristics of the site and design basis flood are explained in connection with OL1 and OL2. As stated during the country visit, the frequency of exceeding seawater level of +3.5 m (N60) is estimated to be less than $1 \cdot 10^{-8}$/a. For Olkiluoto 3, the critical seawater level for safety systems is the same as for units OL1 and OL2.

2.2.1.3 Main requirements applied to this specific area

See 2.2.1.2 above

2.2.1.4 Technical background for requirement, safety assessment and regulatory oversight

According to the estimate made by the Finnish Meteorological Institute, a height of +2.50 m at Loviisa NPP would require a combined wind speed of 30…40 m/s as a 10 minute average or 3-second gust speed of 40…60 m/s at a 10 metre elevation. Seawater level exceeding +3 m would result in flooding of the plant through outer doors. Flooding of underground levels would result in loss of, e.g., electricity distribution systems, emergency feedwater systems and emergency core cooling system (ECCS). Water level above about +3.2 m would probably damage also the auxiliary emergency feed water pumps, and result in core damage.

According to the Finnish Institute of Meteorology, it is highly improbable that the design level of +3.5 m would be exceeded at Olkiluoto site. The frequency of exceeding seawater level + 3.5 m (N60) is estimated to be less than $1 \cdot 10^{-8}$/a.

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

The Finland report provides evidence that PSRs are carried out regularly and have led to significant improvements.

For Loviisa NPP, PSA assumes that the rise of seawater above the +3.0 m level will lead to core damage. Conservatively, no credit is given, e.g., to the flood spreading time inside the buildings.

Based on recent periodic safety reviews (1997, 2008), PSA on external events, and the national clarifications following the Fukushima accident, Olkiluoto 1&2 and the spent fuel storage comply with their current licensing basis.

2.2.1.6 Conclusions on adequacy of design basis

The approach to defining flood requirements is in line with national standard.

For Loviisa NPP, the core damage risk due to high seawater level is estimated to constitute 3% of the current total risk. The risk due to high seawater can be considered small but it is not negligible. The potential vulnerabilities have been identified previously in PSA and PSRs, and the topic has been included in the process of continuous safety improvement. The stress tests did not reveal such new vulnerabilities that would require immediate measures.

For Olkiluoto NPP, the most severe effect of flooding exceeding the design basis would be loss of connections to the off-site power transmission grid and the loss of emergency diesel generators (EDGs), resulting in the loss of residual heat removal.

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

The reports claim that the risk due to high seawater can be considered small but it is not negligible.

For Loviisa NPP, deviations from the licensing basis have not been observed.

Based on recent PSRs (1997, 2008), PSA on external events and the national clarifications following the Fukushima accident, Olkiluoto 1&2 and the spent fuel storage comply with their current licensing basis.

2.2.2 Assessment of robustness of plants beyond the design basis

2.2.2.1 Approach used for safety margins assessment

In principle similar to the procedure reported in the case of earthquakes.

2.2.2.2 Main results on safety margins and cliff edge effects

There is evidence in the national report that the water levels were determined as the situation in which all the factors impacting the level would be at their maximum simultaneously. These factors are: total volume of water in the Baltic Sea; rise in the mean sea level as a result of strong wind; specific phase of a standing wave; low air pressure; and tide. The effect of precipitation on the sea water level has been assumed negligible compared to other factors.

The report claims that in the case of Olkiluoto site a definite maximum height of flooding cannot be derived on a physical basis. In some other countries, design values concerning external events are chosen so that their exceeded frequency is less than 10^{-4}/a. The water level with exceedance frequency of 10^{-4}/a is about +1.5 m (N60). The margin of this value to the de-sign basis is 2 metres. The frequency of exceeding seawater level +3.5 m (N60) is estimated to be less than 10^{-8}/a. Although the uncertainties associated with such low frequencies are very large, the margins can be considered adequate. The critical level + 3.0 m are well above the estimated theoretical maximum in the case of Loviisa.

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

The report claims that the licensee should provide a plan and schedule to ensure plant safety in case of abnormal sea level at the Loviisa and Olkiluoto sites.

2.2.2.4 Possible measures to increase robustness

To respond to STUK requirements after Fukushima accident, Licensee is studying the following improvements to reduce flooding risks.

For Loviisa NPP:

- Modernization the bulkhead gates used to close the cooling water discharge openings. The concrete bulkhead beams would be replaced with steel sluice gates equipped with seals. In the same connection, the top level of the gates would be raised from the +2.1 m level to +2.45 m, which corresponds to the top level of the intake pipe's gates. This would decrease the risk related to flooding during annual outages by the order of magnitude.
- Flood banks and new check valves for rainwater drains could be installed to prevent seawater from flowing inside the plant.
- Higher flooding barriers in the tunnels between the turbine and reactor buildings would prevent, or at least delay, water spreading inside the plant.

For Olkiluoto NPP:

- The door leading from the control room building to the reactor building at level –2.0 m opens in the direction of the reactor building. The water tightness and water pressure tolerance of doors leading to the basement of the reactor building and consequences of the eventual leakages will be investigated and, if needed, the water tightness and pressure tolerance will be improved.
- In case of a renewal of the diesel generators, they could be designed to also allow for air cooling. In this case, they may also be used in a scenario where the possibility to cool them using the shutdown secondary cooling or service water systems has been lost.
- The diesel generators are located in rooms which are separated into fire compartments, including a local control room. The water tightness of the diesel generator room and the local control room could be improved in parallel with the diesel generator renewal project. The improvement of the water tightness, for example raising the doorsteps, etc., would increase further the availability of diesel-backed electricity in the event of flooding at the ground level.

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

The report claims that the licensee is studying: modernization the bulkhead used to close the cooling water discharge openings, etc.

2.2.3 Peer review conclusions and recommendations specific to this area

The DBF has been explained and is considered to be acceptable in comparison with international standards. Margins above DBF are detailed. It is mentioned in Report about measures for improvement. There is evidence that a PSR process has been applied.

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,…)

The report claims that the only quantitative risk targets are given in the YVL 2.8 guides for PSA in Safety Management of NPPs.

2.3.1.2 Derivation of extreme weather loads

Derivation of severe weather events should be performed by the guides YVL 1.10 and YVL 2.8; Section 2.2.

The original design of the plant unit did not take into account all possible aspects of weather phenomena related to safe operation of plant or their combinations with other external conditions of natural origin. However, the plant preparedness and strength against external hazards has been improved due to the plant modifications performed using the principle of continuous improvement.

2.3.1.3 Main requirements applied to this specific area

As identified in 2.3.1.2.

2.3.1.4 Technical background for requirement, safety assessment and regulatory oversight

Weather phenomena and other extreme external conditions including the combinations of phenomena relevant at the plant units have been comprehensively analysed using the weather PSA, which is part of the living PSA. Such extreme weather conditions are e.g. extreme air and seawater temperature, high winds and storms (including tornado), heavy rainfall, lightening.

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

The Finland report provides evidence that PSR are carried out. The potential risks involved in the increasing oil transportation in the vicinity of plant have been assessed in the external hazard risk analysis as a part of PSA.

2.3.1.6 Conclusions on adequacy of design basis

Weather phenomena and other extreme external conditions including the combinations of phenomena relevant at the plant units have been comprehensively analysed using the weather PSA, which is part of the living PSA. The potential risks involved in the increasing oil transportation in the vicinity of plant have been assessed in the external hazard risk analysis as a part of PSA.

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

The plant preparedness and strength against external hazards has been improved due to the plant modifications performed using the principle of continuous improvement.

2.3.2 Assessment of robustness of plants beyond the design basis

2.3.2.1 Approach used for safety margins assessment

As identified in 2.3.1.2.

2.3.2.2 Main results on safety margins and cliff edge effects

The Licensees have proposed to provide a plan to secure decay heat removal to ultimate heat sink in extreme external events and to investigate the effect of extreme environmental temperatures to the plant safety.

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

See 2.3.2.4 below.

2.3.2.4 Possible measures to increase robustness

The licensees have the following plans:

Loviisa NPP:

- As an alternative UHS, the possibility to install independent air-cooled cooling towers with no connections to seawater systems or EDGs. The cooling towers would take care of decay heat removal of reactors and fuel pools of both units and of SFSPs. Preliminary design on the solution is ongoing, and the basic design is estimated to be ready until summer 2012.
- The need for further improvements on the diesel driven auxiliary emergency feedwater pumps. The investigation includes verifying the actual operation of each component of the system without Alternating Current (AC) power from the grid or diesel generators.
- The possibility to improve the diesel driven auxiliary emergency feed water (EFW) pumping station protection against flooding above +3.0 m level.
- Securing the electrical power supply for the pumps that are used to refill the water reservoir of the auxiliary EFW pumps.

Olkiluoto NPP:

- Attention will be paid to the cooling of ventilation in certain rooms containing electrical and Instrumentation and Control (I&C) systems, if thermal loads will rise in future.
- In case of a renewal of the diesel generators, they could be designed to also allow for air cooling.
- The water tightness of the diesel generator room and the local control room could be improved in parallel with the diesel generator renewal project.
- The dependency of the auxiliary feed water system from seawater cooling could be reduced by modifying pump circulation so that water is returned into the auxiliary water tank. Additional water may be supplied into the reactor via the auxiliary feed water system even when the secondary cooling and service water systems are not available.
- The yard around the plant units will be shaped to ensure the passage of water from the pools formed during heavy rain or seawater in cases of seawater channel blockage away from the power plant units and further into the sea. The planning of the tilling has already started based on the rainwater survey completed in 2010.
- In connection with the expansion, a probability-based risk analysis will be prepared for the SFP; it will also contain an analysis of the effects of extreme weather conditions on the spent fuel storage. Based on the risk analysis results, any needs for modifications (such as plant or disturbance procedure modifications) will be considered to ensure sufficient preparations for extreme weather conditions.

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

Loviisa NPP:

- The licensee has installed a backup diesel generator, common to both units in October 2011.

Olkiluoto NPP:

- To respond to STUK's requirements after Fukushima accident, Licensee is investigating the robustness of reactor, control room and auxiliary buildings against extremely high wind speeds.
- The study of effects of extremely low temperatures on spent fuel storage is to be included in the PSA study of the storage as part of its extension project.
- Licensee has stated that current procedures, including restrictions on power operation under extremely high sea water or outdoor temperatures are adequate. STUK is evaluating this assessment.

2.3.3 Peer review conclusions and recommendations specific to this area

The report provides that the original design of the plant unit did not take into account all possible aspects of weather phenomena related to safe operation of plant or their combinations with other external conditions of natural origin. But it was explained that the Design Basis Extreme Weather Conditions has been considered later. Operational experiences regarding the impact of extreme weather phenomena on plant operation have been taken into account in the design of preventive and corrective measures including technical modifications and plant procedures. An assessment of the drainage system capacity in case of high seawater level should be considered.

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

STUK specifies detailed safety requirements concerning the implementation of safety level in accordance with Government Decree 733/2008. There is also a comprehensive legal infrastructure that addresses IAEA requirements and all the relevant international conventions in force.

The safety requirements for NPPs in Finland are specified in a series of Regulatory Guides (YVL), which are divided into 8 categories based on the subject (e.g. general, systems, pressure equipment, building and structures, other structures and components, etc.). Relevant examples of Regulatory Guides are described below.

- Guide YVL 1.0 defines the safety criteria for the design of NPP..
- Guide YVL 1.1 describes how STUK controls the design, construction and operation of NPPS.
- Guide YVL 1.4 presents general requirements for quality management systems and Guide YVL 1.9 for quality management during operation.
- Guide YVL 2.0 applies generally to the design and regulatory control of NPP systems – specifically those assigned to a safety class – and specifies in more detail the general design requirements presented in Guide YVL 1.0.
- Guide YVL 2.1 provides detailed instructions for safety classification of SSC.

3.1.2 Main requirement applied to this specific area

The requirements applicable to the plant electrical systems are contained in Guide YVL 5.2 Electrical power systems and components at nuclear facilities. Heat sink requirements are addressed through YVL 1.0 in terms of redundancy and diversity although there do not appear to be any specific requirements for an alternative heat sink.

Several other YVL guides apply to electrical power systems and components. For example; Guide YVL 1.8 describes how STUK controls the modification, repair and preventative maintenance of systems, components and structures at nuclear facilities during operation; DGs and their auxiliary systems are dealt with in Guide YVL 5.1; valves and valve actuators in Guide YVL 5.3; and I&C systems in Guide YVL 5.5.

It is noted that new regulatory guides (YVL) apply to new NPP units to be built in Finland and that in line with the principle of continuous improvement of nuclear safety; they will be applied to existing plants to the extent possible. The applicability to, and fulfilment of new requirements in the existing units is evaluated separately. Additional requirements arising from the lessons learned from Fukushima will be addressed in updates to the regulatory guides.

3.1.3 Technical background for requirement, safety assessment and regulatory oversight

STUK report that deterministic as well as probabilistic assessment has been used as standard tools in the licensing related safety assessment. The requirement for deterministic and probabilistic assessment is reflected in regulatory guidance.

Operating experience feedback (OEF) includes those events occurring in Finland and abroad pertinent to enhancing nuclear safety or radiation protection. The requirement for continuous improvement through OEF is specified in Section 24 of the Government Decree on the Safety of Nuclear Power Plants [733/2008].

3.1.4 Periodic safety reviews

In Finland, operating licences are granted for a fixed term, typically 10 to 20 years. A comprehensive safety assessment is required to renew the operating licence. If the operating licence is granted for a period exceeding 10 years, an interim safety assessment (PSR) is carried out during the licence period.

The last PSR was performed for Loviisa in 2007 and for Olkiluoto 1&2 in 2009.

3.1.5 Compliance of plants with current requirements

During the country visit, it was confirmed by STUK that the Finnish plants are in compliance with current requirements.

3.2 Assessment of robustness of plants

3.2.1 Approach used for safety margins assessment

The national report summarizes the results of the regulatory review of the licensee reports and generally meets the ENSREG Stress Test Specifications. It describes in detail the design provisions of the plant electrical systems for each NPP design operating in Finland and their ability to cope with loss of off-site power (LOOP) and loss of ultimate heat sink (UHS).

3.2.1.1 LOOP

The general the design solution for LOOP is to transfer the plant to the house load operation if the 400 kV grid connection is lost. If house load operation is not possible, the units can try to switch to the national 110 kV power grid. The switchover is automatic. If the 110 kV grid is available but the automatic switchover fails, operators can make the connection manually.

House load operation is the first line of defence against losing the 400 kV grid connection. If this automatic switchover is successful, the plant can continue house load operation indefinitely.

If main grid, backup grid or house load operation is not possible, the plant safety buses can be powered from the EDG and Uninterruptible Power Supply (UPS) batteries. In case of LOOP, each train of the emergency power supply system is capable of ensuring a safe shutdown state, and signals for start-up of the diesel generators are actuated independently for each EDG.

At Loviisa 1 & 2 each of four EDGs has a 10 hour day tank, which can be automatically refilled from a storage tank. There is one storage tank per two EDGs which ensure EDG operation for three days (two EDG's running at nominal full power).

At Olkiluoto 1 & 2 each of four EDGs has 8 hour day tank which can automatically refilled from a storage tank. There is one storage tank per unit and one storage tank holds enough fuel for one week of EDG operation (all four EDGs running at full nominal power).

At Olkiluoto 3 each of four EDGs has a 2 hour day tank, which can be automatically refilled from storage tanks. There is one storage tank per EDGs which ensures EDG operation for three days.

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

Loviisa 1&2:

At Loviisa 1 & 2, if the EDG operation is not successful, emergency back-up power can be provided from a new diverse non-safety diesel power plant or from a hydropower plant. The EDG plant has to be started and connected manually, but operators can perform all the required operations from the main control room of Loviisa 1 or locally. If the diesel engine is run at its maximum power there is enough fuel for 50 hours of operation. If the diesel power plant is used to substitute two of the EDGs simultaneously the fuel is sufficient for 86 hours of operation.

The hydropower plant is connected to Loviisa 1 & 2 via dedicated 21 kV overhead transmission lines. As a consequence of Fukushima, a test is planned in outage 2012 to investigate replacement of one EDG at both units simultaneously. The connection has to be initiated using local actions in both the hydropower plant and nuclear units. The time required for connection is estimated as 4 hours. It is also possible to provide power between Loviisa 1 & 2 units if one of the units remains on house load operation. Furthermore there are two possible ways of connecting the EDGs to support the power system of the neighbour unit. In both cases the connection is done via 6 kV bus bars.

Olkiluoto 1 & 2:

If EDG operation is not successful, emergency back-up power can be provided from a gas turbine plant. The gas turbine plant has two 50 MW generator units, each with two gas turbines. Each gas turbine alone is capable of providing the required emergency power to all three Olkiluoto units. The gas turbine plant is located above +3.5 m, and is separated from the nuclear units and is air cooled. The gas turbine plant has storage tanks with combined fuel capacity of 48 hours of use at full nominal power. However, one gas turbine providing 20MW of power is sufficient for all three units; under these conditions the fuel supply is sufficient for 9 days operation.

It is also possible to cross-tie the EDG power between Olkiluoto 1 & 2, therefore the four EDGs of one unit can be used to provide all the necessary emergency power to both units. There are permanent underground cable connections, but the manual switching operations required have to be made locally, under normal conditions this would take 30 to 60 minutes, but in some cases the connections may require 1 to 3 hours.

If the 110 kV grid connection is physically intact but the power grid is lost due to a major grid disturbance, it is possible to serve the Olkiluoto units by establishing a dedicated connection to a nearby hydroelectric power plant which is estimated as sufficient to supply power to support the safety functions of existing units Olkiluoto 1, 2 & 3. The connection can be established from the control room of the national grid operator or using manual switch operations in approximately 10 minutes. If the connections require manual remote controls, the required time is approximately 30 minutes. If local controls are required, the connection time is approximately 2 to 3 hours. It is also possible to get power from a nearby electrical company; this requires manual connection operations which would require 3 to 6 hours.

Olkiluoto 3:

If EDG operation is not successful emergency back-up power can be provided from a diverse SBO DG system. There are two SBO DGs, each has a day tank with sufficient fuel for 2 hours operation. The day tanks are automatically filled from storage tanks. There is one storage tank for each SBO DG with enough fuel for 24 hours operation. As noted above Olkiluoto 3 can also be supplied power from a gas turbine plant and a nearby hydroelectric plant.

3.2.1.3 <u>SBO</u>

Loviisa 1&2:

At Loviisa 1 & 2, there is a separate power system for loads needed in SAM, which is independent from other electrical systems of the plant and off-site power systems. The SAM power supply and distribution system is divided into two trains and fulfils the single-failure criterion. The SAM electrical system is common for Loviisa 1 & 2 and has enough capacity to supply power even if both units suffer a severe accident. It includes two air cooled DGs. One DG alone is capable of feeding all SAM-loads on both units. Electrical equipment is designed to withstand environmental conditions that may occur during a severe accident. SAM DGs can sustain 24 hours in autonomous operation. The station batteries can provide the load for about 1 hour and can be recharged from the SAM diesel generator. There are also independent batteries installed providing a control power to the 400 kV and 110 kV switchyards with a 10 hour capacity. A new automation system for 24V batteries will be installed ensuring operability of safety related I&C with a capacity of 3-10 hours.

If a total loss of the AC power occurs (SBO), core heat-up would not occur earlier than 7 to 10 hours after the start of the event, even if no countermeasures were adopted. Using the diesel driven auxiliary EFW pumps the total time before loss of fuel cladding integrity is more than 81 hours, which can be significantly increased with the systems already available on site to about 10 days by using independent diesel driven pumps from fire water system, which can fill up the SG make-up tanks. This system is independent from any electrical power. The fire water pumping system can be connected directly to SG make-up tank by a fire hose via existing connectors, although these additional actions are not included in the current emergency operating procedures.

Following SBO heat removal from the SFP to the seawater is not possible. The limiting worst case situation in terms of time available is the off-loading of the whole reactor core to the SFP for which the decay heat power is about 5.2 MW. If the pool cooling is lost in such a situation, the pool water will start boiling in about 3.4 hours. About 34 hours after the start of the boiling, the radiation level will start to increase. About 9 hours after that, the top of the fuel elements will be uncovered (ie total time to the top of the fuel being uncovered is approximately 46 hours). To prevent the water level dropping in the pools, make-up water supply of about 2.3 kg/s would be needed to compensate for the boiling.

Olkiluoto 1 & 2:

Several SBO situations have been analyzed. If SBO occurs at the time of reactor scram, the top of the fuel elements will be uncovered in about 30 to 35 minutes. This is quite a short time for implementation of corrective measures to restore the power supply to the core injection pump. Core cooling relies upon electrically driven pumps. If SBO causes the loss of the core cooling 24 hours after the reactor trip, the top of the fuel elements will be uncovered in about 130 minutes and core damage will commence about 1.5 to 3.5 hours later (i.e. about 3.5 to 5.5 hours after SBO), depending when the depressurisation of the reactor has been performed.

The station batteries feeding the severe accident handling systems can be also charged by mobile generators stored in the plant area which can be connected to permanently wired sockets outside of the plant buildings. The transport and connection of the generators is managed by the Olkiluoto fire brigade. The battery discharge time is 32 hours, during which the monitoring of the plant parameters, lighting and certain control functions are ensured.

For the SFP the limiting worst case situation is when the whole reactor core has been unloaded to the SFP with the connection to the reactor pool closed. The decay heat power in this case is about 10 MW. If the pool cooling is lost in such a situation, the pool water will start boiling in about 6 hours. About 20 hours after the start of boiling, the radiation level will start to increase rapidly as the water level falls to one meter above the top of the fuel elements. About 3.5 hours after that, the top of the fuel elements will be uncovered. To prevent the water-level drop in the pools, make up water supply of about 4.5 kg/s would be needed to compensate for the boiling.

Olkiluoto 3:

For the case of total loss of AC power there is two hours to prevent fuel overheating and cladding failure. Following total loss of AC power the pressurizer safety valves would open at 1 hour 20 minutes and there would be periodic opening and closing of the valves up to 1 hour and 50 minutes after which they would remain open. Core uncovery would take place within 3 hours with extensive fuel damage within 4 hours and pressure vessel melt-through would take 7 to 8 hours.

During SBO, removal of the decay heat from the spent fuel elements in fuel pools is prevented. The limiting worst-case situation for the available time is the evacuation of the whole reactor core to the pool. The decay heat power after the unload-ing of the core is about 21 MW. If the pool cooling is lost in such a situation, the pool water will start boiling in about 4.5 h. About 25 h after the start of the event water level will be down to two meter above the top of the fuel elements. After 31.8 h the top of the fuel elements will be uncovered. To prevent the water level drop in the pools, make-up water supply of about 9.3 kg/s would be needed to compensate for the boiling.

3.2.1.4 Loss of ultimate heat sink

Loviisa 1&2:

The primary UHS is provided by seawater from the Gulf of Finland. There are several mechanisms that have the potential to result in the loss of the UHS (e.g. due to frazil ice, algae or oil entering the sea water system) and several design provisions are incorporated to prevent this. Loss of the sea water system will threaten the plant safety because virtually all process systems and major heating, ventilation and air conditioning (HVAC) systems use the sea water system either from inlet or outlet channel as the ultimate heat sink. However, the atmosphere can be used as the UHS, if the reactor is closed.

The availability of an alternate heat sink depends on the plant state and feedwater availability. If the primary circuit can be pressurised (i.e. the reactor vessel head is in place) the atmosphere can be used an alternative heat sink for as long there is enough water available for steam venting. If only the primary UHS is lost there is sufficient water in various plant site water tanks to remove decay heat from one reactor for over 10 days.

If a unit's reactor vessel head has been removed the possibility of installing the reactor vessel head before the onset of boiling in primary circuit would be considered. Installation of the reactor vessel head would take 12 to 18 hours on a best estimate basis. If the reactor vessel head cannot be installed, water injection to the open reactor would be performed either by ECCS, or through the fire protection system, which requires manual actions within the containment. Additional coolant water could be brought onto site by tank or fire trucks. The fire fighting systems can be connected to the boron water treatment plant tank with a standard fire water hose. The fuel tanks of the auxiliary EFW system and the SAM DGs can be refilled external to the building.

If a loss of the primary and alternative heat sink occurs after the plant was tripped from full power it will take about 6 hours before the primary circuit relief valves start cycling (pressure increase due to temperature increase in the Reactor Coolant System (RCS)) if no countermeasures are taken. The scenario is similar to that of SBO assuming only the hydro-accumulators and SAM valves are operational for which the core is predicted to uncover in 9 hours.

Olkiluoto 1 & 2:

Sea water is the primary UHS. The sea water inlet is equipped with coarse and fine intake screens as well as travelling basket filters that will prevent fish and other foreign matter from being sucked into the water pumps and heat exchangers. Temporary oil booms are available to prevent marine oil spills entering the cooling tunnel. During winter time when the sea water temperature drops below +2°C, warm water is pumped from the outlet side to the inlet side in order to prevent the formation of frazil ice at the intake screens.

Currently, the heat sink at Olkiluoto 1 & 2 depends on the availability of the sea water. Both units can evaporate residual heat from the reactor core to atmosphere by transferring the steam produced inside the reactor pressure vessel to the condensation pool through the safety relief valves, letting the condensation pool to boil, and by venting the steam from the containment to atmosphere through the filtered venting system. However, the systems required to pump water into the reactor pressure vessel are either dependent on seawater based cooling systems or on the condensation pool water. Nevertheless, the core injection pumps will remain operational until the condensation pool water reaches cavitation temperature, resulting in pump failure.

If the primary UHS is lost completely the emergency core injection pumping will stop after about 4 hours. Core damage will follow 7 to 7.5 hours after the start of the loss of heat sink.

The loss of UHS in a SFsP has been considered. The total heat generation of spent fuel storage on September 9th 2011 was 1225 kW, the time before boiling starts in the spent fuel storage when fuel pool doors are open is around 8.5 days. Radiation levels due to falling water level would start to increase significantly in the hall at around 43 days.

Olkiluoto 3:

Seawater is the normal UHS for decay heat removal. The intake water screening facility screens the circulating water and essential service water required for the plant in order to keep the circulating water and essential service water free of fouling during normal operation. The safety function of the system is to make water for the essential service water system available under all operating conditions as well as under accident conditions except in the case of loss of UHS. The circulating water screening plant is located in the circulating water pump house and provides four screening lines for mechanical cleaning of the circulating water. Each screening line consists of one coarse screen unit with heating equipment and one fine screen unit with wash water equipment.

In the case of loss of primary UHS the decay heat would be released to the atmosphere via the SG secondary side Main Steam Relief Train (MSRT). The water inventories of the emergency feedwater storage tanks and demineralised water tanks are designed to provide 72 hours feedwater supply for a plant at full power at the start of the event.

During a refuelling outage the containment filtered venting system would be used for decay heat removal, with make-up water being provided from the In-containment Water Storage Tank (IRWST).

Loss of the primary UHS (seawater) and the alternate heat sink (atmosphere) is regarded by STUK as very unlikely and was excluded from the analyses. During the country visit it was explained that the consequences are covered by the case of total loss of AC power.

3.2.1.5 Loss of ultimate heat sink and SBO

Loviisa 1&2:

Loss of UHS combined with SBO is bounded by SBO for which core heat-up would not occur earlier than 7 to 10 hours after the start of the event, even if no countermeasures were adopted. Using the diesel driven auxiliary EFW pumps the total time before loss of fuel cladding integrity is more than 81 hours, which can be significantly increased with the systems already available on site to about 10 days by using independent diesel driven pumps from fire water system, which can fill up the SG make-up tanks.

Olkiluoto 1 & 2:

The loss of primary UHS combined with SBO is bounded by SBO alone.

Olkiluoto 3**:**

The loss of primary UHS combined with SBO is bounded by SBO.

3.2.2 Main results on safety margins and cliff edge effects

At Loviisa 1 & 2, if the EDG operation is not successful, emergency back-up power can be provided from a new diverse non-safety diesel power plant or from a hydropower plant. If this new diesel power plant is used to substitute two of the EDGs simultaneously, the fuel is sufficient for 86 hours of operation.

At Olkiluoto 1, 2 & 3, if EDG operation is not successful, emergency back-up power can be provided from a gas turbine plant. The gas turbine plant has two 50 MW generator units, each with two gas turbines. One gas turbine providing 20MW of power is sufficient for all three units, under these conditions the fuel supply is sufficient for 9 days operation.

Also for Olkiluoto 3 if EDG operation is not successful emergency back-up power can be provided from a diverse SBO DG system. There are two SBO DGs, each has a day tank with sufficient fuel for 2 hours operation which can refilled from a storage tank with enough fuel for 24 hours operation.

For Loviisa 1 & 2 the limiting case is SBO for which core heat-up would not occur earlier than 7 to 10 hours after the start of the event, even if no countermeasures were adopted. Using the diesel driven auxiliary EFW pumps the total time before loss of fuel cladding integrity is more than 81 hours, which can be significantly increased with the systems already available on site to about 10 days by using independent diesel driven pumps from the fire water system, which can fill up the SG make-up tanks.

SBO is also the limiting case for Olkiluoto 1 & 2. If SBO occurs at the time of reactor scram, and countermeasures are unsuccessful the top of the fuel elements will be uncovered in about 30 to 35 minutes. Core damage will commence about 25 to 30 minutes later, i.e. about 1 hour after the scram.

SBO is also the limiting case for Olkiluoto 3 for which if countermeasures were unsuccessful core uncovery would take place within 3 hours with extensive fuel damage within 4 hours and pressure vessel melt-through would take 7 to 8 hours.

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

All units have sufficient fuel supplies for the operation of the EDGs for at least three days. Should the EDGs not be available all units have alternative back-up power supplies.

As it can be seen from the analysis for all units, the SBO conditions represent the worst case scenario, in particularly from the SBO coping time point of view. The loss of UHS and alternate heat sink could lead to the same degraded conditions, but the available timescales to restore the heat sink, including by mobile means are longer than for SBO.

STUK concludes that at Loviisa 1 & 2 the station battery capacity for battery backed-up systems is limited and must be assessed further. The battery capacity could be insufficient when the usage of auxiliary EFW pumps is concerned, because the loss of voltage due to battery discharge would lead to loss of monitoring of the plant parameters as well as some control function.

The SAM diesel can be connected and provide for charging the station batteries.

The integrity of main reactor coolant pump seals must also be taken into account in the analyses, so that the water inventory on primary circuit can be secured in the loss of off-site power situation. Nevertheless, a time of 10 hours provides a reasonable opportunity to restore power and avoid a small Loss Of Coolant Accident (LOCA) either through the Reactor Coolant Pump (RCP) seals or pressurizer safety valves.

The following strong features were identified:

- Diesel driven auxiliary EFW pumps, with dedicated water storage tanks and independent piping lines provide decay heat removal capability during a total loss of electricity and loss of UHS.
- Diesel driven fire water pumping station provides the possibility to supply water for cooling also in cases without AC power supply.
- 10 MW air-cooled diesel generator plant as a diverse on-site AC power source (in addition to the original EDGs).

At Olkiluoto 1 & 2, the following strong features were identified:

- High capacity gas turbine plant as a diverse on-site AC power source;
- The renewal of EDGs, both seawater and air-cooled (project is ongoing).
- Station battery capacities are from 13 hours to 30 hours depending on the available redundancy. This is adequate compared to the time after which must be start to use the severe accident handling systems.

3.2.4 Possible measures to increase robustness

STUK has reported that following the Fukushima accident, the licensees are planning several modifications that can provide extra protection for beyond design basis events. These modifications should also address several important issues that were indentified during the Stress tests exercise.

At Loviisa 1 & 2, the measures focus on:

- The long-term operation of the diesel engines, use of biodiesel and the installation of an additional diesel tank;
- Verification of the long term operability of the diesel driven auxiliary EFW system in SBO situation;
- Evaluation of the need for mobile devices to secure boron injection into the RCS, coolant inventory in the RCS, coolant inventory in the secondary circuit, water supply for the diesel driven auxiliary EFW pumps, electricity supply for instrumentation needed in accidents, electricity supply for the RCS depressurisation valves, containment heat removal during severe accidents, decay heat removal from the SFSPs, operation of diesel engines and their support systems, control room lighting, and plant communication systems;
- To increase robustness of the UHS, two air-cooled cooling towers per unit are under consideration, one removing decay heat from the reactor and one the decay heat removal from the in-containment SFP and the SFSPs;
- For combined station blackout and loss of UHS, the possibility of operating the cooling towers, and in addition the boron injection pumps with the air-cooled diesel-generator, has also been investigated;
- For shutdown states, the possibility of using the hydro-accumulators during outage as water storage is to be investigated.

At Olkiluoto 1 & 2, the measures focus on:

- Possible renewal of all eight EDGs; the new EDGs would have two diverse component cooling systems;

– Installation of a so called 9^{th} EDG that could supply electric power to either Olkiluoto 1 or 2. This EDG would be located in a new, separate diesel building, qualified for flooding;
– Installation of diverse and independent way of pumping water to the reactor pressure vessel the via fire fighting diesel driven pumps equipped with a pressure booster to increase the head pressure and ensure sufficient pumping capacity to the pressurized reactor up to 15 bar.

At Olkiluoto 3, the measures focus on:

– Installation of EFW connections to the SG secondary side, connections to the external AC power supply and external make-up water injection into the RCS during refuelling outages.

For the entire Olkiluoto site:

– Feeding of fire water into SFP using fixed fire water system, and additional possibility to use mobile fire water pumps, is considered;
– Extra protection against marine oil spills.

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

At Loviisa 1 & 2, there is a direct connection of electrical buses to the air cooled diesel generator plant (10MW) recently installed at the plant site connected by underground cable either to 6kV plant buses, or by 6/110kV transformer to current plant 110 kV switchyard.

The Licensee has evaluated adequacy of the battery capacity, and concluded that no improvements for the auxiliary EFW pump engines or SAM systems are needed, as battery capacity has been determined on a conservative basis, although the potential for enhancing the ability to charge batteries is being considered. STUK intends evaluating this assessment.

The Licensee has concluded that further improvements on securing the long-term operability of the safety systems and equipment are not necessary and that based on risk studies carried out during the plant operation all significant safety improvements have already been made. STUK intends evaluating this assessment.

With respect to the availability of demineralised water at Loviisa 1 & 2 the Licensee has concluded that there are adequate reservoirs of demineralised water at the plant site. STUK intends evaluating this assessment.

It is noted that STUK is still evaluating the detailed design of Olkiluoto 3, although at the moment STUK reports that no issues within the electricity supply have been identified that would require significant changes for preparation of the license application for operation.

With respect to Olkiluoto 3 in response to STUK's requirements the Licensee has further evaluated the robustness of the EDG building doors against flooding, and the results indicate that there is no threat to loss of EDGs due to flooding. The Licensee has also stated that common cause failures are comprehensively taken into account in the design of Olkiluoto 3. STUK is evaluating this assessment and will take into consideration causes other than flooding leading to loss of EDGs.

3.3 Peer review conclusions and recommendations specific to this area

The Finnish national stress test report is well written, provides an appropriate level of detail and generally complies with the ENSREG specifications. A satisfactory response to the key questions raised during the desktop review was provided during the topical review meeting.

It is noted that Olkiluoto 1 & 2 are vulnerable to SBO, particularly if it occurs at the time of reactor scram. The coping time in that case is very short at 30 to 35 minutes. This is quite a short time for implementation of corrective measure to restore the power supply to the core injection pump. Olkiluoto 1 & 2 core cooling relies upon electrically driven pumps and sea water cooling. In this regard there are plans to improve the existing design, as well as to install independent means to provide for the core cooling function.

It is also noted that a heat sink completely independent of seawater does not currently exist at Olkiluoto 1 & 2; corresponding planned corrective measures seem to be necessary.

With respect to the coping times for LOOP, SBO and loss of the UHS it is noted that in general system code analyses and severe accident analyses have been performed by the licensee. It is reported that

STUK has performed a review of the licensee's assessment and performed some independent analyses. The regulatory review was aimed at verifying the assumptions of the analysis and the process employed by the licensee to ensure the quality of the analysis.

During the topical review meeting it was reported that operators perform regular routine walk downs, surveillance testing and periodical inspections of SSC important to safety. Typically, the inspection and well as surveillance intervals are contained in the plant Technical Specifications. In additional, there are regular walkdowns performed during every shift. STUK's resident inspectors also perform routine inspections of the electrical systems and UHS design features. Additional inspections have also been performed following the events at Fukushima.

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

Severe accidents requirements are included within the Finnish regulation (Government Decree on the safety of Nuclear Power Plants) and more detailed requirements are given in YVL Guides.

New YVL Guides apply to new NPP units to be built in Finland. According to the principle of continuous improvement of nuclear safety, they will be applied to existing plants to the extent possible.

4.1.2 Main requirements applied to this specific area

The guiding principle set by Nuclear Energy Act [990/1987] can be considered as the driving requirement for ensuring continuous improvement of the nuclear safety.

The Government Decree on Safety NPPs [733/2008] includes requirements for limitation of releases (less than 100 TBq of Cs 137), securing of containment integrity, stabilization of molten core and systems, structures and components for controlling and monitoring severe accident.

The Regulatory Guides YVL provide probabilistic acceptance criteria (Core Damage Frequency (CDF)<10^{-5}/year, Large Release Frequency (LRF)<5.10^{-7}/year) and detailed requirements for hardware provisions. The systems for filter venting, hydrogen and hot gases control, prevention of high pressure sequences and stabilization of melt core to prevent containment melt-through, must be: independent of systems designed for plant operational conditions and postulated accidents; single failure tolerant; and of safety class 3. Instrumentation shall be able to monitor progress of severe accident and shall be independent, including power supply, and use suitable measuring methods. Analyses shall be justified by experiments and based on based estimated approach, and conservatism shall be applied in balance with the strategic significance of the functions.

4.1.3 Technical background for requirement, safety assessment and regulatory oversight

Development of the SAM strategies started after the accident in Chernobyl in 1986, and the latest measures were in place in 2003. These strategies are based on ensuring the containment integrity in order to keep the releases below the threshold given in the regulation. STUK has reviewed these strategies and has made inspections in all stages of implementation.

The approach is mainly based on deterministic requirements applicable for the NPP design and operation, but at the same time there are probabilistic acceptance criteria which must be complied with (in full for the new plants, to the extent possible for existing ones).

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

PSR is carried out in ten years intervals during the license period. The scope of PSR is similar to that carried out in conjunction with renewing the operating license. In addition, the capabilities of the operating personnel for continued safe operation of the plant are assessed. In both cases (renewal of the operating license or an interim safety assessment), safety assessment of a facility is made against the latest safety requirements set in force in Finland following the principle of continuous improvement of safety.

The most recent PSR for Olkiluoto 1&2 and Loviisa 1&2 were carried out in 2008 and 2007, respectively and no new issues related to SAM were identified for the both sites.

The SAM issues raised within the "Stress Tests" have been a part of the PSR.

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

The overall information was provided in the SAM chapter of the national report on this issue and to what extent the compliance with the current requirements is obligatory for the existing plants. YVL guides contain requirements on dedicated, single-failure tolerant SAM systems and measurements, as well as procedures and guidelines for the organisation to manage the severe accident situation, which are applicable to the NPPs currently in operation. The compliance with the Governmental Decree is required pro verbatim, in case of the YVL guides the compliance is judged individually by STUK.

The calculated frequencies for core damage and large releases for existing NPP units are higher than those set in Guide YVL 2.8. The frequencies as such, apply for new NPP units to be built in Finland, and for old units the principle of continuous improvement of nuclear safety is applied.

Although the issue of compliance with WENRA Reference Levels for existing reactors was not explicitly in ENSREG specification, the national report contains statements provided in the General conclusions regarding compliance of existing NPPs with the respective WENRA reference levels [WENRA 2008]. Detailed description of compliance with particular WENRA reference levels was given during the country visit.

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 operating shift personnel (control room operators and field operators), plant's fire brigade, and the security personnel are working continuously 24 hours per week. Additionally, the power plant's manager in charge and the on-duty safety engineer are on-call outside daytime working hours.

During a plant disturbance, the shift supervisor must lead the activities of the shift, monitor plant unit status and supervise that all necessary measures are carried out without delay. The plant on-duty safety engineer assists the shift supervisor. The shift supervisor stays as the decision maker also during severe accidents.

Plans for strengthening the site organization in case of emergency include formation of emergency preparedness organization at both sites and, in case of Loviisa plant, also the Technical Support unit.

The emergency organization is headed by an emergency manager who is responsible for the emergency response on the site and liaison with the authorities. The shift manager acts as the emergency manager until one of the managers in charge takes over leadership responsibility for the situation. The emergency manager is in charge of the on-site emergency response activities until the rescue authority notifies that it assumes command over the rescue operations. The shift personnel (i.e. the operators and on-duty safety engineer) deal with the severe accident situation according to EOP/SAMG, until further notice from the emergency manager.

Emergency preparedness organization always acts as a supporting organization and not as a decision maker. Based on the advance planning, the regional rescue service participates in the power plant's rescue operations.

The robustness of this organization for extreme event was not described in detail in FI-NR, but it was clarified during the country visit that, in order to have realistic expectations, further possibilities have been identified for both sites for alternative transportation instead of the road connections in extreme situations.

Since emergency preparedness does not take fully into account cases of accident in multiple units and long term duration, it is still necessary to investigate this issue.

As a Licensee's measure the number of people in the technical support emergency organization of Loviisa 1&2 was recently increased for better preparedness and support against accident situations, whereas Olkiluoto 1&2 Licensee's Teollisuuden Voima (TVO) assessment is that the personnel of the operations organization are adequate for prolonged accident conditions that concern several plant units. In order to better recover in case of loss of all communication systems, TVO has decided to obtain satellite telephones to the emergency centres.

The emergency preparedness organization receives annual refresher training and advanced training. Emergency exercises are held annually. Every third year a nation wide emergency exercise of the plant is held.

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

Loviisa 1&2:

Immediate SAM measures are carried out within the EOP. The transition to SAM Guidelines takes place when there is an indication the reactor core is damaged or is close to doing so, and there is no return to EOPs thereafter. The SAM Guidelines are based on SAM safety functions and focus on monitoring the leak tightness of the containment barrier, and on the long-term issues.

The SAM-handbook contains background material for better understanding of the SAM safety functions and related accident phenomenology The handbook is used primarily by the emergency preparedness organization during the accident, and more generally also for training purposes.

EOPs and SAM Guidelines for power states are verified and validated. EOPs for shutdown states are under development and SAM Guidelines are going through validation and verification.

Olkiluoto 1&2:

Symptom based EOPs for severe accidents are available. The focus of the severe accident EOPs is on ensuring the containment integrity. There is a clear transition from other EOPs environment to the EOPs for severe accidents. The transition to EOPs for severe accident takes place when the actions in other EOPs fail to restore a safe plant state. EOPs are validated and verified. EOPs for severe accident are not envisaged for shutdown states. As clarified during the country visit all the operational modes, except refuelling outage, are covered by EOPs.

The training simulator is used when practicing the accidents, but the simulator is not capable to simulate severe accident at the moment. The table top training is used together with the training simulator to practice severe accidents.

Olkiluoto 3:

For emergency operation at Olkiluoto 3 event-based and symptom-based EOPs will be used. In case of severe accident separate SAM guidance document will be provided for the emergency organization management team to help assess the accident conditions and determine what coping strategies need to be implemented. The emergency organization will train these situations every year.

4.2.2.1 Hardware provisions for severe accident management

Fixed SAM systems have been installed at the Finnish NPPs, taking into account the Finnish national requirements to the extent possible.

Use of mobile devices is not assumed during severe accidents, except for supplementary water that must be provided for long term operation of containment external spray system. The design basis for all SAM safety functions is that the actions can be done, when the other supplies have been lost, with dedicated independent SAM electrical systems and dedicated independent SAM automatic from SAM control room or main control room. In addition to the SAM safety functions, sub-criticality have to be ensured during a severe accident.

The SAM systems were designed to cope with the accidents starting from power operation states. For Olkiluoto 3 the shutdown states were also included. Ensuring the availability of the systems during shutdown has been studied separately for Loviisa. SAM is not possible for Olkiluoto 1&2 during refuelling shutdown as the containment is open, thus the accident management is based on prevention of the core damage. The plant modifications performed in order to facilitate SAM include:

Loviisa 1&2:

1) Containment isolation - automatically, including also manual action based on SAM Guidelines;

2) RCS depressurization - new manually actuated depressurisation capability has been implemented for SAM;
3) In-vessel retention (IVR) of corium by reactor pressure vessel external cooling - mostly ensured by passive means and only active operations are required to lower the neutron and thermal shield ;
4) Hydrogen management - system for opening the ice-condenser doors to ensure adequate flow paths for efficient mixing of the containment atmosphere, Passive Autocatalytic Recombiners (PARs) and glow plug system (powered by SAM-diesels). Hydrogen control outside the containment is not considered;
5) Management of containment pressure and heat removal is ensured by dedicated containment external spray, which is powered by SAM diesels. Activation of containment external spray is included in SAM Guidelines;
6) A new SAM control room, common to both units was constructed.

SAM systems are not seismically qualified, because earthquake risks are low in Finland. Systems for Design Basis Accidents (DBAs) are all seismically qualified, but the requirement was not extended to SA equipment.

Due to the specific design of the Loviisa NPP no containment filtered venting has been installed because large scale venting of non-condensable gases could lead to sub-atmospheric pressures and possibly collapse of the steel shell containment. For that reason pressure reduction will be done by the containment external spray system.

Significant modifications have been made to reduce the probability of by-pass sequences, e.g. steam generator collector modifications to reduce probability of large primary-to-secondary leakage accidents. The containment leak-tightness monitoring system has also been significantly improved.

Olkiluoto 1&2

1) System for filling the containment with water from an external source;
2) Protection of the penetrations in the lower drywell against direct contact with the molten corium;
3) Containment filtered venting system - Venting is opened by a passive rupture disc in the drywell venting line or manually by a venting line from the drywell or wetwell. Closing of the vent has to be operated manually;
4) Dedicated instrumentation system for monitoring the conditions inside the containment in connection with severe accidents. All measurements are single failure tolerant. In case of SBO the containment monitoring system is powered by dedicated batteries without any external power supply for 24 hours.

Several original plant systems also play an important part in the accident management schemes, such as:

1) Reactor depressurisation system to prevent pressure vessel melt-through under high pressure - depressurisation is performed by manually opening of valves of the reactor relief system. The valves can also be opened manually and some of them can be locked in the open position using nitrogen system or fire fighting water system;
2) Containment vessel spray system and containment over-pressure protection;
3) Devices for gravity driven flooding of the lower drywell - this can be done using two pipelines that belong to the original containment spray system. The valves can be opened remotely or manually;
4) The fire fighting water systems provides water for filling the containment;
5) Inertisation of the whole containment by nitrogen to prevent hydrogen combustions. Hydrogen control outside the containment is not considered. It was clarified during the country visit that passive top-venting system is presently being considered for the reactor hall (as this information was not available during preparation of FI-NR).

The main control rooms are shielded against radiation and have filtered emergency ventilation systems, but so far there are no secondary control rooms in OL1&2 although plans exist to build them. The SAM systems are designed to withstand earthquakes (peak ground acceleration of 0,1g).

Olkiluoto 3:

Design of the European Pressurized water Reactor (EPR) reactor under construction in Olkiluoto includes all provisions necessary for management of severe accidents. Newly identified issues after Fukushima, like seismic resistance of severe management systems, possible leak of hydrogen into the surrounding buildings and associated hydrogen combustion phenomena, etc should be further analyzed.

4.2.2.2 Accident management for events in the spent fuel pools

At Loviisa NPP there is SFP one in each of the containments and two separate spent fuel interim storages. At Olkiluoto site all SFPs are located outside the containment.

The primary means to restrict releases from damaged fuel in the spent fuel pool inside the containment is to ensure the containment integrity. The only specific question is the hydrogen management and molten core-concrete interaction, which are discussed not in detail in the national report.

The only possibility to restrict radioactive releases from the spent fuel storages outside the containment is to ensure submergence of fuel. Existing equipment is used for SAM with guidance to use it, and improvements to this guidance are under development.

The SFP status can be determined by measurements of the normal and SAM measurements. These measurements will be included in SAM Guidelines and SAM handbook although currently in the spent fuel storages there are no SAM measurements.

Temporary connections can be made outside the containment for most systems and they are not exposed to high pressures, temperatures or radiation levels but inoperability may arise. Fire water systems remain operational also if the steam can not be vented out from the spent fuel storages or in case of containment bypass and can be used to feed water into the fuel pools. Although time to bring these means and systems into use has not been evaluated, the time delays are considered sufficient to gain control over the situation.

If cooling of the SFPs outside the containment fails, the time delays to boiling are considerable (several days) and regarded as sufficient for countermeasures, except in case a complete core is unloaded in the pool. In this latter case, boiling begins in less than 2 days; however, it is considered feasible to provide rapidly cooling by fire water systems. Even in case of fuel uncovery, radiation is not assumed to prevent actions, except those requiring access to the containment or spent fuel storages.

It is not obvious from the national report if these actions are fully described in Emergency Operating Procedure (EOP). It was clarified during the country visit that this kind of procedures does not exist, however STUK considers the need for written procedures.

Precautions to maintain sub-criticality in SFPs can include administrative measures to use borated water, although the fuel pool remains subcritical if pure water is used as well.

Improvements are envisaged at both sites. Strategies are under consideration to improve the possibilities of prevention of fuel uncovery, and ready made connections to SAM I&C and SAM diesel generators are envisaged, as well as improvements in instrumentation.

Events when damage of fuel in more SFPs at the same time would occur are not analyzed.

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

The Finnish authorities and operators have put an array of measures in place to prevent the impediment of foreseen accident management measures. An extensive destruction of infrastructure or flooding around the installation that hinders access to the site is first to be covered by the plant personnel present when the accident starts. Depending on weather conditions, boats or helicopters might be used for transportation. Regional rescue services with heavy duty clearing equipment are foreseen to participate in the rescue operations. Based on legislation the Regional Rescue services have the option officially request for help from any authority. In an accident situation, the rescue authority also has the right for a requisition of private owned equipment.

In case of loss of off site power the NPPs internal telephone systems will operate on battery backup and the external landline network and the mobile telephone network are estimated to operate for about 24 h. In addition Loviisa NPP has purchased satellite telephones; Olkiluoto NPP plans to do it.

Analyses for main control room confirm the original design basis of habitability. In case of high local dose rates, radioactive contamination and destruction of some facilities on site, local shielding, alternative operating centres and crisis rooms are available. The emergency manager decides on evacuation of the main control room based on actual conditions.

The emergency centres are located in shelters that ensure long time habitability during a severe accident. If the accessibility and habitability of the main and secondary control rooms (not applied for Olkiluoto 1&2) is compromised specific SAM control room exist at Loviisa 1&2, which is habitable during the severe accident. Habitability of control centres are not discussed in connection with spent fuel pools for Loviisa 1&2 whereas accident in the fuel pools would not jeopardize the habitability of the control rooms at Olkiluoto 1&2. Some actions, but limited in time, can be performed from shielded local control centres using SAM power supply.

Most of the SAM measures are independent of the availability of alternating current power by relying on battery back up power, local manual operations, passive safety features, mobile equipment like diesel generators, pumps etc.

Dedicated severe accident instrumentation is installed to monitor essential plant parameters under harsh accident conditions, which is independent and qualified.

In case of multi-unit accidents at first each unit will have to manage the accident separately. Due to increased dose rates movement on the sites might be restricted. Crisis centres in some distance to the sites is foreseen to serve as operational basis in case of habitability problems Additional staffing is foreseen for the crisis teams to be able to cope with more than one unit.

Analysis of radiological conditions related to the accessibility for local manual actions during severe accident have been done and appropriate modifications have been implemented.

The systems for management of severe accidents at Olkiluoto 1&2 are situated in rooms with floor elevation at the ground level or above. They could be jeopardized only if the flood level reaches several tens of centimetres above the ground level. No similar information was provided for Loviisa 1&2.

4.2.3 Margins, cliff edge effects and areas for improvements

SAM strategy at Loviisa 1&2 strongly relies on retaining corium inside the pressure vessel. Unavailability of SAM systems and containment leak-tightness in shutdown states can be considered as a cliff edge.

Typical time to pressure vessel melt-through at Olkiluoto 1&2 is around 1 h in case of Large Break Loss of Coolant Accident (LBLOCA) and consequent SBO, and around 2-3 h in case of SBO only.

Considering a loss of safety functions, OL3 is designed to survive 72 h without core damage in case of loss of UHS. By applying air-cooled EDGs, the AC power supply would be ensured, although the primary ultimate heat sink would be lost.

4.2.3.1 Strong points, good practices

The detailed and strict legal basis regarding the emergency preparedness and severe accidents management is a strong point. Already implemented provisions enhancing robustness can be considered as advantages when assessing the safety of Finish NPPs against hazards that contributed the Fukushima accident:

Loviisa 1&2:

- Dedicated SAM valves for RCS depressurization;
- Technical measure providing external cooling of the vessel in case of a core meltdown accident;
- Autocatalytic hydrogen recombiners and hydrogen igniters powered by the SAM DGs;
- Containment external spray (dedicated SAM system), also operational by mobile equipment in case of loss of its own pumping capability;
- Independent air cooled SAM DGs (not depending on EDGs).

Olkiluoto 1&2:

- Flooding of the lower drywell
- Depressurisation of the RCS and diversification for keeping the valves open;
- Modifications to protect the drywell penetrations against pressure and thermal loads);

- Filtered venting system of the containment (a dedicated SAM system);
- Possibility to fill the containment with water,

4.2.3.2 Weak points, deficiencies (areas for improvements)

Loviisa 1&2:

- Bypass sequences - Reactor Pressure Vessel (RPV) external cooling needs water filled reactor cavity and in containment by-pass sequences this cavity flooding can not be shown. Significant risk reductions have been made, and the work is still ongoing;
- Shutdown states - additional safety assessment from the severe accident management point of view is needed. Procedural changes to improve the availability of the safety systems have been made, and the work is ongoing.
- The adverse feature of the steel shell containment is that the containment structure does not provide efficient protection against radiation to upward direction.

Olkiluoto 1&2

- There are several emergency control posts, but no centralized emergency control room (planning is underway to develop such a facility);
- Shutdown states – severe accidents cannot be mitigated when the containment is open. This is a general problem for current Boiling Water Reactor (BWR) designs.

It was noted that there are no special provisions in place for restricting the releases in a hypothetical situation with extensive fuel damage due to uncovery and overheating of fuel in fuel pools outside the containment. The strategy is to keep the fuel submerged in all situations. There are plans to improve reliability and diversity to supply water to the pools at both sites.

4.2.4 Possible measures to increase robustness

4.2.4.1 Upgrading of the plants since the original design

The requirements for SAM were included in the Finnish nuclear safety regulations in 1982 when a YVL Guide on safety principles in NPP design was issued. After the accident at Chernobyl NPP in 1986, it was required that these principles had to be applied also to plants already in operation. Requirements include dedicated, single-failure tolerant SAM systems and measurements, as well as procedures and guidelines for the organisation to manage the severe accident situation. Major safety systems upgrades in Loviisa 1&2 and Olkiluoto 1&2 have been made to fulfil the requirements. The respective WENRA reference levels [WENRA 2008] are fulfilled by these safety upgrades.

Loviisa 1&2 was heavily modified already in the design phase in comparison with original design. Large modifications included for example the containment system (leak tight ice-condenser containment with Westinghouse ice condenser), automation systems (Siemens) and safety systems. Significant modifications have been made at the end of 1980s or beginning of 90´s, based on regulatory requirements and utility commitments throughout the plant lifetime as well. For example new systems have been constructed (e.g. auxiliary emergency feed water system, severe accident management systems) and many existing systems have been modified. Renewal of automation is currently under way.

Continuous improvement of nuclear safety is the driving force for enhancing nuclear safety in Olkiluoto 1&2 since start-up of its operation. The issues raised within the 'Stress Tests', have been a part of the Olkiluoto 1&2 PSA studies since 1990's, and risk-based improvements have been carried out by plant modifications and through revising and updating the emergency operating procedures. Furthermore, these issues have been a part of PSRs carried out at intervals of ten years.

4.2.4.2 Ongoing upgrading programmes in the area of accident management

Loviisa 1&2

Shutdown states need additional safety assessment from the SAM point of view, as a part of the safety systems is not available and the containment is open in some situations during shutdown. Procedural changes to improve the availability of the safety systems have been made, and the work is on-going to make the accident management more reliable in shutdown states.

Olkiluoto 1&2

A project is on-going to renew the existing EDGs. The new EDGs will be both seawater and air-cooled, which provides a possibility to cool them in connection with a variety of different external hazards.

4.2.5 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

4.2.5.1 Upgrading programmes initiated/accelerated after Fukushima

Following the principle of continuous improvement, the licensees have long term programmes for plant ageing management, for modernisation of the plants, and for improving safety. Also in accordance with this principle, some actions will be implemented based on the stress tests, both at the operating NPP units and at Olkiluoto 3, to further enhance the safety of the units.

The experiences from the Fukushima accident will also be taken into consideration in the ongoing renewal of the Finnish Regulatory Guides called YVL Guides and a plan has been prepared. The final draft of new Guide dealing with the design of NPPs already incorporates lessons from the Fukushima accident by requiring autonomous systems that enable the decay heat removal from the reactor and the containment and arrangements to ensure sufficient cooling of the fuel in fuel storages. The YVL Guides need to be taken into account in the design of new NPPs as such. A separate decision will be made concerning their application at the operating units and also the unit under construction.

The National Research Programme on Nuclear Power Plant Safety 2011 – 2014 will address lessons learned from the Fukushima accident.

4.2.5.2 Further studies envisaged

Several provisions for further improvement of safety levels and increase of robustness of NPPs in case of severe accident were identified and they are summarized below.

Licensee has proposed the following measures:

At Loviisa 1&2, Licensee has proposed the following measures to enhance the accident management capabilities:

- to take in consideration in the emergency instructions a case where an accident is considering both units and all fuel pools;
- improvement of the accident management training;
- to arrange emergency exercises in a date not informed to participants beforehand;
- ensure availability of sufficient communication systems from electrical systems available in severe accidents.

Licensee has performed the following measures to enhance the accident management capabilities:

- number of people in the technical support emergency organization was recently increased for better preparedness and support against accident situations;
- improvements to guidance for accident management (SAM Guidelines and SAM handbook) concerning spent fuel pools and storages are under development;
- continuous efforts have been made to reduce frequencies of bypass sequences and this work will continue in the future.

The strategy to manage accident situations in spent fuel storages should be decided and corresponding plant modifications done. Improvements in instrumentation are foreseen in all SFPs.

The actions foreseen to cope with the situation at the plant should be included in the instructions or procedures, although the time for corrective actions is considered long.

Readymade connections to SAM I&C and SAM DGs would further improve the reliability of decay heat removal from the SFSPs.

Guidance for SAM without electricity or possibility to perform RCS depressurization with external equipment would further enhance the effectiveness of severe accident management in these situations.

At Olkiluoto 1&2, Licensee has proposed the following:

- improvements of plant procedures for dealing with station blackout or loss of UHS (EOPs)
- improvement of communication facilities/systems, using satellite telephones to the emergency centres
- implementation of a level measurement system with a measurement range from the normal water level down to the top of the fuel assemblies in the fuel pools
- provisions for adding makeup water from the fire fighting system to the SFPs from safe locations.

STUK has requested the licensees to:

- investigate the need to secure containment heat removal without the sea water systems (Loviisa 1&2);
- provide a plan and schedule to increase fuel reserve for emergency power at the site (Loviisa 1&2);
- provide a plan to secure decay heat removal from SFP to UHS in extreme external events (Loviisa 1&2);
- provide a plan and schedule to secure alternative means of decay heat removal from in-containment fuel pools and (Loviisa 1&2)
- investigate to secure decay heat removal from the SFSPs (Loviisa 1&2);
- investigate, and if needed to provide a plan to secure fuel reserve for emergency power at the site (Olkiluoto 1&2);
- provide a plan and schedule to secure decay heat removal from reactor core and containment in case of total loss of AC power (Olkiluoto 1&2);
- provide a plan and schedule to secure decay heat removal from fuel storage pools located in the reactor building in case of loss of existing systems, and to investigate alternative methods to supply coolant to fuel storage pools, including potential need for new instrumentation (Olkiluoto 1&2);
- provide a plan and schedule to secure direct current power for long time needs;
- investigate availability (and operability) of safety systems and their components in accidents of long duration;
- investigate needs and possibilities to use mobile power supply and mobile pumps in accidents;
- investigate possibilities to secure availability of demineralised water at the site in an accident of long duration;
- review of the applicability of procedures and availability of personnel in case of accident in multiple units.

Olkiluoto 3

The issues raised within the “Stress Tests”, are required as a part of the designs bases of the Olkiluoto unit 3. External events are comprehensively taken into account in the design and the adequacy of the design has been demonstrated by PSA studies.

STUK is still evaluating the design of Olkiluoto 3, but the overall SAM strategy and approach has been accepted. No such hazards or deficiencies that would require changes to this approach have been found.

4.2.5.3 Decisions regarding future operation of plants

In evaluations of Finnish nuclear power plants, which focussed on findings from Fukushima accident, no hazards requiring immediate actions at the operating Finnish nuclear power plants were identified. Also, in the European stress tests until now, no needs for immediate actions have been identified.

4.3 Peer review conclusions and recommendations specific to this area

The requirements and guidelines are more stringent than usually established in legislation of other countries or in relevant IAEA Safety Standards.

A main difference with respect to the practice in many other countries is the role of the shift and especially the shift supervisor which carry out operations according to procedures also during severe accidents. The emergency manager (typically plant manager) takes overall responsibility of the site when arriving at the plant. The shift supervisor can make the decisions according to the procedures at all times, unless otherwise ordered by the emergency manager. Position of STUK is that this is a good approach because the operators on site are in the best position to decide what the appropriate actions are.

According the Finnish national report there are still several areas to investigate (like hydrogen management in buildings different that containment, spent fuel pool performance under severe accidents, or possibility of multi units severe accident situation) or to improve. Reassessment of the emergency preparedness should address events that occur at the all units on site at the same time. The implementation of the improvements should be over sighted by STUK under the appropriate regulatory process. It was clarified during the country visit that top venting of reactor hall is being considered at the moment for Olkiluoto 1&2.

The availability of dedicated systems and components to be used during severe accidents scenarios must be verified. This has been performed as a part of the design and qualification process, as required by YVL guides.

General suggestion is to perform special tests of several equipments, among them DC batteries up to depletion, endurance tests of diesel generators, under extreme conditions, training of some activities as for instance hoses installation etc.

The scope of EOPs/SAMG should also include all shut down states.

The estimation of time for the occurrence of significant events during specific scenarios would be very useful. Although the details were not provided in FI-NR during the Topical review, however the existence of relevant accident analysis was clarified during the country visit.

List of acronyms

AC	Alternating Current
CDF	Core Damage Frequency
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DG	Diesel Generator
ECCS	Emergency Core Cooling System
EDG	Emergency Diesel Generator
EFW	Emergency Feed Water
ENSREG	European Nuclear Safety Regulators Group
EOP	Emergency Operating Procedure
EPR	European Pressurized water Reactor
FI-NR	Finish National report
HCLPF	High Confidence of Low Probability of Failure
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Control
LOCA	Loss Of Coolant Accident
LOOP	Loss Of Offsite Power
NPP	Nuclear Power Plant
OEF	Operating experience feedback
PAR	Passive Autocatalytic Recombiner
PGA	Peak Ground Acceleration
PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Review
RCS	Reactor Coolant System
RCP	Reactor Coolant Pump
RPV	Reactor Pressure Vessel
SAM	Severe Accident Management
SBO	Station Blackout
SG	Steam Generator
SFP	Spent Fuel Pool
SFSP	Spent Fuel Storage Pool
SSCs	Structures, Systems and Components
STUK	Radiation and Nuclear Safety Authority
UHS	Ultimate Heat Sink
WENRA	Western European Nuclear Regulators' Association
YVL Guide	Ydinvoimalaitosohjeet/Regulatory Guides on nuclear safety