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Finnish report on nuclear safety

Finnish 6th national report as referred to in Article 5 of the Convention on Nuclear Safety

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

STUK

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Executive summary

Finland signed on 20 September 1994 the Convention on Nuclear Safety which was adopted on 17 June 1994 in the Vienna Diplomatic Conference. The Convention was ratified on 5 January 1996, and it came into force in Finland on 24 October 1996. This report is the Finnish National Report for the Sixth Review Meeting in March/April 2014.

There are two nuclear power plants operating in Finland: the Loviisa and Olkiluoto plants. The Loviisa plant comprises of two VVER units (Russian type pressurised water reactors), operated by Fortum Power and Heat Oy, and the Olkiluoto plant two BWR units (boiling water reactors), operated by Teollisuuden Voima Oyj. In addition, a new nuclear power plant unit is being constructed at the Olkiluoto site (PWR). At both sites there are interim storages for spent fuel as well as final disposal facilities for medium and low level radioactive wastes. Posiva, a joint company by Fortum and TVO, submitted a construction licence application for the spent nuclear fuel repository in the end of 2012. Furthermore, there is a Triga Mark II research reactor operated in Espoo by VTT Technical Research Centre of Finland who has commenced an environmental impact assessment procedure for the decommissioning of the reactor.

In this report, latest development in the various topics of the Convention on Nuclear Safety is described. Major safety reviews and plant modernisations are explained including safety assessment methods and key results. Safety performance of the Finnish nuclear power plants is also presented by using representative indicators. Finnish regulatory practices in licensing, provision of regulatory guidance, safety assessment, inspection and enforcement are also covered. Major developments in Finland since the Fifth Review Meeting are as follows: updating of legislation and regulatory guides, carrying out the safety assessments related to the lessons learnt from the TEPCO Fukushima Dai-ichi accident, IRRS mission (IAEA's Integrated Regulatory Review Service) carried out in Finland (STUK and other authorities), and continued construction of the new nuclear power plant unit.

In the report, the implementation of each of the Articles 6 to 19 of the Convention is separately evaluated. Based on the evaluation, the following features emphasising Finnish safety management practices in the field of nuclear safety can be concluded:

- During the recent years Finnish legislation and regulatory guidance have been further developed and the revised regulatory guide system will be finalised in 2013. The overall revision of the regulatory guides takes into account international guidance such as IAEA standards and WENRA (Western European Regulators' Association) reference levels for existing reactors and safety objectives for new reactors. In addition, the lessons learnt from the TEPCO Fukushima Dai-ichi accident are taken into account. No deviation from the convention obligations has been identified in the Finnish regulatory infrastructure including nuclear and radiation regulations.
- The licensees have shown good safety performance and rigorous safety management practices in carrying out their safety related responsibilities in the operation and modernisation of existing NPPs. During recent years, only minor operational events

(INES 1 and below) have been taken place and no major safety problems have appeared. The licensees' practices are considered to comply with the Convention obligations.
- Safety assessment is a continuous process and living probabilistic risk assessment (PRA) practices are effectively used for the further development of safety. Periodic safety review of the Loviisa plant was carried out in 2005–2007 in connection with the operating licence renewal, and the periodic safety review of the Olkiluoto plant was carried out in 2007–2009. Several plant modifications have been carried out at the operating NPPs during the recent years to further improve the safety. Safety assessment carried out after the TEPCO Fukushima Dai-ichi accident also identified some further enhancement needs which are being planned and implemented.
- The resources of the Radiation and Nuclear Safety Authority (STUK) are adequate to fulfil the needs for independent regulation, and have been increased to meet the needs to oversee the construction of the new plant in Finland. The recent IRRS mission results will be used to further improve regulatory guidance and practices. VTT Technical Research Centre of Finland supports effectively the regulatory body in the safety assessment work providing safety analysis capabilities and tools and performing safety analyses. There are also national research programmes which support and develop the competencies in nuclear safety and waste management also in universities.

The Fifth Review Meeting in 2011 identified some challenges and recorded some planned measures to improve safety in Finland. These issues are included and responded in this sixth national report of Finland. These items were (in brackets the Articles, in which the issues are addressed):
- revising the existing regulatory guide system (see Article 7)
- response to the Fukushima accident; improvements on national and plant level (see Articles 5, 7, 14, 16, 17, 18, and 19)
- aging management of reactors in operation; renewal of I&C systems, reactor pressure vessel material embrittlement and use of risk-informed methods to further develop the plant safety (see Articles 14 and 18)
- challenges in new NPP construction project (Olkiluoto unit 3); competence, training and oversight of subcontractors, operating licence application review, compliance with QA programme, adequacy of oversight resources at site (vendor, licensee), and safety culture of organisations and personnel (see Articles 10, 11, 13, and Annex 4)
- preparation for the new build (see Annex 5)
- maintaining competence and responding to the growing needs for professional staff (see Articles 8 and 11)
- ensuring reliability of digital I&C, verification & validation (see Article 18)
- integration of safety and security arrangements (see Article 8)
- responding to increased demand for timely and effective communication to public (see Articles 8, 16, and 17)
- IRRS mission in 2012; results will be used to further improve regulatory practices (see Articles 7, 8, 10, 13, 15, 16, and Annex 6).

Still some of these issues require further development to enhance safety, i.e., including provision for plant ageing, reliability of digital I&C and management of competence taking into account the new build projects and retirement. Other important issues cover new technologies, security arrangements and the growing need for new research and development programmes. These are generic issues that require international attention in all countries using nuclear energy.

The existing regulatory guidance system (YVL Guides) is being restructured. The goal is to have updated legislation and new regulatory guides published during 2013. This task is highly prioritised because of new nuclear power plant projects in Finland.

The expected lifetime of the existing nuclear power plants requires renewal of systems and components and modernisation of technologies. The regulation of the existing nuclear power plants emphasises the management of ageing and the quality of plant operations. The I&C and other systems at the Loviisa and Olkiluoto plants are undergoing and planning modernisation, and extra care is needed to ensure operational safety during this work. Operating experience has shown that special attention has to be paid on the meticulous planning and controlled implementation and testing of the plant modifications and STUK is following this in its regulatory inspections.

Security arrangements in the use of nuclear power also call for efficient supervision. The procedures, preparations and information exchange related to antiterrorism activities need to be enhanced worldwide. In Finland, the need for strengthened security has been addressed in the amended legislation and regulatory guidance. IAEA's International Physical Protection Advisory Service (IPPAS) mission was carried out in Finland in 2009 and the follow-up in 2012. As a result, STUK has increased its resources in the security area and its co-operation with other authorities.

The retirement of large age groups in Finland will affect public administration and industry throughout, including STUK, utilities and the spent fuel management company Posiva as well as organisations providing technical support and education to them. The plans for new NPP construction projects and the above mentioned challenges and activities require additional manpower and efforts from the nuclear power utilities and regulatory body as well as from technical support organisations. Thus, ensuring an adequate national supply of experts in nuclear science and technology and ensuring high quality research infrastructure are continuous challenges in Finland. During 2010–2012 a committee set up by the Ministry of Employment and the Economy worked on a report aiming at giving recommendations and steps to be taken until the 2020's for ensuring competence and resources needed for the nuclear sector. In addition, the Ministry of Employment and the Economy set up at the end of January 2013 a working group to prepare a research and development strategy. Education and training programmes have been developed for newcomers at STUK as well as on national level to all organisations (such as utilities, waste management company and research organisations).

Due to the increasing interest in nuclear power in Finland, communication and information sharing on nuclear and radiation safety has become an increasingly important success factor for STUK and utilities. Regulatory processes and decisions have to be clear and understandable to general public. Interactions with media are important since media plays an important role in communication.

Actions taken as a result of the TEPCO Fukushima Dai-ichi accident

Following the accident at the Fukushima Dai-ichi nuclear power plant on the 11th of March in 2011 (TEPCO Fukushima Dai-ichi accident), safety assessments in Finland were initiated after STUK received a letter from the Ministry of Employment and the Economy on 15 March 2011. The Ministry asked STUK to carry out a study on how the Finnish NPPs have prepared against loss of electric power supply and extreme natural phenomena in order to ensure nuclear safety. STUK asked the licensees to carry out assessments and submitted the study report to the Ministry of Employment and the Economy on 16 May 2011. Although immediate actions to ensure safety of public and environment were not considered necessary, STUK required the NPP licensees to carry out additional assessments and present action plans for safety improvements. Assessments were conducted and reported by the Finnish licensees to STUK on 15 December 2011. STUK has reviewed the results of national assessments, and made licensee specific decisions on 19 July 2012 on the suggested safety improvements and additional analyses.

Finland also participated in the EU Stress Tests and submitted the national report to European Commission at the end of 2011. An EU level peer review on the report was completed by April 2012. The recommendations of the EU peer review have been taken into account in the regulatory decisions and will be considered in the development of national regulations. A National Action Plan was prepared addressing the measures initiated on a national level and at the nuclear power plants as a result of the TEPCO Fukushima Dai-ichi accident. The National Action Plan was sent to the European Nuclear Regulators Group (ENSREG) and peer reviewed in April 2013. In addition, Finland participated in the second Extraordinary Meeting of the Convention of Nuclear Safety (CNS) in August 2012 and prepared a report introducing all Fukushima related actions. All STUK's related decisions, the national report to European Commission, the report to the Extraordinary CNS, and the Finnish National Action Plan have been published on STUK's website.

Based on the results of assessments conducted in Finland to date, it is concluded that no such hazards or deficiencies have been found that would require immediate actions at the Finnish NPPs. However, areas where safety can be further enhanced have been identified and there are plans on how to address these areas. The experiences from the TEPCO Fukushima Dai-ichi accident are also taken into consideration in the ongoing renewal of the legislation and Finnish Regulatory Guides (YVL Guides) and in the nuclear safety research programme (SAFIR 2014), see Articles 7 and 8.

In addition to the periodic safety reviews carried out at the nuclear power plants, an extraordinary review of site related issues was performed after the TEPCO Fukushima Dai-ichi accident in connection with the so called European stress tests. Assessment of the safety margins and effects of exceeding the design basis values have been available and utilised for all identified relevant hazards (including extreme weather conditions) in connection with external events probabilistic risk assessments (PRA) which are mandatory for the Finnish NPPs. The stress tests did not reveal any new site-related external hazards or vulnerabilities of the plants to external events. No need for immediate action was recognised, but some additional studies of external hazards and feasibility studies for plant modifications to improve robustness against external events were found justified (see Article 17). For example at the Loviisa NPP, protection against high seawater level will be enhanced and detailed structural analysis of spent fuel pools in the case of an earthquake with consequential boiling in the pools will be carried out. At the Olkiluoto NPP, structural analysis of the spent fuel pools has been studied and seismic walk-downs of the fire extinguishing water system have been performed.

The systems needed for residual heat removal from the reactor, containment and spent fuel pools require external power at both Finnish NPPs. At both sites, the ultimate heat sink is the sea. Depending on the design features of the plant, the time margins to withstand station blackout and loss of ultimate heat sink vary. A reliable supply of electrical power to the systems providing for basic safety functions at the Finnish NPPs is ensured by the Defence-in-Depth concept. As a result of multiple and diversified electrical power sources at different levels, the probability of loss of all electrical supply systems is considered very low at the Finnish NPPs. However, as a result of the studies made after the TEPCO Fukushima Dai-ichi accident, further changes are expected to be implemented at the both NPPs (see Article 18). Examples of improvements under planning for the Loviisa NPP include installation of independent cooling towers for decay heat removal from the reactor core and from the spent fuel pools and diverse cooling of the spent fuel pools. Cooling towers were considered already before the Fukushima Dai-ichi accident due to the increased risks of oil transport on the Finnish Gulf. Safety improvement examples at the Olkiluoto units 1 and 2 include ensuring cooling of the reactor core in case of total loss of AC systems, ensuring operation of the auxiliary feed water system pumps independently of availability of the sea water systems, and plans for diverse cooling of the spent fuel pools.

A comprehensive severe accident management (SAM) strategy has been developed and implemented at the operating Finnish NPPs during 1980's and 1990's after the accidents in TMI and Chernobyl (see Annexes 2 and 3). These strategies are based on ensuring the containment integrity which is required in the existing national regulations. STUK has reviewed these strategies and has made inspections in all stages of implementation. As a result of the studies made after the TEPCO Fukushima Dai-ichi accident, no major changes at the plants are considered necessary. However, the licensees are expected to consider ensuring the cooling of spent fuel pools in the SAM procedures (see Article 19). In addition, there are many actions related to the update of the emergency plans (see Article 16). Both NPPs were required to clarify and update their emergency preparedness plans with respect to issues like the possibility of several reactor units' simultaneous accident, evaluation of the suitability of emergency response personnel to their duties, management of access control and contamination control in the case when the normal arrangements are out of function and restoring the access routes and connections to the site in case of massive destruction of the infrastructure.

Fukushima related modifications at the Loviisa and Olkiluoto NPPs are described in more detail also in Annexes 2, 3 and 4.

Concerning the off-site emergency preparedness and response (see Article 16), there is a need to ensure accessibility to the site in case of extreme weather conditions, provide a sufficient amount of radiation protection equipment and radiation monitoring capabilities for rescue services and improve communication capabilities. The rescue planning is strengthened in a co-operation between the nuclear power utility, regional rescue services, regional police departments and STUK. In addition, a National Nuclear Power Plant Emergency Preparedness Forum is needed in order to have co-operation and combination between permanent groups and the establishment of the National Forum has been agreed. The Ministry of the Interior and the Ministry of Social Affairs and Health, the regional rescue service authorities, STUK and the NPP licensees will be participating in the Forum.

In conclusion, Finland has implemented the obligations of the Convention and also the objectives of the Convention are complied with. Safety improvements have been annually implemented at the Loviisa and Olkiluoto plants since their commissioning. Legislation and regulatory guidance have been further developed taking into account nuclear safety research and advances in science and technology as well as the operating and construction experiences. Additional safety assessments and implementation plans for safety improvements have been made at the Loviisa and Olkiluoto plants based on the lessons learnt from the Fukushima Dai-ichi accident. IRRS mission (IAEA's Integrated Regulatory Review Team) was carried out in October 2012 and STUK has developed its action plan for improvement on the basis of the IRRS mission results and the self-assessment. There exists no urgent need for additional improvements to upgrade the safety of the Finnish nuclear power plants in the context of the Convention.

Contents

1 Introduction

Finland signed on 20 September 1994 the Convention on Nuclear Safety which was adopted on 17 June 1994 in the Vienna Diplomatic Conference. The Convention was ratified on 5 January 1996, and it came into force in Finland on 24 October 1996. This report is the Finnish National Report for the Sixth Review Meeting in March/April 2014.

In Chapter 2 of this report, the measures related to each of the Articles 6 to 19 of the Convention are separately evaluated. The evaluation is based on the Finnish legislation and regulations as well as on the situation at the Finnish nuclear power plants. The reference is made to the IAEA Safety Requirements and other safety standards as appropriate. IAEA's Information Circular 572, Rev. 4, 28 January 2013, was used as a guideline for the context of the report.

In the report, latest safety reviews and plant modernisations are explained in detail including safety assessment methods and key results. Safety performance of Finnish nuclear power plants is also presented by using representative indicators. The topics of the Second Extraordinary Meeting of the Contracting Parties to the Convention of Nuclear Safety are discussed under applicable Articles. Finnish regulatory practices in licensing, provision of regulatory guidance, safety assessment, inspection and enforcement are also covered in detail. The results of the latest IRRS mission (IAEA's Integrated Regulatory Review Service) carried out in Finland in October 2012 are described under Article 8 and detailed actions related to recommendations and suggestions under applicable Articles.

The sixth National Report is aimed to be a stand-alone document and does not require familiarisation with the earlier reports. The fulfilment of the obligations of the Convention is described in general and the latest development since the Fifth Review Meeting is specifically described.

2 Compliance with Articles 6 to 19 – Article-by-article review

Article 6. Existing nuclear installations

Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of the nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shut-down may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact.

In Finland, there are two nuclear power plants: the Loviisa and Olkiluoto plants. The Loviisa plant comprises of two VVER units that are operated by Fortum Power and Heat Oy (Fortum), and the Olkiluoto plant comprises of two BWR units that are operated by Teollisuuden Voima Oyj (TVO). TVO has also a Construction Licence for the new plant unit of nominal reactor thermal power 4300 MW at the Olkiluoto site (Olkiluoto unit 3). At both sites there are fresh and spent fuel storage facilities, and facilities for storage and treatment of low and medium level radioactive wastes. Other existing nuclear installations in Finland are the final disposal facilities for low and medium level radioactive waste at the Olkiluoto and Loviisa plant sites. The disposal facility at Olkiluoto was taken into operation in 1992 and at Loviisa in 1998.

For taking care of the spent fuel final disposal, a joint company Posiva Oy has been established in 1995 by Fortum and TVO. Research, development and planning work for spent fuel disposal is in progress and the disposal facility is envisaged to be operational in about 2022. The Decision-in-Principle (DiP) on the spent fuel disposal facility in deep crystalline bedrock was made by the Government in 2000 and ratified by the Parliament in 2001. In the connection of approving the DiP in May 2002 for the construction of the fifth power reactor in Finland, the Parliament also approved the DiP for expanding the capacity of the planned spent fuel disposal facility in Olkiluoto to also include the spent fuel from this new reactor unit. The repository will be constructed in the vicinity of the Olkiluoto NPP site. To confirm the suitability of the site, construction of an underground rock characterisation facility was commenced in 2004. Posiva submitted a construction licence application for the spent nuclear fuel repository to the Ministry of Employment and Economy in the end of 2012. The detailed technical documentation of the application is planned to be reviewed by STUK during 2013-2014 and based on the review STUK will give a safety assessment for the Ministry of Employment and Economy during 2014.

Three new nuclear power plant units have been under consideration in Finland (see more details of the licensing process under Articles 7 and 17). Environmental Impact Assessment (EIA) procedures were carried out in 2007–2009. In May 2010, the Government granted two Decision-in-Principles for new reactor units, one to TVO (Olkiluoto site) and another to Fennovoima Oy (alternative sites in Pyhäjoki and Simo). At the same time the Government rejected Fortum's DiP application to construct a new reactor unit to the Loviisa site. The Government also granted a Decision-in-Principle applied by the spent fuel management company Posiva Oy for expanding the capacity of the planned spent fuel disposal facility in Olkiluoto to also include spent fuel from Olkiluoto unit 4. The Parliament ratified all granted DiPs in July 2010. The Decision-in-Principles set a schedule for

Fennovoima and TVO to conclude their licensing feasibility studies, bidding processes and preparations for the construction licence applications to the Government by mid 2015.

In its application to build a nuclear power plant Fennovoima did not present a plan for disposal of spent fuel. The DiP regarding Fennovoima's application includes a requirement that Fennovoima shall further develop its plan for spent fuel disposal. The first option required that Fennovoima shall present to Parliament before end of June 2016 an agreement on co-operation with the present licensees (TVO and Fortum) under the waste management obligation regarding nuclear waste management. According to the second option Fennovoima shall prepare within six years a programme for environmental impact assessment for its own facility taking care of the final disposal of spent fuel. In March 2012, the Ministry of Employment and the Economy appointed a working group to steer nuclear power companies' joint investigation of the alternatives available for final disposal of nuclear fuel. The working group's final report assesses the environmental impacts of the various options (one or two final disposal facilities in Finland), safety, costs and a review of these with respect to the overall interests of society. In the working group's opinion, both options can be safely implemented.

Finland observes the principles of the Convention, when applicable, also in other uses of nuclear energy than nuclear power plants, e.g. in the use of a research reactor. In Finland, there is one TRIGA Mark II research reactor (250 kW), FiR 1, situated in Espoo. The research reactor was taken into operation in 1962, and it is operated by VTT Technical Research Centre of Finland. In 2012, VTT decided to commence the activities related to the planning of the decommissioning of the research reactor. The preparation of the programme for the environmental impact assessment procedure for the decommissioning of FiR 1 was started in May 2013.

In Finland, the continuous safety assessment and enhancement approach is presented in the nuclear legislation. Nuclear Energy Act states that *the safety of nuclear energy use shall be maintained at as high a level as practically possible. For the further development of safety, measures shall be implemented that can be considered justified considering operating experience and safety research and advances in science and technology.* The implementation of safety improvements has been a continuing process at both Finnish nuclear power plants since the commissioning of the operating reactor units and there exists no urgent need to upgrade the safety of these plants in the context of the Convention.

Loviisa NPP units 1 and 2

The reactor units at the Loviisa nuclear power plant were connected to the electrical grid in February 8, 1977 (Loviisa 1) and November 4, 1980 (Loviisa 2). The nominal thermal power of both of the Loviisa units is 1500 MW (109% as compared to the original power of 1375 MW). The increase of the power level was implemented and licensed in 1998.

The latest overall safety review of the Loviisa plant took place in 2005–2007 in connection of the relicensing of the operation of the plant. The Loviisa plant was reaching its original design age in 2007–2010, but the technical and economical lifetime of the plant is estimated to be at least 50 years according to the current knowledge of the plant ageing. Based on the application, Radiation and Nuclear Safety Authority (STUK) carried out a comprehensive review of the safety of the Loviisa plant. The review was completed in July 2007 when STUK provided the Ministry of Employment and the Economy (former Ministry of Trade and Industry) with its statement on the safety of the plant (see more details in Annex 2). The Finnish Government granted in July 2007 to Fortum new Operating Licences for unit 1 until the end of 2027

Figure 1. Loviisa nuclear power plant units 1 and 2. Source: Fortum.

and for unit 2 until the end of 2030. The length of the Operating Licences corresponds to the current goal for the plant's lifetime, which is 50 years. Two periodic safety reviews (by the end of the year 2015 and 2023) are to be carried out by the licensee as a licence condition.

Due to consistent plant improvements, the safety level of the plant has been increased as shown by the probabilistic risk assessment (see Article 14). For continued safe operation, plant improvement projects are still necessary. The largest ongoing improvement is the complete renewal of the plant I&C system, where the safety classified parts of the project are intended to be completed in 2017.

Due to the TEPCO Fukushima Dai-ichi accident, additional safety improvements have been initiated at the Loviisa NPP. The issues under planning and implementation include among other things:

- Installation of independent cooling towers for decay heat removal from the reactor core and from the spent fuel pools. The cooling towers would provide an alternative ultimate heat sink in case of loss of sea water cooling and they were considered already before the Fukushima Dai-ichi accident due to the increased risks of oil transport on the Finnish Gulf. Installation of the towers is planned for 2014.
- Flood protection. The utility has estimated the effects of high sea level to the plant behaviour. The utility will submit a detailed plan on improved flood protection in 2014 (protection during annual maintenance shutdown already partly implemented).
- Design plans of diverse cooling water supply to the spent fuel pools have been submitted to STUK in 2013.
- Evaluation of the availability of cooling water and emergency diesel fuel in case of simultaneous accidents at multiple reactor units and other nuclear facilities at the same site.

Plant lifetime management includes credible procedures for the follow-up of the plant ageing. The conditions of components which are practically impossible to be replaced by new ones (pressure vessel, steam generators, etc.) are monitored most actively. One specific issue with Loviisa plant units is the risk of reactor pressure vessel brittle fracture. Several modifications have been made at both units to reduce the risk. Fortum submitted during the latest operating licence renewal process a comprehensive analysis based on which the brittle fracture risk can be managed until the end of the 50 years plant lifetime. The permit renewal for the use of the reactor pressure vessels was carried out at the Loviisa unit 2 in 2010 and at the Loviisa unit 1 in 2012. STUK approved the applications to extend the operation of the pressure vessels at the both units to the end of the operating licence, i.e. until the end of 2027 for the Loviisa unit 1 and until the end of 2030 for the Loviisa unit 2.

The large plant modernisation projects carried out at the Loviisa nuclear power plant and STUK's safety reviews are described in more detail in Article 18 and in Annex 2. During recent years, only minor operational events have been taken place and no major safety issues have appeared (see also Article 19).

In addition to the regulatory oversight and safety assessment, there have been independent safety reviews conducted by international organisations such as IAEA and WANO (World Association of Nuclear Operators). IAEA OSART (Operational Safety Review Team) missions have been organised at the Loviisa power plant in November 1990 and March 2007 with a latest follow-up review in July 2008. The WANO peer reviews have been carried out at the Loviisa nuclear power plant at the beginning of 2001 and in March 2010. A follow-up for the last WANO peer review was carried out in April 2012.

In 2011, the net production of the Loviisa unit 1 was 4030 GWh and the load factor was 94.7%. The annual refuelling and maintenance outage lasted 17 days. The net production of the Loviisa unit 2 was 4040 GWh, the load factor 94.8% and the length of the refuelling and maintenance outage was 19 days. The annual collective radiation doses were 0.43 manSv and 0.29 manSv for Loviisa units 1 and 2 respectively.

In 2012, the net production of the Loviisa unit 1 was 3650 GWh, the load factor was 84.0% and the refuelling and maintenance outage lasted 54 days. The net production of the Loviisa unit 2 was 3960 GWh, the load factor was 91.3%, and the refuelling and maintenance outage lasted 20 days. The collective radiation doses in 2012 were 1.35 manSv for the Loviisa unit 1 and 0.33 manSv for the Loviisa unit 2.

Olkiluoto NPP units 1 and 2

The Olkiluoto nuclear power plant units were connected to the electrical network in September 2, 1978 (Olkiluoto 1) and February 18, 1980 (Olkiluoto 2). The nominal thermal power of both Olkiluoto units is 2500 MW, which was licensed in 1998. The new power level is 115.7% as compared to the earlier nominal power 2160 MW licensed in 1983. The original power level of both units was 2000 MW. The Operating Licences of the units are valid until the end of 2018.

The latest periodic safety review (PSR) of the Olkiluoto plant took place in 2007–2009. Regulatory guide YVL 1.1 specifies the contents of the PSR. For a separate periodic safety review without operating licence renewal, STUK shall be provided with similar safety-related reports as in applying for the operating licence or operating licence renewal. STUK made a decision concerning the PSR in October 2009. The decision included also STUK's safety assessment which provided a summary of the reviews, inspections and continuous oversight carried out by STUK.

Due to the TEPCO Fukushima Dai-ichi accident, additional safety improvements have been initiated at the Olkiluoto NPP units 1 and 2. The issues under planning include among other things:

- Assessing possibilities to ensure cooling of the reactor core in case of total loss of AC supplies and systems. Evaluations of feasible solutions are under way.
- Ensuring operation of the auxiliary feed water system pumps independently of availability of the sea water cooling systems. The modification is planned for 2014–2015.
- Design plans of diverse cooling water supply to the spent fuel pools will be completed in 2013.
- The utility is assessing plans for new mobile equipment (diesel generators, pumps).
- Evaluation of the availability of cooling water and emergency diesel fuel in case of accidents at multiple reactor units and other nuclear facilities at the same site.

Figure 2. Olkiluoto nuclear power plant units 1 and 2. Source: TVO.

The large plant modernisation projects carried out at the Olkiluoto nuclear power plant and STUK's safety reviews are described in more detail in Annex 3. During recent years, only minor operational events have taken place and no major safety issues have appeared (see also Article 19).

In addition to the regulatory safety assessment, there have been independent safety reviews conducted by international organisations. IAEA OSART mission has been organised at Olkiluoto in March 1986. The WANO peer reviews have been carried out at the Olkiluoto nuclear power plant in 1999, in 2006 with a follow-up review in 2009, and in 2012.

In 2011, net production at the Olkiluoto unit 1 was 7290 GWh and the load factor 94.8%. The annual refuelling and maintenance outage of the Olkiluoto unit 1 lasted 9 days. The net production of the Olkiluoto unit 2 was 6910 GWh and the load factor was 90.9%. The annual refuelling and maintenance outage of the Olkiluoto unit 2 lasted 29 days. The collective radiation doses in 2008 were 0.21 manSv for the Olkiluoto unit 1 and 0.76 manSv for the Olkiluoto unit 2.

In 2012, net production at the Olkiluoto unit 1 was 6970 GWh and the load factor was 90.4%. The annual refuelling and maintenance outage of the Olkiluoto unit 1 lasted 31 days. The net production of the Olkiluoto unit 2 was 7480 GWh and the load factor was 96.9%. The annual refuelling and maintenance outage of the Olkiluoto unit 2 lasted 9 days. The collective radiation doses in 2012 were 0.53 manSv for the Olkiluoto unit 1 and 0.19 manSv for the Olkiluoto unit 2.

Olkiluoto NPP unit 3

Construction Licence application for the fifth nuclear power plant unit in Finland on the Olkiluoto site was submitted by TVO to the Ministry of Trade and Industry (predecessor of the Ministry of Employment and the Economy) in January 2004. The new unit, Olkiluoto 3 is a 1600 MWe European Pressurised Water Reactor (EPR), the design of which is based on the French N4 and German Konvoi type PWR's. A turn key delivery is provided by the Consortium Areva NP and Siemens. The technical requirements for Olkiluoto unit 3 were specified by using the European Utility Requirements (EUR) document as a reference. TVO's specifications complemented the EUR mainly in those points where Finnish requirements are more stringent. STUK gave its statement in January 2005 on nuclear safety based on the review of the licensing documentation and the Government issued the Construction Licence in February 2005.

Construction work is going on and next licensing step is the Operating Licence. Operating Licence is needed prior to loading nuclear fuel into the reactor core. IAEA has agreed to carry out a pre-OSART (Operational Safety Review Team) mission to Olkiluoto NPP before the fuel loading. Licensing and construction of the Olkiluoto unit 3 is described in more detail in Annex 4.

Due to the TEPCO Fukushima Dai-ichi accident, additional safety improvements have also been initiated for the Olkiluoto NPP unit 3. The licensee has assessed possibilities to implement external feed water connections to the steam generator secondary side, connections to external AC power supply and external make-up water injection into the reactor cooling system during refuelling outages in order to have independent means to fulfil residual heat removal function in case plant's normal systems are inoperable. In the fuel building, the possibility to use fire extinguishing water systems for coolong the spent fuel pools and boiling-out of the pool water have been evaluated. Additional mobile pumps to provide water injection into the fire fighting water system are to be acquired before the start of operation of the Olkiluoto unit 3.

In conclusion, Finnish regulations and practices are in compliance with Article 6.

Figure 3. Olkiluoto NPP unit 3 in construction phase in April 2013. Source: TVO.

Article 7. Legislative and regulatory framework

1. ***Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.***
2. ***The legislative and regulatory framework shall provide for:***
   - *i.* ***the establishment of applicable national safety requirements and regulations;***
   - *ii.* ***a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a licence;***
   - *iii.* ***a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of licences;***
   - *iv.* ***the enforcement of applicable regulations and of the terms of licences, including suspension, modification or revocation.***

Legislative and regulatory framework

The current nuclear energy legislation in Finland (see Annex 1) is based on the Nuclear Energy Act originally from 1987. The Act has been amended 22 times during the years it has been in force: most changes are minor and originate from changes to other Finnish legislation. In 2008, nuclear energy legislation was updated to correspond to current level of safety requirements and the new Finnish Constitution which came into force in 2000. Together with a supporting Nuclear Energy Decree originally from 1988, the scope of this legislation covers e.g.

- the construction and operation of nuclear facilities; nuclear facilities refer to facilities for producing nuclear energy, including research reactors, facilities for extensive disposal of nuclear wastes, and facilities used for extensive fabrication, production, use, handling or storage of nuclear materials or nuclear wastes
- the possession, fabrication, production, transfer, handling, use, storage, transport, export and import of nuclear materials and nuclear wastes as well as the export and import of ores and ore concentrates containing uranium or thorium.

The current radiation protection legislation is based on the Radiation Act and Decree, both of which are from 1991 and take into account the ICRP Publication 60 (1990 Recommendations of the International Commission on Radiological Protection). Section 2, General principles, and Chapter 9, Radiation work, of the Act are applied to the use of nuclear energy.

The Nuclear Energy Act was amended in 2011 to include provisions on mining and milling operations aimed at producing uranium or thorium. In 2012, the Nuclear Energy Act was amended with some minor clarifications and to extend the use of inspection organisations. Some other minor amendments were also made during 2011–2012 in nuclear and radiation legislation to reflect changes of other legislation. Amendments in other national legislation have not caused essential changes to the regulatory control of nuclear facilities nor to the safety requirements set for them.

Finland is a Member State of the European Union. In 2011 some amendments were done in the Nuclear Energy Act due to the Nuclear Safety Directive (Council Directive 2009/71/Euratom). In 2013, the Nuclear Energy Act and the Radiation Act are under an amendment process to implement the Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste.

In 2012, the Finnish regulatory framework for nuclear and radiation safety was reviewed in the IRRS (Integrated Regulatory Review Service) peer review process. According to the IRRS recommendations, some amendments need to be considered for the legislation concerning mainly the independency of STUK. The amendments to the Nuclear Energy Act and the Radiation Act are being prepared in 2013.

Based on the Nuclear Energy Act, the Government issued in 2008 the following regulations:

- Government Decree on the Safety of Nuclear Power Plants (733/2008)
- Government Decree on the Security in the Use of Nuclear Energy (734/2008)
- Government Decree on Emergency Response Arrangements at Nuclear Power Plants (735/2008)

- Government Decree on the Safety of Disposal of Nuclear Waste (736/2008).

The Decrees 733/2008 and 735/2008 are applied to a nuclear power plant which is defined to be a nuclear facility equipped with a nuclear reactor for the purpose of electricity or heat production or a complex consisting of reactor units and other related nuclear facilities located on the same plant site. The regulations are also applied to other nuclear facilities to the extent applicable. Decree 734/2008 is applied to all use of Nuclear Energy, i.e., it covers all nuclear facilities and activities.

Decrees 733/2008 and 735/2008 will be amended in 2013 mainly due to tightening of safety requirements after the TEPCO Fukushima Dai-ichi accident and new WENRA Safety objectives. A Government Decree on the safety of mining and milling operations aimed at producing uranium or thorium is being prepared in 2013.

As described above, nuclear legislation has been amended several times and therefore the Ministry of Employment and the Economy has started an evaluation of the need of a comprehensive reform of the legislation.

At the same time with the international negotiations to update the Paris and Brussels Conventions on Nuclear Liability also the Finnish Nuclear Liability Act was reviewed by a special governmental committee already in 2002. The financial provisions to cover the possible damage and resulting costs caused by a nuclear accident have been arranged according to the Paris and Brussels Conventions. A remarkable increase in the sum available for compensation of nuclear damages is expected in the future since international negotiations about the revision of the Paris/Brussels agreements on nuclear liability were successfully completed in 2004. In addition to the revised agreements, Finland has decided to enact unlimited licensee liability by law. This means, that insurance coverage will be required for a minimum amount of EUR 700 million and the liability of Finnish operators shall be unlimited in cases where nuclear damage has occurred in Finland and also the third tier of the Brussels Supplementary Convention (providing cover up to EUR 1500 million) has been exhausted. The revised law will also have some other improvements, like extending the claiming period up to 30 years for victims of nuclear accidents (personal injuries). The law amendment (2005) has not taken effect yet. It will enter into force at a later date as determined by Government Decree. The entering into force of the amending act will take place as the 2004 Protocols amending the Paris and Brussels Conventions will enter into force.

As the ratification of the 2004 Protocols has been delayed, Finland made a temporary amendment in the Finnish Nuclear Liability Act in 2012, implementing the provision on unlimited liability and requirement of insurance coverage for a minimum amount of EUR 700 million by the operator. The temporary law came into force in January 2012 and will be repealed when the 2005 law amendment takes effect. In Finland, the finishing off the international ratification process of the convention amendments without any undue delay is considered to be extremely important.

Provision of regulatory guidance

According to Section 7 r of the Nuclear Energy Act, STUK shall specify detailed safety requirements concerning the implementation of safety level in accordance with the Act. These requirements are presented in regulatory guides which are called YVL Guides. STUK shall specify the safety requirements it sets and publish them as part of the regulations issued by the STUK.

The safety requirements of STUK are binding on the licensee, while preserving the licensee's right to propose an alternative procedure or solution to that provided for in the regulations. If the licensee can convincingly demonstrate that the proposed procedure or solution will implement safety level in accordance with the Nuclear Energy Act, STUK may approve this procedure or solution.

The procedure to apply new guides to existing nuclear facilities is such that the publication of an YVL Guide does not, as such, alter any previous decisions made by STUK. After having heard those concerned, STUK makes a separate decision on how a new or revised YVL Guide applies to operating nuclear power plants, or to those under construction, and to licensee's operational activities as well as to other nuclear facilities related to nuclear waste management and disposal and to the research reactor. To new nuclear facilities, however, the guides apply as such.

Nowadays the most important references considered in rulemaking are the IAEA safety standards, especially the Requirements-documents, and WENRA (Western European Nuclear Regulators' Association) Safety Reference Levels. Also the WENRA Safety Objectives for new reactors and the WENRA positions on some key technical issues are considered. Other sources of safety information are worldwide co-operation with other countries using nuclear energy, e.g. OECD/NEA, MDEP (Multinational Design Evaluation Programme) and VVER Forum. The Finnish policy is to participate actively in the international discussions on developing safety standards and adopt or adapt the new safety requirements into national regulations. At the moment STUK has a set of about 70 regulatory guides in force (see Annex 1). The regulatory guides have been continuously re-evaluated for updating.

After amending the nuclear energy legislation in 2008, also the revision of the existing nuclear safety guide system (YVL Guides) has been commenced. The updating of regulatory guides on security arrangements is also included in the ongoing activity. The main objectives of this effort on the revision of the guide system have been the following:

- to restructure the guide system to better reflect the various areas of safety; at the same time to limit the total number of guides and need for cross-referencing between the guides (see Figure 4)

Structure of the new YVL guides

A Safety management of a nuclear facility

A.1 Regulatory control of the safe use of nuclear energy
A.2 Siting of a nuclear facility
A.3 Management systems of a nuclear facility
A.4 Organisation and personnel of a nuclear facility
A.5 Construction of a NPP
A.6 Operation and accident management of a NPP
A.7 Risk management of a NPP
A.8 Ageing management of a nuclear facility
A.9 Reporting on the operation of a nuclear facility
A.10 Operating experience feedback of a nuclear facility
A.11 Security arrangements of a nuclear facility
A.12 Control of information security on a nuclear facility

B Plant and system design

B.1 Design of the safety systems of a nuclear facility
B.2 Classification of systems, structures and equipment of a nuclear facility
B.3 Safety assessment a NPP
B.4 Nuclear fuel and reactor
B.5 Reactor coolant circuit of a NPP
B.6 Containment of a NPP
B.7 Preparing for the internal and external threats to a nuclear facility
B.8 Fire protection of a nuclear facility

C Radiation safety of a nuclear facility and environment

C.1 Structural radiation safety and radiation monitoring of a nuclear facility
C.2 Radiation protection and dose control of the personnel of a nuclear facility
C.3 Control and measuring of radioactive releases to the environment of a nuclear facility
C.4 Radiological control of the environment of a nuclear facility
C.5 Emergency preparedness arrangements of a NPP

D Nuclear materials and waste

D.1 Regulatory control of nuclear non-proliferation
D.2 Transport of nuclear materials and nuclear waste
D.3 Handling and storage of nuclear fuel
D.4 Handling of low- and intermediate-level waste and decommissioning of a nuclear facility
D.5 Final disposal of nuclear waste
D.6 Production of uranium and torium

E Structures and equipment of a nuclear facility

E.1 Inspection, testing and certifying organisations
E.2 Manufacture and use of nuclear fuel
E.3 Pressure vessels and pipings of a nuclear facility
E.4 Verification of strength of pressure equipment of a nuclear facility
E.5 In-service inspections of pressure equipment of a nuclear facility
E.6 Buildings and structures of a nuclear facility
E.7 Electrical and I&C equipment of a nuclear facility
E.8 Valve units of a nuclear facility
E.9 Pump units of a nuclear facility
E.10 Emergency power supply of a nuclear facility
E.11 Hoisting and transfer equipment of a nuclear facility
E.12 Testing organisations in nuclear facilities

Figure 4. The re-structured system of regulatory YVL Guides.

- to compile requirements concerning related safety issues to the same guide making it easier to use by the licensees and other stakeholders; also they will be coupled to the stage of licensing process
- to rewrite the separate requirements in such a way that each requirement will have its own number, be short and clearly stating who-what-when shall be doing something; requirements are expressed in shall-format, descriptive text is provided only when necessary in the guide itself and additional information is provided in a separate justification memorandum (bases of the guide)
- when considering the requirements, special attention is paid to the opportunities to limit unnecessary prescriptiveness
- to update the contents of the regulatory guides, especially with the lessons learnt from the Olkiluoto unit 3 project.

After the TEPCO Fukushima Dai-ichi accident it was decided to include lessons learned from the accident into the revised guides, which has delayed the completion of the new guides. The original schedule was to have all of them ready by the end of 2011.The new revised schedule of the overall revision of YVL Guides is that all the new guides will be published during the autumn of 2013.

Considering the WENRA Safety Reference Levels published in 2007 and 2008, the Finnish policy is to include all of them in the revised regulatory guide system. This is confirmed already during the work through a systematic approach to earmark all the Reference Levels to certain guides.

To include the lessons from the TEPCO Fukushima accident in the new YVL Guides, a detailed plan was prepared in the beginning of 2012. Available information from the accident and evaluation reports concerning the accident were considered in the preparation of the plan. Also the IAEA Action Plan and the draft WENRA report on Safety of new NPP designs were considered. The plan was revised in the end of 2012. In this revision the results of the European stress tests and the outcomes of the Extraordinary Meeting to the Convention on Nuclear Safety were considered. The most important changes that will be included in the new YVL Guides due to the TEPCO Fukushima accident deal with the design of NPPs and spent fuel storages, consideration of severe external hazards and with the requirements concerning on-site emergency preparedness including multi-unit accidents.

System of licensing

The licensing process is defined in the legislation. The construction and operation of a nuclear facility is not allowed without a licence. The licences are been prepared by the Ministry of Employment and the Economy and granted by the Government. The conditions for granting a licence are prescribed in the Nuclear Energy Act.

Before a Construction Licence for a nuclear power plant, nuclear waste disposal facility, or other significant nuclear facility can be applied, a Decision-in-Principle by the Government is needed. A condition for granting the Decision-in-Principle is that the operation of the facility in question is in line with the overall good of society. The municipality of the intended site of the nuclear facility has to be in favour of constructing the facility. There shall also be sufficient prerequisites for constructing the facility according to the Nuclear Energy Act: the use of nuclear energy shall be safe; it shall not cause injury to people, or damage to the environment or property.

The coming into force of the Decision-in-Principle further requires that it will be confirmed by the simple majority of the Parliament. The Parliament can not make any changes to the Decision; it can only approve it or reject it as it is. The parties involved in the Decision-in-Principle process and their tasks are described in Figure 5. In Decision-in-Principle phase STUK prepares a statement on safety and preliminary safety assessment concerning the applicant, the proposed plant designs and plant sites. STUK asks also a statements e.g. from the Advisory Commission on Nuclear Safety and from the Ministry of the Interior concerning the emergency preparedness and physical protection arrangements.

For the Construction and Operating Licence application, the Ministry of Employment and the Economy asks STUK's statement on safety. Construction and Operating Licence documents to be submitted to STUK for approval in this phase are defined in Sections 35 and 36 of the Nuclear Energy Decree. STUK asks also statements e.g. from the Advisory Commission on Nuclear Safety and from the Ministry of the Interior. After receiving all statements for the Construction or Operating Licence, the Government will make its decision.

System of licensing was assessed in the IRRS mission conducted in Finland in October 2012. The IRRS team gave a recommendation that the Finnish Government should seek to modify the Nuclear Energy Act so that the law clearly and unambiguously stipulates STUK's legal authorities in the authorization process for safety. In particular, the changes should ensure that STUK has the legal authority to specify any licence conditions necessary for safety.

Decision-in-Principle procedure was been applied several times over the past 13 years. First time DiP procedure was applied for a nuclear power plant unit during the period November 2000 – May 2002 when Teollisuuden Voima Oyj (TVO) applied a Decision-in-Principle for the fifth NPP unit in Finland and the Government approved it and the Parliament confirmed the approval. The DiP procedure was already earlier applied when the DiP application of Posiva Oy for spent fuel disposal facility was confirmed by the Parliament in 2001 and also in connection with confirmation in May 2002 by the Parliament of the Government's Decision-in-Principle for expanding the capacity of spent fuel disposal facility to cover the spent fuel from the fifth reactor. The Decision-in-Principle procedure was also applied during the period April 2008 – July 2010 when three applications for new nuclear power plants (Fennovoima Oy, Fortum Power and Heat Oy and TVO), and two applications for expanding the planned capacity of the future spent fuel disposal facility in Olkiluoto were first handled by the Government and subsequently approved by the Parliament (see Article 14). The DiP application of Fortum regarding the proposed new Loviisa unit 3 and the corresponding DiP application to expand the capacity of the spent fuel disposal facility were not approved by the Government.

In accordance with Section 108 of the Nuclear Energy Decree, the different phases of construction of a nuclear facility may be begun only after STUK

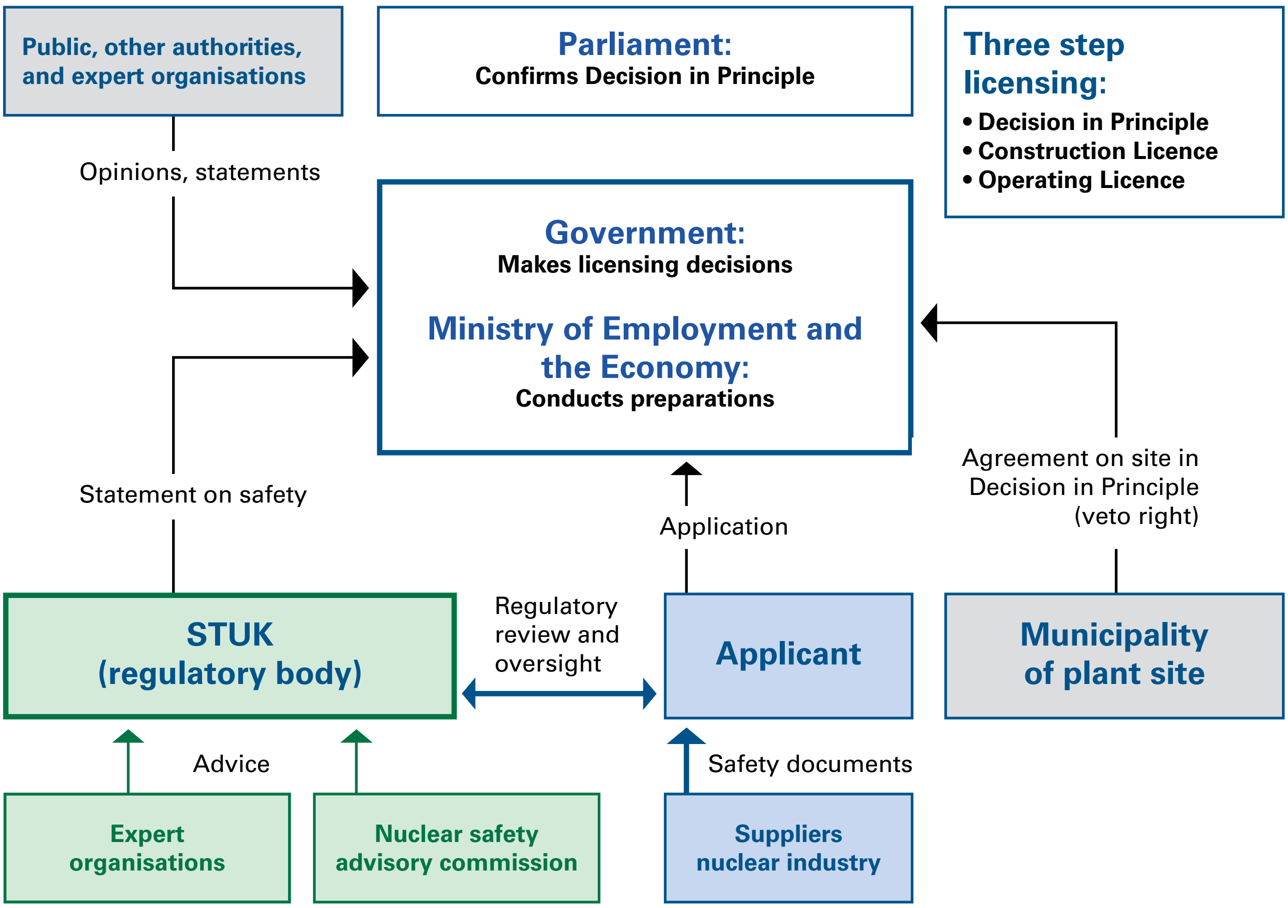


Figure 5. Licensing of nuclear facilities in Finland.

has, on the basis of the Construction Licence application documents and other detailed plans and documents it requires, verified in respect of each phase that the safety-related factors and safety regulations have been given sufficient consideration.

Review of the detailed design of structures and equipment can be begun after STUK has found that the system-level design data of the system concerned are sufficient and acceptable. This assessment may take place as part of the review of the Preliminary Safety Analysis Report or separate system-specific descriptions, which are subsequently added to the Final Safety Analysis Report.

In accordance with Section 109 of the Nuclear Energy Decree, STUK oversees the construction of the facility in detail. The purpose is to ensure that the safety and quality requirements, regulations for pressure equipment and approved plans are complied with and that the nuclear facility is constructed in other respects in accordance with the regulations. In particular, the oversight is aimed to verify that working methods ensuring high quality are employed for the construction.

Before loading fuel into the reactor, an Operating Licence is needed. The Operating Licences are granted for a limited period of time. This period has been at the beginning of Loviisa and Olkiluoto NPP operations five years and then about ten years. The periodic re-licensing has allowed good opportunities for a comprehensive, periodic safety review. Current operating licences of the Loviisa and Olkiluoto units are valid for about 20 years, but periodic safety reviews (PSRs) are required as a condition of continued operation in the licences.

System of regulatory inspection and assessment

The legislation provides the regulatory control system for the use of nuclear energy. According to the Nuclear Energy Act, STUK is responsible for the regulatory oversight of the safety of the use of nuclear energy. The rights and responsibilities of STUK are provided in the Nuclear Energy Act. Safety review and assessment as well as inspection activities are covered by the regulatory oversight.

Oversight during operation

STUK's oversight during plant operation includes periodic inspection programme, continuous oversight performed by STUK's resident inspectors, regular reporting and reporting of events and oversight performed at the plant site during operation and maintenance outages.

STUK's periodic inspection programme is focused on the licensee's main working processes and covers the most relevant areas of nuclear power plant safety. The objective of the inspection programme is to assess the safety level at the plants as well as safety management. Possible problems at the plants and in procedures of the operating organisations are to be recognised.

Inspection programme has been modified during the years. Latest changes were made in 2012, when inspection programme was updated and additional tools for organisational oversight was introduced into all inspections. Each year STUK defines the programme for the next year, including additional inspections as necessary. In addition to the periodic inspection programmes, STUK conducts unannounced inspections if seen necessary.

STUK has put special emphasis on the management of the entire inspection programme, including the timely conduct, resource allocation and accurate reporting of results, but there are some issues which can be further improved. Periodic inspection programme was assessed in the IRRS mission conducted in Finland in October 2012. The IRRS mission team suggested that STUK can further enhance the effectiveness of its inspection activities by enhancing the focus of inspection on the most safety-significant areas, by defining more concrete criteria for reactive inspections and conducting higher number of unannounced inspections. STUK is updating the internal guidance of the periodic inspection programme by the end of year 2013 taking into account the IRRS recommendations and suggestions. In addition, unannounced inspections are included in the yearly inspection programmes.

In the event review, the safety significance of the event is first evaluated based on the information given by the operator and STUK's resident inspectors. Later operating experience is reported to STUK as an event report, which STUK evaluates and may require additional information or actions. STUK maintains internal database for events which disseminates operating experiences and provides easy access to operational event reports. STUK may assign own investigation team for events deemed to have special importance, especially when the operations at the nuclear power plant have not been performed as planned and expected. It is also possible to nominate an investigation team to investigate a number of events together in order to look for possible generic issues associated with the events. These inspections are usually conducted by a leadership of the STUK's event investigation manager, and an investigation team includes normally 3–5 experts from STUK or from external organisations nominated on case-by-case basis.

Numbers of operational events are followed through STUK's plant performance indicator system. Risk significance of operational events is followed by PRA based indicators.

STUK's oversight and safety assessment concerning plant modifications is described in Article 14.

Oversight during construction

In accordance with Section 109 of the Nuclear Energy Decree, STUK oversees the construction of the facility in detail. Oversight consists of inspections within the frame of the Construction Inspection Programme and inspections on manufacturing and construction of systems, structures and components important to safety. In addition, STUK has four resident inspectors overseeing the construction, installations and commissioning work at the Olkiluoto site. Licensee reports regularly about the progress of the construction.

To oversee the licensee's performance in a construction project, STUK has established a Construction Inspection Programme. The purpose of the programme is to verify that the performance and organisation of the licensee ensure high-quality construction and implementation in accordance with the approved designs while complying with the regulations and official decisions. The Construction Inspection Programme is divided into two main levels: the upper level assesses the licensee's general operations to manage the construction, such as safety management and safety culture, organisation, corrective actions programme, the licensee's expertise and use of expertise and project quality management. The next level, known as the operation level, assesses e.g. project quality assurance, training of the operating personnel, utilisation of the PRA, radiation safety issues, and licensee's review and assessment process for system, structure and component-specific design reviews and inspections in the various fields of technology. Furthermore, the emergency response arrangements during construction, physical protection, fire protection and nuclear waste treatment are subjects of the Construction Inspection Programme as far as the scope is considered necessary by STUK. In addition to the above-mentioned inspections, of which the licensee is informed in advance, STUK carries out inspections without prior notice at its discretion. Construction Inspection Programme was also assessed in the IRRS mission and the recommendations and suggestions given for the periodic inspection programme of the operating plants concern also the Construction Inspection Programme. STUK is updating the internal guidance of the Construction Inspection Programme by the end of year 2013.

STUK performs inspections on manufacturing and construction of buildings, concrete and steel structures, and components as specified in YVL Guides. Inspections are determined in details when STUK reviews component or structure specific construction plans. Inspections are defined either as hold or witness points. Licensee is responsible for inviting STUK to perform the inspection at a right time. Goal of the inspections is to verify that manufacturer, vendor and licensee have performed their duties as expected and that QC results of manufacturing and construction are acceptable. In addition, STUK performs inspections on installation and commissioning of systems, structures and components. The safety class of systems, structures and components as well as the complexity of the SSCs are taken into account when determining the scope of inspections. On the licensee's application, STUK may approve separate inspection organisations to carry out specified regulatory control duties.

Enforcement

The Nuclear Energy Act defines the enforcement system and rules for suspension, modification or revocation of a licence. The enforcement system includes provisions for executive assistance if needed and for sanctions in case the law is violated. The enforcement tools and procedures of the regulator are considered to fully meet the needs.

In practice, the enforcement tools include: oral notice or written request for action by the inspector, and written notice or order for actions by STUK. Actions can include shutting down the plant operation immediately or decrease of reactor power and for unlimited time. Legally stronger instruments would be 1) setting a conditional imposition of a fine, 2) threatening with interruption or limiting the operation and, 3) threatening that STUK enforces the neglected action to be made at the licensee's expense.

The repertoire of these tools together with some practical examples for implementing them has been presented in an internal policy document as part of STUK's Quality System.

In conclusion, Finnish regulations and practices are in compliance with Article 7.

Article 8. Regulatory body

1. ***Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities.***
2. ***Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.***

STUK in the regulatory framework

According to the Nuclear Energy Act, the overall authority in the field of nuclear energy is the Ministry of Employment and the Economy. The Ministry prepares matters concerning nuclear energy to the Government for decision-making. Among other duties, the Ministry of Employment and the Economy is responsible for the formulation of a national energy policy.

The mission of the Radiation and Nuclear Safety Authority (STUK) is 'to protect people, society, environment, and future generations from harmful effects of radiation'. STUK is an independent governmental organisation for the regulatory control of radiation and nuclear safety as well as nuclear security and nuclear materials. STUK is administratively under the Ministry of Social Affairs and Health. Interfaces to ministries

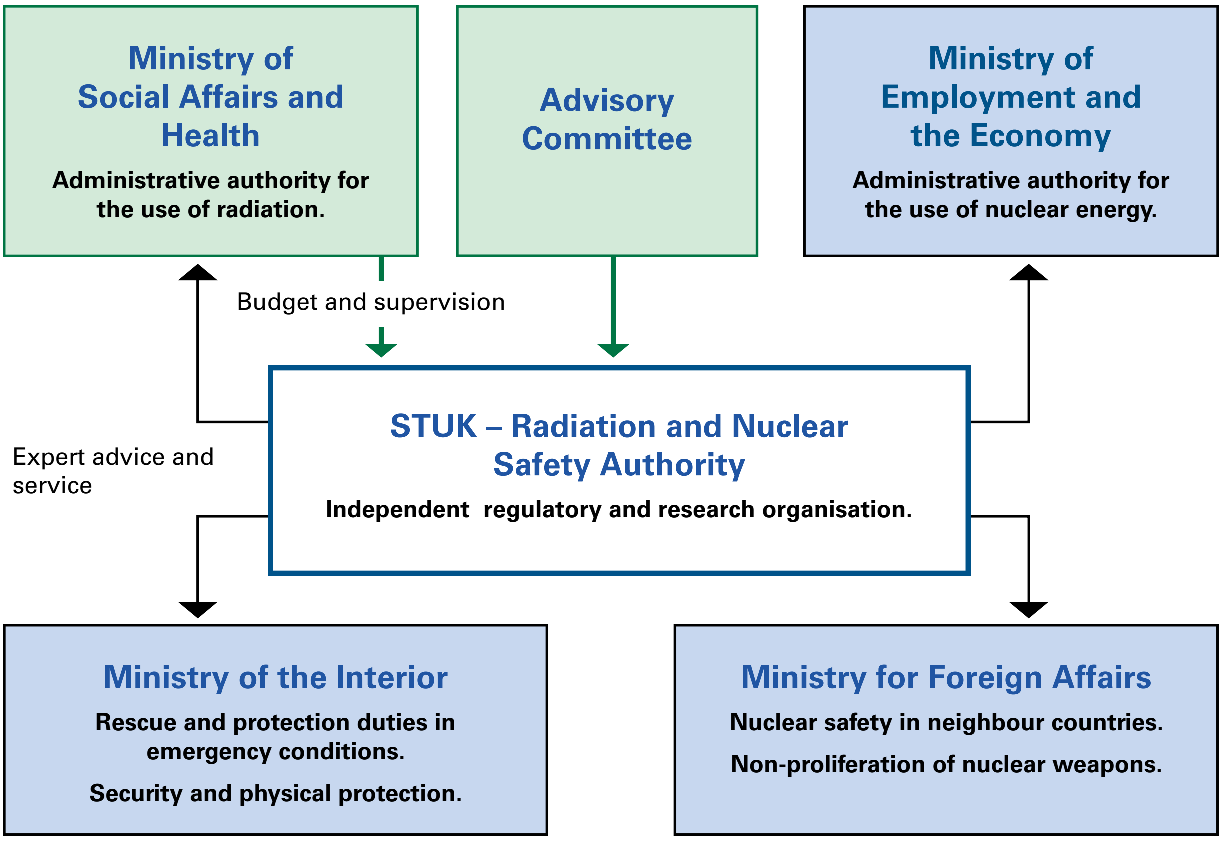


Figure 6. Co-operation and interfaces between STUK and Ministries and other organisations.

and governmental organisations are described in Figure 6. It is emphasised that the regulatory control of the safe use of radiation and nuclear energy is independently carried out by STUK. No Ministry can take for its decision-making a matter that has been defined by law to be on the responsibility of STUK. STUK has no responsibilities or duties which would be in conflict with regulatory control.

The current Act on STUK was given in 1983 and the Decree in 1997. According to the Decree, STUK has the following duties:

- regulatory oversight of safety of the use of nuclear energy, emergency preparedness, security and nuclear materials
- regulatory control of the use of radiation and other radiation practices
- monitoring of the radiation situation in Finland, and maintaining of preparedness for abnormal radiation situations
- maintaining national metrological standards in its field of activity
- research and development work for enhancing radiation and nuclear safety
- informing on radiation and nuclear safety issues, and participating in training activities in the field
- producing expert services in the field of its activity
- making proposals for developing the legislation in the field, and issuing general guides concerning radiation and nuclear safety
- participating in international co-operation in the field, and taking care of international control, contact or reporting activities as enacted or defined.

STUK has the legal authority to carry out regulatory oversight. The responsibilities and rights of STUK, as regards the regulation of the use of nuclear energy, are provided in the Nuclear Energy Act. They cover the safety review and assessment of licence applications, and the regulatory oversight of the construction, operation and decommissioning of a nuclear facility. The regulatory oversight of nuclear power plants is described in detail in the Guide YVL 1.1. STUK has e.g. legal rights to require modifications to nuclear power plants, to limit the power of plants and to require shutdown of a plant when necessary for safety reasons, as described in Article 7.

STUK does not grant any construction or operating licences for nuclear facilities. However, in practice no such licence would be issued without STUK's statement where the fulfilment of the safety regulations is confirmed as described in Article 7.

STUK's Advisory Committee was established in March 2008. Advisory Committee helps STUK to develop its functions as a regulatory, research and expert organisation in such a way that the activities are in balance with the society's expectations and the needs of the citizens. Advisory Committee can also make assessments of the STUK's actions and give recommendations to STUK.

An Advisory Commission on Nuclear Safety has been established in 1988 by a Decree. This Commission gives advice to STUK on important safety issues and regulations. The Commission also gives its statements on licence applications. The Commission has now two international committees, one for reactor safety and one for waste safety issues. In addition, an Advisory Committee on Radiation Safety has been established for advising the Ministry for Health and Social Affairs. The members of the Advisory Commission on Nuclear Safety and the Advisory Committee on Radiation Safety are nominated by the Government.

To assist STUK's work in nuclear security, an Advisory Committee on Nuclear Security was established in 2009. The members of the committee come from the various Finnish authorities, and the nuclear licensees also have their representatives. The duties of the committee include the assessment of the threats in the nuclear field as well as consultation to STUK in important security issues. The committee also aims to follow and promote both the international and internal co-operation in the field of nuclear security.

STUK is responsible for informing the public and media on radiation and nuclear safety. STUK aims to communicate proactively, openly, timely and understandably. A prerequisite for successful communication is that STUK is known among media and general public and the information given by STUK is regarded as truthful. Communication is based on best available information. STUK's web site is an important tool in communication. It is important that the web pages are professionally edited and updated regularly. The information on web pages must be easy to find and understandable. Internal communication provides the personnel information about STUK's activities and supports its capability in participating in the external communication.

STUK's role and responsibilities have been assessed by a peer review. Full-scope IRRT mission (IAEA's International Regulatory Review Team) was carried out in 2000 and a follow-up mission in 2003. IRRS mission (IAEA's Integrated Regulatory Review Service) was carried out in October 2012.

In the latest IRRS mission, 18 international experts and 5 IAEA staff members reviewed regulatory activities in Finland on the basis of IAEA Safety Standards, International practices and experiences and lessons learned from the TEPCO Fukushima Dai-ichi accident. The scope of the mission was nuclear facilities, except the research reactor FiR-1 (preparations for environmental impact assessment for decommissioning of this reactor were commenced earlier in 2012), radiation sources and transport. In its preparations to this mission, STUK carried out a comprehensive self-assessment and developed a preliminary action plan for improvement.

As a result of the IRRS mission, the review team recognised several strengths and good practices such as effective safety assessment of new nuclear power plants, STUK's organisation and conduction of emergency exercises and active contribution of STUK to the global improvement of radiation and nuclear safety. They identified also areas for improvement, such as a need to strengthen the legislative framework by embedding in law the separation of STUK from entities having responsibilities or interests that could unduly influence its decisions, enhancing the effectiveness of STUK inspection activities and implementing of an independent monitoring programme for the environment of NPPs. STUK has developed its action plan for improvement on the basis of the IRRS mission results and the self-assessment. These actions have been included in STUK's strategy, operating programmes and annual plans. Follow-up mission is preliminarily planned for 2015.

IAEA's International Physical Protection Advisory Service (IPPAS) mission was carried out in Finland in 2009 and the follow-up in 2012.

Finance and resources of STUK

The organisational structure and the responsibilities within STUK are described in the Management System of STUK. Also processes for regulatory oversight and other activities of STUK are presented in the Management System. The organisation of STUK is described in the Figure 7.

STUK receives about 33% of its financial resources through the government budget. However, the costs of regulatory oversight are charged in full to the licensees. The model of financing the regulatory work is called net-budgeting model and it has been applied since 2000. In this model the licensees pay the regulatory oversight fees directly to STUK. In 2012, the costs of the regulatory oversight of nuclear safety were 17 million €.

STUK has adequate resources to fulfil its responsibilities. The net-budgeting model makes it possible to increase for example personnel resources based on needs in a flexible way.

At the end of 2012, number of staff in the department of Nuclear Reactor Regulation was 115. The number of staff has increased by 9 since the time of the fifth review meeting. The expertise of STUK covers all the essential areas needed in the oversight of the use of nuclear energy. As needed STUK orders independent analyses, review and assessment from technical support organisations to complement its own review and assessment work. The main technical support organisation of STUK is the VTT Technical Research Centre of Finland, but also Lappeenranta University of Technology (LUT) and Aalto University (former Helsinki University of Technology) are important. Also international technical support organisations and experts have been used, especially to support review and inspection activities related to Olkiluoto unit 3.

New personnel have been recruited since 2003 mainly for the safety review and assessment and inspection activities related to the Olkiluoto unit 3. The number of personnel in the department of Nuclear Reactor Regulation over the period of 2001–2012 is shown in Figure 8. The resources used for the oversight of existing nuclear power plants (Loviisa units 1 and 2 and Olkiluoto units 1 and 2), Olkiluoto unit 3 which is under con-

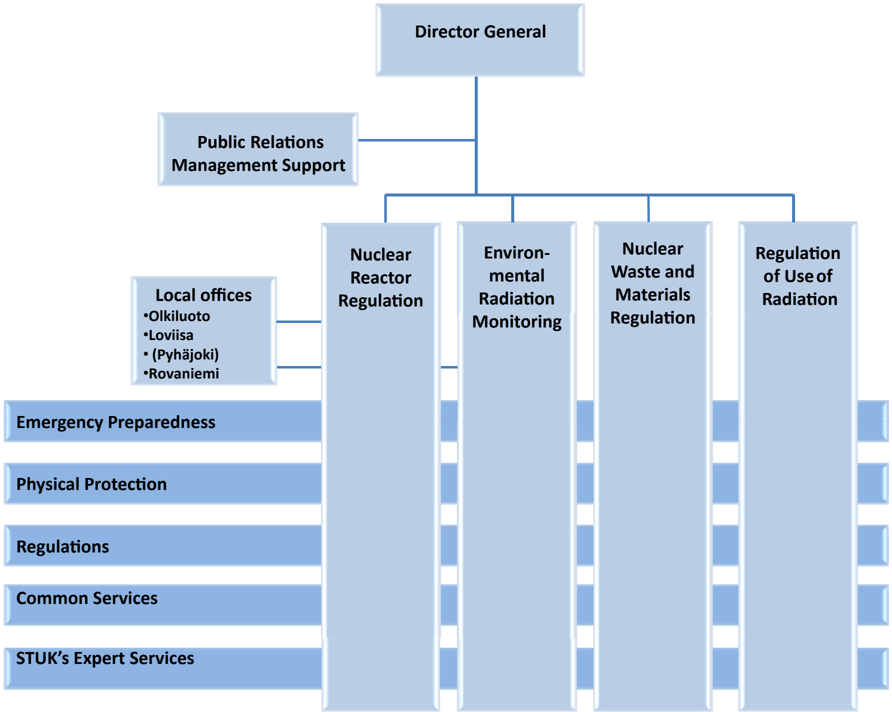


Figure 7. Organisation of STUK. The total number of staff at the end of 2012 was 358.

struction and new plant projects (Loviisa unit 3, Olkiluoto unit 4 and Fennovoima's unit 1) are shown in Figure 9. Annual volume of the oversight of the Olkiluoto unit 3 construction was about 30 man-year in 2012. Starting from year 2003, inspection organisations have been performing construction inspections in lower safety classes.

STUK has also increased the number of personnel in the areas of security of nuclear facilities as well as in activities related to nuclear waste management and disposal. In 2009, a separate unit for security with three experts was founded in the department of Nuclear Reactor Regulation and in the end of 2012, 4 experts worked in this unit.

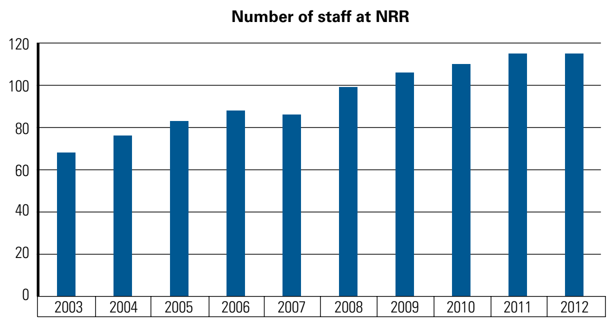


Figure 8. Number of personnel in the department of Nuclear Reactor Regulation.

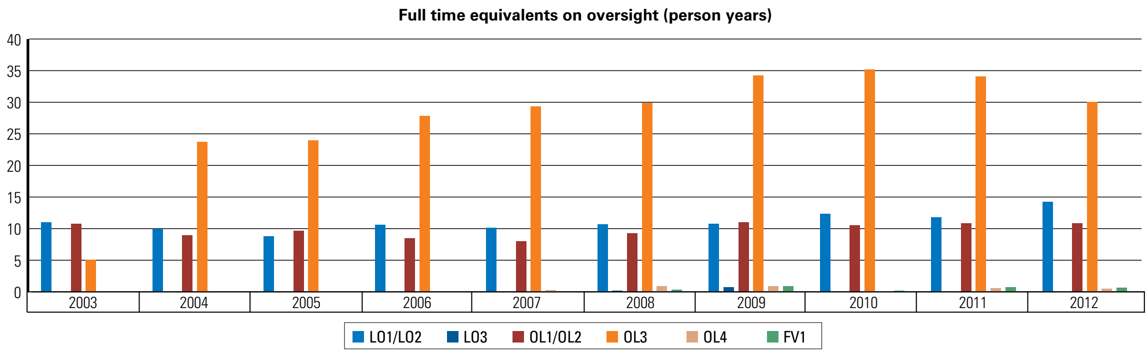


Figure 9. Resources used for the regulatory oversight in full time equivalents.

Ensuring competence

The management of STUK highlights the need for competent workforce. STUK has adopted a competence management system and nuclear safety and regulatory competencies are also emphasised in STUK's strategy. Implementation of the strategy is reflected into the annual training programmes, on the job training and new recruitments. The national nuclear safety and waste management research programmes have an important role in the competence building of all essential organisations involved in nuclear energy. These research programmes have two roles: for the first ensuring the availability of experts and for the second ensuring the on-line transfer of the research results to the organisations participating to the steering of the programmes and fostering the expertise. STUK has an important role in the steering of these programmes.

Most of the professional staff of STUK conducting safety assessments and inspections has a degree of university level. The average experience of the staff is about 15 years in the nuclear field. The competence analysis is carried out on regular basis and the results are used as the basis for the training programmes and the new recruitments. The training programme includes internal courses as well as courses organised by external organisations. On an average 5 % of the annual working hours has been used to enhance the competence.

An induction programme is set up at STUK for all new recruited inspectors. In addition to administrative issues, the induction programme includes familiarisation with legislation, regulatory guidance and regulatory oversight practices. Programme is tailored to each new inspector and followed by the manager.

STUK has participated in the preparation and execution of a basic professional training course on nuclear safety with other Finnish organisations in the field. The first 6-week course commenced in September 2003 and the 11th basic professional training course will commence in autumn 2013. At the moment, over 600 newcomers and junior experts, of whom more than 70 have been from STUK, have participated in these courses. The content and structure of the course has been enhanced according to the feedback received from the participants.

In Finland, VTT Technical Research Centre of Finland is the largest research organisation in the field of nuclear energy. At VTT, about 200 experts are working in the field of nuclear energy, about half of them full-time. The total volume of the nuclear energy research in Finland in the year 2012 was over 75 million € (estimate of the Ministry of Employment and the Economy). This figure includes research related to use of nuclear energy made in all the stakeholder organisations. Two thirds of the research is focused on the final disposal of the spent fuel. The largest individual organizations are VTT, LUT (Lappeenranta University of Technology), GTK (Geological Survey of Finland), and Aalto University (former Helsinki University of Technology, HUT).

The Nuclear Energy Act was amended in 2003 to ensure funding for a long-term nuclear safety and nuclear waste management research in Finland. Funds are collected annually from the licence holders to a special fund. Regarding nuclear safety research the amount of money is proportional to the actual thermal power of the licensed power plants or the thermal power presented in the Decision-in-Principle. For the nuclear waste research, the annual funding payments are proportional to the current fund holdings for the future waste management activities.

The research projects are selected so that they support and develop the competences in nuclear safety and to create preparedness for the regulator to be able to respond on emerging and urgent safety issues. The topics of the recent nuclear safety research programme (SAFIR2014) are organisation and human factors, automation and control room, fuel and reactor physics, thermal hydraulics, severe accidents, structural safety of reactor circuit, construction safety, probabilistic safety analysis and development of research infrastructure. The amount of money collected from the licensees in year 2012 was about 5.6 million € for nuclear safety research. The research projects have also additional funding from other sources. The total volume of the programme in 2012 was 10 million €. As a result of the TEPCO Fukushima Dai-ichi accident, a reassessment was made how the accident should be taken into account, and the research programme was supplemented with research topics related to natural hazards and multiple failure events, the adequacy and scope of nuclear power plant design basis, mitigating the impact of accidents (e.g. high concentration of boron in the reactor circuit, hydrogen formation and transport, range of fission products released in core melt), and the overall life cycle of nuclear fuel including spent fuel pools.

The objective of KYT2014 (Finnish Research programme on Nuclear Waste Management) is to ensure the sufficient and comprehensive availability of the nuclear technological expertise and other capabilities required by the authorities when comparing different nuclear waste management ways and implementation methods. KYT2014 is divided into three main categories:

- new and alternative technologies in nuclear waste management
- safety research in nuclear waste management and
- social science studies related to nuclear waste management,

and the main emphasis is on safety related research. The programme is conducted during 2011–2014 and the total annual funding is 2.8 M€, of which State Nuclear Waste Management Fund (VYR) covers 1.7 M€.

In conclusion, Finnish regulations and practices are in compliance with Article 8.

Article 9. Responsibility of the licence holder

Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility.

The responsibility for the safety rests with the licensee as prescribed in the Nuclear Energy Act. According to Section 9 of the Act, it shall be the licensee's obligation to assure safe use of nuclear energy. Furthermore, it shall be the licensee's obligation to assure such physical protection and emergency planning and other arrangements, necessary to ensure limitation of nuclear damage, which do not rest with the authorities.

It is the responsibility of the regulatory body to verify that the licensees fulfil the regulations. This verification is carried out through continuous oversight, safety review and assessment as well as inspection programmes established by STUK. In its activities, STUK emphasises the licensee's commitment to the strong safety culture. The obvious elements of licensee's actions to meet these responsibilities are strict adherence of regulations, prompt, timely and open actions towards the regulator in unusual situations, active role in developing the safety based on improvements of technology and science as well as effective exploitation of experience feedback. In addition to inspections and safety assessment, the follow-up of licensee's efforts in achieving results is based on safety indicators. This system includes indicators e.g. for plant availability, incidents, probabilistic risk assessment results, safety system operability, radiation doses to personnel as well as releases to the environment and resulting radiation exposures to the general public.

Based on the Chapter 7 of the Nuclear Energy Act, to ensure that the financial liability for the future management and disposal of nuclear wastes and for the decommissioning of nuclear facilities is covered, the nuclear power companies are every third year obliged to present estimates for future costs of these operations and take care that the required amount of money is set aside to the State Nuclear Waste Management Fund. In order to provide for the insolvency of the nuclear utilities, they shall provide securities to the Ministry of Employment and Economy for the part of financial liability which is not yet covered by the Fund. At the end of the year 2012, the funded money (2 160 million euros) covered most part of the whole liability (2 238 million euros). Under the Nuclear Energy Act, nuclear companies should supplement the fund by payment of 83 million euros in early April 2013 (see also Article 11).

The arrangements for the Olkiluoto unit 3 will follow the same lines after the start of the operation. The licensee with a waste management obligation shall submit the waste management scheme and the calculations of waste management costs, which are based on the scheme, to the Ministry for approval for the first time early enough before beginning the operations producing nuclear waste, and at the latest in connection with the operating licence application. The waste management scheme shall cover all phases of waste management including the decommissioning of the nuclear facilities and the final disposal of all arising nuclear wastes. The scheme must be sufficiently detailed to allow the calculations for the assessed liability.

The financial provisions to cover the possible damages to third parties caused by a nuclear accident have been arranged in Finland according to the Paris and Brussels Conventions. Related to the revision of the Paris and Brussels Conventions in 2004, Finland has decided to enact unlimited licensee's liability by law (see Article 7). The revised law will also have some other modifications, such as extending the claiming period up to 30 years for victims of nuclear accidents. As the international ratification of the 2004 Protocols has been delayed, Finland made a temporary amendment in the Finnish Nuclear Liability Act in 2012, implementing the provision on unlimited liability and requirement of insurance coverage for a minimum amount of EUR 700 million. The temporary law came into force in January 2012 and will be repealed when the 2005 law amendment takes effect after the international ratification of the Paris and Brussels Conventions.

In conclusion, Finnish regulations and practices are in compliance with Article 9.

Article 10. Priority to safety

Each Contracting Party shall take the appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety.

Regulatory requirements regarding safety culture and safety management

The importance of a good safety culture is emphasised in the Nuclear Energy Act and in the Government Decree on the Safety of Nuclear Power Plants (733/2008, Sections 21, 28 and 29), which state that when designing, constructing, operating and decommissioning a nuclear power plant, a good safety culture must be maintained by making sure that the decisions and activities of the entire organisation reflect commitment to safety. Licensee has to ensure that these requirements are applied in all organisations that participate in safety significant activities. An open working atmosphere must be promoted to encourage identification, reporting and elimination of factors endangering safety, and the personnel must be given opportunity to contribute to the continuous enhancement of safety. According to the Nuclear Energy Act, a responsible director has to be appointed for the construction and operation of a nuclear power plant. The appointment is subject to approval by STUK. The responsible director has a duty to ensure the safe use of nuclear energy and to see that the arrangements for physical protection and emergency preparedness and the safeguards control are complied with. The responsible director must have real possibilities to take effectively care of this duty.

STUK's Guide YVL 1.4 sets general requirements for management systems. An updated guide YVL A.3 concerning the management systems is under development and will be implemented during 2013-2014. The new YVL A.3 is also based on IAEA GS-R-3, and it includes even more detailed requirements for promoting good safety culture than the current guide YVL 1.4. The management system must support the characteristics of the organisational culture that promote good safety culture, and the management must express its commitment to safety. Safety culture expertise must be available for developing the safety culture. The development of the safety culture must be target oriented and systematic. The procedures used must strengthen a vigilant, questioning and initiative attitude at all levels of the organisation. The management system must also contain procedures for identification and continuous promotion of safety culture. The licensee has to also establish a process to measure, assess and improve its' safety culture.

STUK is also developing a new YVL guide concerning nuclear facility construction and modifications, i.e., YVL A.5. Also in this guide there are requirements concerning safety culture and risk management. During construction and modifications the licensee must ensure that the contributing parties are able to perform according to safety requirements and there must be training on safety culture issues for the personnel taking part in the activities. The licensee must have procedures for evaluating and developing the safety culture of the contributing parties. Guide YVL A.5 is planned to be published in 2013 and implemented at the existing nuclear power plants or plants under construction in 2013-2014. The new guide is applied as such to new nuclear facilities.

TEPCO Fukushima Dai-ichi accident has highlighted the importance of safety culture and its continuous assessment and improvement. The Diet report in 2012 concluded that *"fundamental causes of the accident are to be found in the* *ingrained conventions of Japanese culture; our reflexive obedience; our reluctance to question authority; our devotion to 'sticking with the program'; our groupism; and our insularity"*. These ingrained conventions were seen as factors preventing necessary stakeholders (Licensee, Regulatory Body and Government) to take needed actions to ensure safety and therefore also contradicting with good safety culture. The influence of ingrained conventions in national culture is considered in Finland to be one of the key messages in the Diet report. To better understand the ingrained conventions in the Finnish culture and their possible positive and/or negative impacts on safety culture, STUK has made a decision to conduct a research in the near future.

Measures taken by licence holders

Loviisa NPP

Fortum Nuclear Competence Center consists of Loviisa NPP, Technical Support and the Nuclear Safety Oversight (NSO). NSO oversees the Fortum Nuclear operations and Loviisa NPP, is independent from operations and reports to the licensee management. Loviisa NPP has made organisational changes that aim at also promoting the safety culture development. There is a unit especially dedicated for operational experience and safety culture. In addition, the Loviisa NPP has an independent advisory body for safety issues, i.e., a nuclear safety committee with external expert members. Fortum has established documented quality and safety policies for the Loviisa NPP.

Fortum has continued having international evaluations of safety management and procedures at the Loviisa NPP in order to improve its own operations. IAEA carried out an OSART safety review in Loviisa in March 2007, with a follow-up review in July 2008. WANO peer review was performed in March 2010, with a follow-up review in April 2012. In the latest WANO follow-up review, WANO stated that most development actions were completed where as a couple of them are still in progress, although they have been appropriately started.

Loviisa NPP has conducted a safety culture self evaluation according to a renewed procedure during 2012. Based on the results from the evaluation Loviisa NPP has formed an action plan.

Fortum has continued the special training programme for the Loviisa NPP contractors, with which the licensee aims to ensure the right attitudes and safety culture among the contractors working at the NPP. In the training, Fortum communicates the safety-first-principle and nuclear and radiation safety issues for contractor personnel working at the site. The contractor training is valid only for a determined time and has to be repeated when expired. All contractors and suppliers are regularly evaluated by Fortum to ensure that they can fulfil the regulatory and safety requirements. Fortum has developed procedures for ensuring appropriate competence for the auditors conducting contractor evaluations and audits.

Olkiluoto NPP

The Olkiluoto NPP has worked several years with safety culture evaluation and development. The operator TVO has founded a special safety culture team that is independent from operations and construction. This team meets regularly about 10 times a year and the mission is to form a comprehensive view of the safety culture situation in the whole TVO and report and give suggestions to the top management of the organisation. The NPP has had a safety culture specialist available who has facilitated the safety culture self evaluations and also implementations of different safety culture promoting methods. An example is the Human Performance Improvement program including peer checking, two way communication etc.

TVO has also an independent cross functional safety group that consists of specialists among NPP's own staff and also external expert members that are called in for special topics.

TVO has assessed the safety culture of the Olkiluoto NPP through several methods. The safety culture issues have been regularly discussed in the safety group meetings. The self-assessment is repeated approximately every third year. Personnel surveys and the peer review method of the World Association of Nuclear Operators (WANO) have also been utilised actively. TVO has also documented quality and safety policies for the Olkiluoto NPP and so called 'Management Expectations' flyers, where the managers communicate very clearly their expectations for safe working and safety attitudes.

TVO has continued using and developing the safety culture promotion and assessment methods concerning the Olkiluoto unit 3 project and the contributing parties. Assessment method consists of a questionnaire, interviews and analysis of safety observations, authority inspections and nonconformance records. The Safety Culture report is prepared twice a year. Safety culture promotion methods include safety culture pilots, info tv and materials, regular safety culture meetings with the supplier and so on. A strong safety culture is also essential during the commissioning phase, which has been taken into account in cooperation with the commissioning personnel.

TVO administrates and follows up the competence of contractors that work at the plant regularly or for longer terms. These contractors have to complete the same basic training as NPP's own personnel as appropriate. Basic nuclear and radiation safety training is prerequisite for all persons working at the site. Priority to safety is addressed in the training. TVO regularly audits and evaluates contractors and suppliers to ensure that they can fulfil the regulatory and safety requirements.

Regulatory oversight

STUK has continued to regularly inspect the management systems of both licensees (Fortum and TVO) to ensure that they are fulfilling the requirements of the legislations and the Guide YVL 1.4. Based on the inspections, there is still need for development actions to fulfil the requirements especially concerning the process based management and supply chain management. The safety culture is also included as a topic in the STUK's periodic inspection programme. During 2010–2013 the inspections have dealt with especially safety culture evaluation methods and management commitment for safety culture and the responsibility for the management to define and communicate the requirement for a good safety culture. There is a special top level inspection in the periodic inspection programme, "Management and Safety Culture", that includes an assessment of safety culture issues, management and leadership. Additionally, safety culture issues are included in quality assurance audits and event analyses. Safety culture related findings from different inspections are discussed in regular meetings in STUK and between the senior management of the nuclear power plants and the regulatory body.

In the end of 2010 and beginning of 2011, STUK conducted an event investigation concerning the Olkiluoto NPP unit 3 Emergency Diesel Generator procurement. The investigation underlined the importance of strict supply chain management especially stressing the safety requirements and the communication of these during the whole procurement and delivery process and to all involved parties. The importance of the management's lead in enhancing safety culture and priority to safety was also recognised and unility's attitude was also crucial in communication with all stake-holders.

STUK has developed a special inspection tool for gathering information about issues related to Human and Organisational Factors (HOF) within periodic inspection programme for operating NPPs. The tool was implemented during 2012. Based on the findings according to four predefined areas, i.e. personnel planning, communication, handling of non-conformances and process management, STUK can obtain an overall picture of the licensee's situation concerning these HOF topics. STUK developed also in 2012 a special database for collecting HOF related findings made during the oversight of the Olkiluoto NPP unit 3. The IRRS mission team suggested that STUK should consider the development and implementation of a more systematic method for collection and assessment of indications of the licensee's safety culture. STUK will continue developing the collection and analysis of all HOF related findings by expanding the database for both operating NPPs and NPPs under construction.

STUK co-operates with VTT Technical Research Centre of Finland on safety culture related inspections and VTT is conducting a re-assessment on safety culture at the Olkiluoto unit 3 construction site. Safety culture related seminars have also been arranged together with both VTT and the licensees, and vendors.

Means used by regulatory body in its own activities

Safety is emphasised in the Quality Manuals of STUK as well as in the framework contract between STUK and its technical support organisation VTT Technical Research Centre of Finland. STUK's Quality Policy includes STUK's values that give the highest priority to keeping the radiation exposure of people as low as reasonably achievable and preventing radiation and nuclear accidents. STUK has taken an active role in this area and both developed its own culture and taken the initiative in the assessment of cultures of the licensee organisations. The IRRS mission was carried out in fall 2012 and the reviewers suggested that STUK could emphasise safety culture also in its quality manual in a more detailed way as well as to assure the safety consciousness of the staff. To meet this suggestion, STUK decided to update its management system and to include self-assessment of safety culture into annual self-assessment programme.

Both the periodic inspection programme and the construction inspection programme are established according to STUK's strategic decisions about safety critical areas at NPPs. These areas are covered at least every third year at the operating nuclear power plants. STUK conducts self-assessments and personnel questionnaires to follow up the internal opinions regarding the priority devoted to different topics of nuclear safety. STUK arranges regularly training for the inspectors and an introduction programme is set up for all new recruited inspectors. STUK has added resources to and reorganised the organisation that handles NPP security issues. Similarly STUK has strengthened its personal resources for the review of the construction licence application submitted by Posiva Oy at the end of 2012 for the spent fuel encapsulation and disposal facility in Olkiluoto.

In conclusion, Finnish regulations and practices are in compliance with Article 10.

Article 11. Financial and human resources

1. ***Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.***
2. ***Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life.***

Financial resources

Nuclear Energy Act defines as a condition for granting a Construction or Operating Licence that the applicant has sufficient financial resources, necessary expertise and, in particular, that the operating organisation and the competence of the operating staff are appropriate. According to the Nuclear Energy Act, the licensee shall also have adequate financial resources to take care of the safety of the plant. In addition, Nuclear Energy Act provides detailed regulations for the financial arrangements for taking care of nuclear waste management. The Act on Third Party Liability provides regulations on financial arrangements for nuclear accidents, taking into account that Finland is a party to the Paris and Brussels conventions.

The financial preconditions are primarily assessed by authorities other than STUK (mainly the Ministry of Employment and the Economy). The financial position and business environment of the licensee also affect the safety of plants, and STUK therefore follows licensees' plans to improve safety of nuclear power plants, as well as organisational reforms, safety research conducted by licensees, the number of employees and the competence of personnel. The annual reports of Fortum Corporation and Teollisuuden Voima Oyj provide financial information on the utilities. Both utilities have annually invested typically about 40–50 M€ for maintaining the plant and improving safety. For example, TVO has recently made a decision to renew all emergency diesel generators where the overall investment is more than 100 M€.

A financing system for the costs of future waste management and decommissioning exists to ensure that the producers of nuclear waste bear their full financial liability on the coverage of those costs and that the costs can be covered even in case of insolvency of the waste generator. The pertinent licence-holders submit every three years for regulatory review the technical plans and cost calculations on which the liability estimates are based. After confirmation of the financial liabilities, the licensees pay fees to a State controlled Nuclear Waste Management Fund and provide securities for the liability not yet covered by the funded money. At the end of 2012, the funded money (2 160 million euros) covered most part of whole liability (2 238 million euros). Under the Nuclear

Energy Act, nuclear companies should supplement the fund by payment of 83 million euros in early April 2013.

Human resources

The licensee has the prime responsibility for ensuring that all the employees are qualified and authorised to their jobs. The regulatory requirements for human resources are stated in the Nuclear Energy Act (Sections 7 and 20), the Government Decree on the Safety of Nuclear Power Plants (733/2008) and STUK's Guides YVL 1.6 and YVL 1.7. The Nuclear Energy Act Section 7 was modified during 2012 with a demand to appoint also deputies for the responsible persons for emergency preparedness, security and safeguards. According to Section 30 of the Government Decree 733/2008, significant functions with respect to safety within nuclear power plants must be designated, and training programmes must be prepared for development and maintenance of professional qualifications of the persons working in these positions. Adequate command of the functions in question must also be verified. The Guide YVL 1.6 sets requirements for NPP operator competence, and the Guide YVL 1.7 for training and qualifications of personnel working in functions that are important for plant safety. The YVL Guides concerning human resources are currently being updated and will be replaced by the guide YVL A.4 during 2013. This new YVL guide has more specific requirements for safety critical positions, e.g. for responsible director and persons responsible for safeguards, emergency preparedness and security. The guide also has specific requirements on management and leadership competencies.

Human resource planning at the Loviisa NPP is based on a ten-year plan, which is subject to annual management review and updating. Loviisa NPP has taken into use a project management procedure which includes a resource management approach that will support the NPP in evaluating and following up the resources needed for accomplishing the projects.

The training activities and procedures at the Loviisa NPP are constantly developing. Much responsibility is given to the line manager and the individual defining of qualification and training needs. The training unit can support the line organisation with their expertise, but the responsibility for developing the specialist competence lies on the line organisation. The training unit's main responsibility is to develop the human resource management procedures and organise the general training sessions. The training organisation has been strengthened with experts in behavioural sciences. Fortum has a procedure for setting up individual development plans for all newcomers and for persons changing positions. Fortum has defined the qualification needs for the different positions based on job descriptions, but the challenge is to break down the descriptions to real competencies and development needs. Loviisa NPP has to develop more its strategic competence management to be able to ensure the resources needed for a longer term. STUK has by inspections identified a need for human resource development in, for example, quality assurance. Loviisa NPP has during 2012 recruited some full time project managers and increased the quality management training to improve the situation. Fortum has a full scope simulator at the Loviisa NPP to ensure the training of operators. Fortum takes actively part in developing and executing the national nuclear safety training (YK) course to ensure competence for the nuclear field now but also in the coming years.

TVO has updated the personnel plan regularly according to the phases of Olkiluoto NPP unit 3 construction phase and also considering the planning of the fourth reactor Olkiluoto unit 4, for which TVO got the Government Decision in Principle in 2010. TVO has also started a trainee program for developing young recruits for a career at TVO. TVO has also during 2012 actively started to seek solutions for planning resources efficiently between projects and day to day operations. The ageing power plants and the more demanding safety requirements need more and more improvement projects with critical time schedules. An efficient plant modification and project procedure is of high importance for safe and successful operations. TVO has revised their training program and procedures taking into account the commissioning of the Olkiluoto unit 3 and the increasing need for systematic and strategic competence management due to the growing organisation (OL3, OL4). TVO uses an IT-system that supports the managers e.g. in defining and following up individual development plans. TVO has defined training requirements for each position or job that automatically will be included in the new recruited person's development plan. In 2010 TVO had a WANO Technical Support Mission that gave TVO good bench-marking input for the development actions.

Personnel and human resources related issues are included in STUK's periodic and construction inspection programmes at the nuclear power plants. A top level inspection of the periodic inspection programme, "Human Resources and Competence", includes assessment of human resource management, competence development and training programmes. It also covers the licensee's procedures for managing human resources and competence of suppliers, sub-suppliers and other partners participating in functions affecting safety. During the years 2010–2013 STUK has paid attention especially to personnel planning and ensuring resources in development and modification projects. STUK also participates in examinations of shift personnel, where the operators working in the control rooms show that they are conversant with all salient matters related to plant operation and safety. STUK further approves the appointment of certain key personnel, such as the responsible director and his/her deputies.

Ensuring an adequate national supply of experts in nuclear science and technology and high quality research infrastructure is recognised as a continuous challenge in Finland because of the retirement of large age groups, ongoing Olkiluoto unit 3 construction project and the new reactors, that got the government Decision in Principle in May 2010. In addition to the measures to maintain and develop the capabilities and amount of professional staff of STUK and the utilities, the similar requirements for maintaining and developing the human resources in the nuclear energy sector apply to VTT Technical Research Centre of Finland, which acts as the main technical support organisation to STUK. In the same way one has to devote appropriate measures to develop the educational resources in technical universities and other high-level universities in Finland.

The main organisations in the nuclear energy area develop and organise the basic professional training course on nuclear safety, which is a yearly held approximately 5-week training programme for students and staff members of the participating organisations (STUK, the licensees, VTT, Aalto University and Lappeenranta University of Technology, Ministry of Employment and the Economy).

During 2010–2012 a committee set up by the Ministry of Employment and the Economy worked on a report aiming at giving recommendations and steps to be taken until the 2020's for ensuring competence and resources needed for the nuclear sector. STUK was an active part in this committee. One of the recommendations of the committee was: The future needs and focus areas of Finnish nuclear energy sector research must be accurately defined and a long-term strategy drawn up for further development of research activities. This calls for a separate joint project among research organisations and other stakeholders in the field. The report can be found on http://www.TEM.fi/files/33099/TEMjul_14_2012_web.pdf.

At the end of January 2013 the Ministry of Employment and the Economy set up a working group to prepare a research and development strategy. The objectives of the working group include the following tasks: (1) definition of main development lines for the Finnish research activities in the area of nuclear energy (vision until 2030, road maps, nuclear energy research in general, nuclear safety research, research on advanced nuclear reactor concepts, research on nuclear fusion technology), (2) identification of priority areas for nuclear energy research taking into account future research needs and the required knowledge base, (3) definition of the needs for the development of research infrastructure covering the needs of different actors in the nuclear energy sector, (4) optimization of the management of national research programmes as well as the provision of funding to the research programmes and (5) enable more significant than presently participation of Finland in the international research activities in the nuclear energy sector. The working group will be chaired by a representative of the Ministry of Employment and the Economy. The Ministry will also provide secretariat to the working group. The nominated members of the working group include experts from STUK, VTT, Finnish Academy, Aalto University, Technical University of Lappeenranta, University of Helsinki, Fortum, TVO and Posiva.

In conclusion, Finnish regulations and practices are in compliance with Article 11.

Article 12. Human factors

Each Contracting party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation.

Regulatory requirements regarding human factors

Human reliability in the plant operations is largely based on good plant design and proper procedures and training. According to Section 6 of the Government Decree on the Safety of Nuclear Power Plants (733/2008), special attention must be paid to the avoidance, detection and correction of any human error during design, construction, operation and maintenance. The possibility of human errors shall be taken into account in the design of a nuclear power plant and in the planning of its operation and maintenance, so that human errors and deviations from normal plant operations due to human error do not endanger plant safety. The impacts of human error shall be reduced by using various safety principles, including defence-in-depth, redundancy, diversity and separation.

According to Section 19 of the Government Decree 733/2008, the control rooms of a nuclear power plant must contain equipment that provides information on the operational state of the nuclear reactor and any deviations from normal operation. Furthermore, the nuclear power plant shall contain automatic systems that actuate safety functions whenever required and control and supervise their functioning during operational occurrences and accidents. These automatic systems shall be capable of maintaining the plant in a controlled state long enough to provide the operators with sufficient time to consider and implement the correct actions. The nuclear power plant shall have an emergency control room independent of the control room, and the necessary local control systems for shutting down and cooling the nuclear reactor, and for removing residual heat from the nuclear reactor and spent fuel stored at the plant.

Measures taken by licence holders

Loviisa nuclear power plant

Measures at the Loviisa plant to ensure adequate human performance have been focused on development of operating procedures. Large part of plant's emergency operating procedures (EOPs) have been modified into flowchart format. These EOPs include symptom based identification which guides operators to event based procedures. Complex accident sequences and core melt accidents lead to symptom based operation. Human redundancy is provided by independent on-duty safety engineer. These emergency operating procedures have gone through a comprehensive set of verification and validation activities which include background analysis of the plant behaviour. Loviisa plant is equipped with a full scope training simulator which is used for operator training, including accident situations.

Fortum evaluates human reliability as part of the probabilistic risk assessment (PRA). For analysing hidden defects influencing the course of a possible transient or accident, Fortum has evaluated regularly different types of duties performed at the plant. In the analysis such operational and maintenance mistakes have been evaluated which may act as an initiating event of a transient or an accident. Different plant states and duties related to them have been evaluated in detail.

Control actions needed during an accident have been divided in the PRA evaluation into two parts: a diagnosis and actions taken to prevent the accident. Possibilities for mistakes have been studied with the help of a simulator. Plant procedures for emergency situations have been developed and will be further developed, taking also into account the results of PRA. For preventing human errors it is important, that the operating events are carefully evaluated and, if necessary, procedures of the nuclear power plant are developed to prevent similar mistakes. Fortum has developed the utilisation of operating experiences and conducts the root cause analyses out of most significant events.

The protection systems of the plant initiate the safety systems automatically when needed so that the operators will have enough time to consider actions according to operating and emergency procedures. Due to the inherent characteristics of the Loviisa plant, the operators will have more time for consideration in a transient situation than usually at other nuclear power plants. The Loviisa units 1 and 2 have their own independent main control rooms where the needed process information is available and control actions can be performed.

Alarm signals from the interim spent fuel storage are also available in the Loviisa unit 2 main control room. Process information is presented in the main control room with indicating meters, indicator lights and recorders as well as with the monitors of the process computer system. There are two redundant alarm systems in the main control room. These systems have been realised by using two different techniques, conventional and computer-based techniques. Indicator light fields are on the operator's consoles, and two monitors have been reserved for computer alarms. In addition, data on events and conditions as well as the exceeding of warning and alarm limits are recorded by the alarm printers. The process computer gives process information in an illustrative format for the use of the operators.

In addition to the main control room, the shutdown of the reactor as well as the control and monitoring actions necessary for safety can be performed by means of a so-called emergency control room table, located in the main control room of the other unit. For severe accidents there is a separate dedicated control room shared by both units.

The I&C systems are currently being renewed at the Loviisa plant. Human performance is taken into account in the modification. This automation renewal project has a dedicated control room design team, which is in charge of the human factors engineering (HFE).

Olkiluoto nuclear power plant

Basis for safe operation is laid already in design phase. A so-called 30-minute rule has been the design basis for the protection system at the Olkiluoto units 1 and 2. Important protection measures and safety systems start up automatically so, that no actions of operating personnel are needed during the first thirty minutes after the beginning of the operational transient or postulated accident. Proper emergency and transient situation procedures as well as training for those situations reduce the possibility of human errors further.

Olkiluoto units 1 and 2 have their own independent control rooms, where the necessary process information is available, and from where all necessary control measures can be conducted. The alarms covering the interim spent fuel storage are available in the control room of the Olkiluoto unit 1. The technical solutions of the main control rooms are based on the proven control room technology. During the renewal of turbine automation system several new computerised operator workstations and a large screen display system were installed into the main control room. Process information is presented by the indicating measuring equipment installed in the steering desks and panels as well as with several computer display units. Conventional and computer aided alarm systems are used to facilitate the management of main processes and other sub and auxiliary processes. The alarms are indicated primarily by the alarm lamp panels. The parallel alarms received through the computer are seen on the monitors. In addition, the event and state data as well as deviations from warning/alarm limits are printed on the alarm printers. A safety parameter display system (SPDS), which improves the performance capability of the operating personnel in controlling transient and accident situations, is in use at the Olkiluoto plant units. Main control room can now be described as a hybrid control room. All the main control room related modifications are tested at the training simulator, and operators are trained for managing the modified systems prior to the modifications are installed.

Both Olkiluoto plant units have an emergency control post, from where the reactor can be tripped and where the main parameters of the reactor such as neutron flux, pressure, temperature and water level can be monitored. Cooling the reactor down to a cold state and removal of decay heat can be carried out after the shutdown by using local control posts. The requirement of another, independent emergency control room emerged after the revision of the STUK's Guide YVL 5.5 "Instrumentation systems and components at nuclear facilities" in 2002. TVO is evaluating possibilities to improve and centralise the emergency controls to better comply the present requirements. Modifications are currently under detailed design.

There are methods for preventing human errors during operation. Main areas to be considered are operation, maintenance and modification projects. Human reliability can be enhanced in every day activities with certain methods. These methods include pre-job-briefing, de-briefing, peer checking, independent verification and clear communication. TVO has trained and introduced these methods in feasible activities. Proper work planning and

Permit-to-Work-system in addition to up-to-date procedures are key methods in maintenance related activities to ensure safety during maintenance. Checking and approval requirements are also considered when requalifying systems back into operation. This work is part of a company wide project called “Human Performance 2012” which incorporates also other measures to improve human performance. The aim is to support managers and the personnel in managing human performance to avoid as many human mistakes as possible.

Human Factor issues are taken into account in all events. Lessons learned from the events are taken into account in the corrective action plans and lessons learned are used in internal training and organisational development. TVO has utilised operating experience and results of root cause analyses in the development of human aspects in the operating procedures. Errors related to the maintenance actions have also been examined and measures have been developed to avoid corresponding errors. Fatigue has been identified as an important factor to be managed.

TVO has conducted a probabilistic risk assessment (PRA) where the consequences of human errors have been studied. Latent maintenance and testing errors have been studied in connection with the system analyses related to the PRA. In addition to the human factor experts, experienced staff members from the operating and maintenance personnel have participated in assessing the possibility of errors. The identified error possibilities have been classified into groups according to their importance and the most important ones have been modelled in the PRA study to clarify the risks related to errors. The reliability of operator actions conducted during accident conditions was assessed as a part of the PRA analysis. The diagnostic errors that may be made in connection with accidents have also been assessed. Based on the results of the analyses concerning the human errors, a few additions and modifications have been made on the emergency and operating procedures of the Olkiluoto units 1 and 2. Emergency operating procedures have been recently re-evaluated in order to identify any previously unnoticed errors. Some clarifications have been made into procedures based on these talk/walk-throughs and simulator tests.

For the Olkiluoto unit 3, human factors engineering has been part of the design phase. Concept of operation is taken from existing units and reference plants. Main control room has operational I&C system with operating terminals and large screen displays. This interface can be used in all plant conditions. Additional information can be integrated into this system, e.g. alarm systems and operating procedures. Safety related I&C system has own traditional operating panels which are diverse control method for operational I&C. These safety panels include also hardwired controls which are additional back-up for all I&C systems. Olkiluoto unit 3 has also remote shutdown station. Feasibilty of human factors engineering will be demonstrated in validation studies. Integrated validation will be done at a full scope simulator before plant commissioning.

Regulatory oversight

Human factors have to be taken into account in the design and analysed in the failure analyses of plant safety systems and in probabilistic risk assessments. Such analyses have been completed for both Finnish nuclear power plants. In addition to this high level licensing documentation, individual system design needs to be reviewed by STUK. Main emphasis is on the control room design approvals. Design documentation needs to reflect proper human factors design and design shall be coordinated with quality plans, change processes and verification/validation plans. Finally licensee shall demonstrate the safety with integrated system validation and analyse the results. Human error discrepancies need to be addressed if there are major findings, before commissioning of the control room systems can proceed.

In conclusion, Finnish regulations and practices are in compliance with Article 12.

Article 13. Quality assurance

Each Contracting Party shall take the appropriate steps to ensure that quality assurance programmes are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation.

Regulatory requirements regarding management systems

According to Section 29 of the Government Decree on the Safety of Nuclear Power Plants (733/2008), the organisations participating in the design, construction, operation, and decommissioning of a nuclear power plant are required to employ a management system. The quality management system must cover all functions influencing plant safety, and the licensees are further required to ensure that all their suppliers, sub-suppliers and other partners participating in functions that affect nuclear and radiation safety adhere to the quality management system. Along with the management system, the Decree sets requirements for the documentation of the lines of management and monitoring of the operations.

STUK's Guide YVL 1.4 sets general requirements for management systems. An updated Guide YVL A.3 concerning the management system is under development and will be published in 2013. Guide YVL A.3 adheres to IAEA Safety Standard GS-R-3 on management systems. Requirements for the quality assurance programme during operation are presented in the Guide YVL 1.9 and requirements for quality management of system design in the Guide YVL 2.0. The quality management requirements related to specific technical areas are presented in the corresponding technical guides. STUK is also developing a new YVL guide concerning nuclear facility construction and modifications, i.e., YVL A.5. In this new guide, there are requirements for example on supplier management. The management systems of the licensees and applicants are subject to approval by STUK. According to the Guide YVL 1.4, any safety-significant revisions to the management system must be submitted for approval to STUK, but minor revisions are only submitted for information prior to their use.

Measures taken by licence holders

Loviisa nuclear power plant

Fortum's Policy Commitment to Quality in the Nuclear Power Operations was revised and confirmed by the management of Fortum in 2010. The development of Loviisa NPP's quality management system is based on the principle of continuous improvement in accordance with the observations and remarks made in quality audits and quality assessments. The environmental management system of the plant was certified in 2002 according to the ISO 14001:1996 standard. During the preparation phase an environmental policy and a new chapter on environmental system were introduced in the Quality Manual.

Fortum has developed their management system, according to the Guide YVL 1.4 requirements. The quality management system of Fortum Power & Heat Oy for the Loviisa NPP complies with the requirements of the Guide YVL 1.4 in most respects, but some deviations still remain of which the most significant is the lack of process based management approach. Fortum applied in 2012 for a deviation from the requirements of the process management but STUK made an assessment that Loviisa NPP has already made progress on the path towards a process based management system and that this development shall be continued. Another area where deviations exist is the supplier management. Fortum conducted an independent evaluation of the purchasing activities at the Loviisa NPP in the end of 2012 and this evaluation will result in a development program for year 2013 with licensee top management strong commitment. Loviisa NPP has clearly defined the responsibilities for developing the management system and reformed the management procedures for reviewing the management system. Loviisa NPP has had special training sessions for defined personnel on the topic management system and the Guide YVL 1.4. Loviisa has reformed also the quality assurance (QA) personnel qualification demands and procedures for evaluating and developing the QA-competence.

Olkiluoto nuclear power plant

TVO's quality management system is described in the Quality Management Manual. It takes into account the requirements from YVL 1.4, IAEA

GS-R-3 and ISO 9001:2000. TVO is actively developing the management system towards a process based management system due to the growing organisation and the need for systematic and efficient operations throughout the organisation. The Management System guides all TVO's operations and provides each staff member with procedures for the safe, economical, high-quality and environmentally friendly generation of electricity. TVO's company-level policies are nuclear safety and quality policy, social responsibility policy, production policy and corporate security policy. The functions and responsibilities of TVO's organisations and personnel are described in detail in the TVO's Administrative Rules, in the Organisational Manual and in the manuals and instructions of individual organisational units. For the Olkiluoto unit 3 construction phase, STUK has approved "The Quality Manual for Olkiluoto 3 Project". The review of document as well as review of the QM systems of plant vendor and major suppliers is carried out by STUK. STUK has also asked external QM experts' opinions on the QM systems.

The quality management system of TVO for the Olkiluoto units 1 and 2 mainly complies with the requirements of the Guide YVL 1.4. The most significant development need concerns the process management and process descriptions. TVO also needs to develop the purchasing processes and the quality assurance competence in procurement. The lessons learned from the Olkiluoto unit 3 emergency diesel generator event investigation were to be applied to Olkiluoto units 1, 2 and 3 (see Article 10). According to STUK's review, the management system of Olkiluoto unit 3 complies with the Guide YVL 1.4.

Regulatory oversight

STUK has followed up the implementation of the YVL 1.4 requirements in the management systems of the licensees during the periodic inspection program. The top level inspection of the STUK's periodic inspection programme, "Functioning of the Management System", includes assessment of functioning, development and assessment of the management system as well as assessment of the organisation for quality management. The "Management and Safety Culture" inspection (see Article 10) also contains items concerning management systems. During 2010–2013 the management system inspections have especially dealt with the process management, quality assurance competence in procurement and supply management. The management systems of the main suppliers are also reviewed and assessed and their implementation is verified through inspections and audits mainly by the licensee where STUK is taking part as an observer.

Concerning the Olkiluoto unit 3 construction project, STUK has performed quality management and quality assurance inspections as a part of the construction inspection programme. In addition, STUK has participated as an observer in the licensee's and vendor's quality audits at the subcontractors. STUK's inspections have been focussed on the forthcoming integration of the management system of Olkiluoto unit 3 to TVO's management system during commissioning phase.

During 2012 STUK had an external consultant evaluating the licensees' procurement and supply management procedures and instructions to get an independent specialist opinion about the maturity of the procedures.

Management system of the regulatory body

STUK has an own Quality Manual that includes quality policy, description of the quality system, organisation and management, main and supporting working processes and personnel policy. The results of internal audits, self-assessments and international evaluations are used as inputs for the enhancement projects of the Quality Management System at STUK. In addition to STUK's Quality Manual, all main functions of STUK have their own more detailed Quality Manuals.

STUK's management system will be further developed during the next years according to the suggestions of the IRRS mission. For example, STUK will review and revise the existing Quality Manuals and guidance documents for consistency and improve overall descriptions of the processes including sub-processes and their interdependency. STUK will also develop further a systematic long-term programme for self-assessments, internal and external audits and evaluations on the effectiveness of the processes. In addition, STUK will develop more detailed procedures for the use of graded approach in the authorisation of systems, structures and components and in the planning and conducting inspections.

In conclusion, Finnish regulations and practices are in compliance with Article 13.

Article 14. Assessment and verification of safety

Each Contracting Party shall take the appropriate steps to ensure that:

i. ***comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented, subsequently updated in the light of operating experience and significant new safety information, and reviewed under the authority of the regulatory body;***

ii. ***verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions.***

Regulatory approach to safety assessment

The prerequisite of the Construction and Operating Licences is that the licence applicant has made its own safety assessment. The fulfilment of the safety requirements is demonstrated in the Construction and Operating Licence documentation. STUK makes an independent safety assessment concerning the application and this assessment is required in the Nuclear Energy Act. Conditions for granting a Licence are provided in the Nuclear Energy Act. For example, there is a requirement that the use of nuclear energy must be safe. In Section 20 of the Act it is further stated that the operation of the nuclear facility shall not be started until STUK has ascertained that the nuclear facility meets the prescribed safety requirements.

The Nuclear Energy Decree requires that when applying for a construction licence, the applicant must submit to STUK the following documents: a Preliminary Safety Analysis Report, a design phase Probabilistic Risk Assessment, a proposal for a safety classification document, a description of Quality Management during the construction of the nuclear facility, preliminary plans for the arrangements for security and emergency preparedness, and a plan for arranging the safeguards control. For the operating licence, the applicant must submit to STUK: the Final Safety Analysis Report, the Probabilistic Risk Assessment, the safety classification document, the quality management programme for the operation of the nuclear facility, Operational Limits and Conditions, a programme for periodic inspections, security and emergency plans, a description on administrative rules for safeguards, a programme for radiation monitoring in the environment of the nuclear facility, a description of how safety requirements are met, and a programme for the management of ageing. In addition, the Decree gives STUK a possibility to ask other documents considered necessary for safety demonstration.

Design of the facility is described in the Preliminary (PSAR) and Final (FSAR) Safety Analysis Reports. The reports are submitted to STUK for approval with the applications for Construction and Operating Licences. PSAR/FSAR forms the basis to STUK's safety assessment which is required before granting the Construction/Operation Licence (see Article 7). According to the Nuclear Energy Decree, FSAR has to be continuously updated, and changes to FSAR have to be submitted to STUK for approval. Requirements for the plant modification process are presented in the Guide YVL 2.0, "Systems design for nuclear power plants". The main principle in plant modification process is that conceptual design plans and system-specific pre-inspection documents of Safety Class 1, 2 and 3 systems must be submitted to STUK for approval. STUK reviews and approves the modification prior to its implementation at the plant. In connection with a system modification, the Final Safety Analysis Report shall be amended accordingly without delay.

The general design bases for nuclear fuel have been defined in the Guides YVL 1.0 and YVL 6.2. The design objective is that the probability of fuel failure is low during normal operational conditions and anticipated operational transients, and that during a postulated accident the rate of fuel failures remains low and the fuel remains in a coolable state. Detailed requirements for the design, quality management and control, handling, storage and transport of fuel are specified in the Guides YVL 6.2, YVL 6.3, YVL 6.4, YVL 6.5, YVL 6.7 and YVL 6.8.

According to the Nuclear Energy Act, the operating licence is granted for a fixed term. However, legislation has not prescribed the length of the term. The term is proposed by the licensee in the application, and must be justified on the basis of the ageing and planned future operation of the nuclear facility. Particular attention is paid to licensee's processes and activities and planned safety improvements to ensure safety for the estimated duration of operation. The procedure for operating licence renewal is in general the same as in applying for an operating licence for a new nuclear facility. Specific requirements on the documents to be submitted to STUK for the renewal of the operating licence are described in the Guide YVL 1.1 "Regulatory control of safety at nuclear facilities". Renewal of the operating licence always involves a periodic safety review of the facility. If a licence is granted for a significantly longer term than ten years, STUK requires the licensee to carry out a periodic safety review within about ten years of receiving the operating licence or of conducting the previous periodic safety review. For a separate periodic safety review, STUK must be provided with similar safety-related reports as in applying for renewal of the operating licence. Renewal of the operating licence of the Loviisa nuclear power plant took place in 2005–2007 and the periodic safety review of the Olkiluoto units 1 and 2 in 2007–2009 (see Article 6).

The Government Decree on the Safety of Nuclear Power plants (733/2008) requires that nuclear power plant safety and the technical solutions of its safety systems shall be substantiated by using experimental and calculation methods. These include among others analyses of operational occurrences and accidents, strength analyses, failure mode and effect analyses, and probabilistic risk assessments. Analyses shall be maintained and revised if necessary, taking into account operating experience, the results of experimental research, plant modifications and the advancement of calculation methods. The calculation methods employed for demonstrating compliance with safety regulations shall be reliable and well qualified for the purpose. They shall be applied so that the resulting system design bases meet the acceptance criteria with high certainty. Any uncertainty in the results shall be assessed and considered when defining safety margins. STUK's review of these analyses includes independent safety analyses.

Detailed requirements concerning transient and accident analyses, including sensitivity analyses, are presented in the Guide YVL 2.2, "Transient and Accident Analyses for Justification of Technical Solutions at Nuclear Power Plants". Requirements for probabilistic risk assessments are given in the Guide YVL 2.8, "Probabilistic safety analysis in safety management of nuclear power plants". Acceptance criteria for the analyses are presented in Guides YVL 6.2 "Design bases and general design criteria for nuclear fuel" and YVL 7.1, "Limitation of public exposure in the environment of and limitation of radioactive releases from a nuclear power plant".

Deterministic safety assessment

Detailed requirements concerning transient and accident analyses, including sensitivity analyses, are presented in the Guide YVL 2.2, "Transient and Accident Analyses for Justification of Technical Solutions at Nuclear Power Plants".

Fortum submitted with the licence renewal documentation in 2005–2007 the revised Final Safety Analysis Report, including the transient and accident analyses of the Loviisa units 1 and 2. Fortum has revised the analyses taking into account plant modifications implemented at both units as well as new regulatory requirements. The analyses presented in the Safety Analysis Report cover anticipated operational transients, category 1 and 2 accidents, and severe accidents. The analyses cover all operating states and include accident analyses for the storages of spent fuel and reactor waste. Fortum has supplemented the deterministic safety analyses in 2008 by analyses of design extension conditions.

STUK assessed the submitted analyses for the Loviisa NPP and methods applied in the analyses. STUK contracted VTT Technical Research Centre of Finland to carry out independent analyses to verify the results given in the licence renewal documentation and to conduct sensitivity analyses. STUK concluded that the plant behaviour in different transient and accident situations has been analysed comprehensively and that the methods used in the analyses are properly validated to describe the operation of the Loviisa plant.

Accident and transient analyses of the Olkiluoto units 1 and 2, as well as the analysis methods, have been updated and developed throughout the operation of the plant. TVO revised completely the accident and transient analyses in conjunction with the application for the renewal of its operating licence in 1995–1998. The analyses were at that time carried out for nuclear fuel that is no longer being used at the NPP units. For the periodic safety review in 2007–2009, TVO updated the accident analyses using the SVEA-96 Optima 2 as a reference fuel. The plant modifications carried out after the renewal of the operating licence in 1998 were also taken into account in the update. Since renewal of the operating licence, Guides YVL 2.2 and YVL 6.2 have been revised and a requirement regarding analyses of design extension conditions was introduced. When updating its analyses for periodic safety review, TVO has taken into account the new regulation.

The calculation methods used for analysing the plant normal operating conditions, transients and postulated accidents were developed by the supplier of the Olkiluoto plant units. The methods have been qualified to an extent corresponding to a good level from the international perspective. STUK reviewed the updated analyses and the calculation methods used. The conclusion was that the analyses of transients and accidents of the Olkiluoto units 1 and 2 were conducted as referred to in Section 3 of Government Decree 733/2008. However, STUK required updating of the loss of coolant analyses assuming a level of system availability specified in the Guide YVL 2.2. TVO submitted the required updates in 2010.

The preliminary analyses of Olkiluoto unit 3 were presented to STUK in PSAR and the Topical Reports appended to PSAR with the application for the construction licence. STUK contracted technical support organisations to carry out independent analyses to verify the results. STUK approved the PSAR of Olkiluoto unit 3 in January 2005 just before the construction licence was granted by the Government. TVO has submitted updated analyses for the Final Safety Analysis Report in 2008–2012. The analyses will be reviewed as a part of the Olkiluoto unit 3 operating licence application.

Probabilistic risk assessment

Regulatory requirements on PRA

In the Nuclear Energy Decree, probabilistic risk assessment (PRA) has been included since 1988 in the list of documents to be submitted to STUK for the review of the operating licence application. Since 2008 the preliminary design phase PRA has been in the list of documents to be submitted to STUK for the review of the construction licence application according to the Nuclear Energy Decree, but a limited preliminary PRA has been required in Regulatory YVL Guides since 1996. PRA for construction licence application is based on preliminary design information and generic reliability data for components. PRA for operating licence application is based on essentially final design information and vendor specific component reliability data, where available, and system modelling is also more detailed.

According to the Government Decree on Nuclear Safety, PRA shall be maintained and revised if necessary, taking into account operating experience, the results of experimental research, plant modifications and the advancement of calculation methods. The detailed requirements on the use of PRA are set forth in the Regulatory Guide YVL 2.8. Detailed requirements on risk-informed applications are included in several other YVL Guides.

STUK required in 1984 that the Finnish utilities Fortum (former Imatran Voima Oy) and TVO shall make extensive probabilistic risk assessments for the Loviisa and Olkiluoto nuclear power plants. The objective of the study was to determine the plant-specific risk topographies of the essential accident sequences. Another important objective was to enhance the plant personnel's understanding of the plant and its behaviour in different situations. Therefore STUK also required that the PRAs are performed mainly by the utility personnel and external consultants are used only for special topics.

In 1987 STUK published the Regulatory Guide YVL 2.8 on PRA. The Guide was updated in 1996 and 2003. Currently the Guide requires a full-scope (including internal events, fires, floods, seismic events, harsh weather and other external events) PRA for power operation and low-power and shut-down states. PRA shall cover the analysis of the probability of core damage (Level 1) and large release of radioactive substances (Level 2). PRA shall be updated continuously to reflect plant and procedure modifications and changes in reliability data (Living PRA).

Guide YVL 2.8 includes the following probabilistic safety goals:

- Core damage frequency less than $1 \cdot 10^{-5}$/year
- Large radioactive release (> 100 TBq Cs-137) frequency less than $5 \cdot 10^{-7}$/year.

These safety goals apply as such to new plant units. For operating units, instead of the numerical safety goals, the SAHARA (safety as high as reasonably achievable) principle and the principle of continuous improvement are applied.

Guide YVL 2.8 also includes requirements on several risk informed applications, such as analysis of plant modifications, risk-informed in-service inspections and testing, development of emergency operating procedures and training programmes and review of safety classification and Operational Limits and Conditions.

For a new plant unit, a preliminary PRA covering Levels 1 and 2 shall be submitted to STUK for the review of the construction licence application (design phase PRA) and the updated and complemented PRA (Levels 1 and 2) shall be submitted for the review of the operating licence application.

PRA's computer models shall be made available to STUK. STUK uses PRA routinely to support its decision making, for example, in review of plant modifications and applications for exemption from Operational Limits and Conditions and in analysis of operating events.

The Guide YVL 2.8 is being updated in STUK's ongoing renewal of Regulatory Guides. In the new guide YVL A.7, requirements on the use of PRA in the decommissioning phase have been added and the list of applications and documents to be submitted to STUK have been specified.

Main developments in risk informed regulation and safety management during the reporting period

During the reporting period the role of risk informed regulation and safety management has been further strengthened by STUK and the licensees. The following activities can be given as examples of the increased role of risk informed methods:

- Risk-Informed In-Service Inspection programmes for the operating units were implemented by TVO in 2012.
- TVO and Fortum have applied PRA in support of the review of safety classification of the operating units.
- The finalisation of the PRA for Olkiluoto unit 3 under construction is still ongoing. Risk informed applications have been used in the design of the unit and the risk informed applications for the operating phase are under development in accordance with the Guide YVL 2.8. PRA is also used in the planning of commissioning testing programmes.
- Risk informed methods have been used to support ageing management, for example, trend analysis of failure data. In connection with the life extension of Loviisa unit 1 reactor pressure vessel, the probabilistic analysis of pressurised thermal shock was used to evaluate the safety significance of radiation induced embrittlement of weld seams.
- Risk informed approach has been used also for inspections of Loviisa reactor vessel internals. Preliminary results show that risk reduction could be gained by doubling the inspection interval, which would decrease the risk due to heavy load drop significantly.

The use of PRA in several well-established applications has been continued and the methods have been further refined.

In addition to the risk informed applications based on regulatory requirements, the licensees use PRA in applications supporting their operating activities, for example availability analysis and risk centred maintenance.

Further development of the PRA computer code system developed at STUK has been continued in a joint project with VTT Technical Research Centre of Finland. The software is used in the review of the PRAs submitted by the licensees and in support of risk informed decision making at STUK.

Probabilistic risk assessment of the Loviisa NPP

Fortum provided STUK with Level 1 PRA in 1989. Since 1990 Fortum has extended PRA by analysing risks related to fires, floods, earthquakes, severe weather conditions and outages, as well as by conducting Level 2 PRA. Plant modifications have been carried out continuously at the Loviisa NPP, including safety system improvements, fire safety improvements, implementation of Severe Accident Management systems and a major modernisation programme in mid 1990's (see Annex 2). By means of these modifications risks have been decreased and the risk topography of the plant has been balanced. Technical solutions of the modifications have also been often justified with PRA.

The development of the core damage frequency

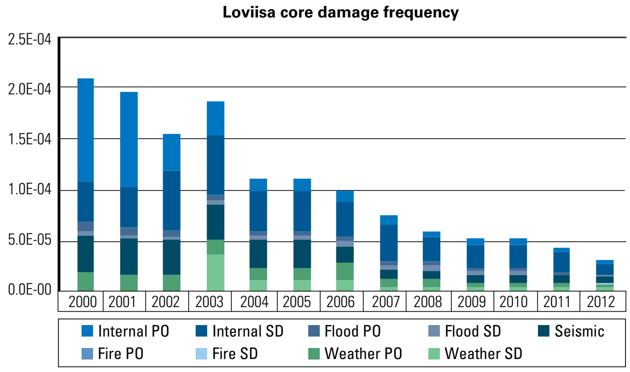


Figure 10. Development of the estimate of annual core damage frequency of the Loviisa NPP in 2000–2012. The increase in the core damage frequency in 2003 was due to extension of the PRA scope with non-seismic external events during shutdown states. The preliminary conservative analyses showed relatively high risk due to exceptionally high outside air temperature and oil spills in the Gulf of Finland in cold shutdown states. Later the risk estimate was decreased due to plant modifications and more realistic analyses.

since 2000 is shown in Figure 10. At the end of year 2012 the calculated estimate for the total probability of reactor core damage was about $3.0 \cdot 10^{-5}$ per reactor year. The relative contribution to the annual core damage frequency from different groups of initiating events are shown in Figure 11. The Loviisa plant has full scope PRA covering Levels 1 and 2. The latest completion included fire risk analysis for shutdown states in 2011.

Fortum has also provided STUK with the Level 2 PRA, in which the integrity of the containment and the release of radioactive materials from the plant to the environment are evaluated. In the latest update in 2012, it was estimated that the total probability of a large release to the environment is about $1.4 \cdot 10^{-5}$ per year. The estimate includes a detailed study for internal events, fires, floods and severe weather conditions at power states and at outages, whereas some specific events (seismic, shutdown fires, heavy load drop, loss of DC power, etc.) are based on rough estimates on the accident progession. In 2012, mainly the following modifications have decreased core damage frequency and large release frequency: renewal of auxiliary service water system (VF62), modifications in power distribution for some containment systems, renewal of Pressuriser Overpressure Protection Valve (PORV), renewal of pressuriser spray system and new procedures for sump recirculation in shutdown states.

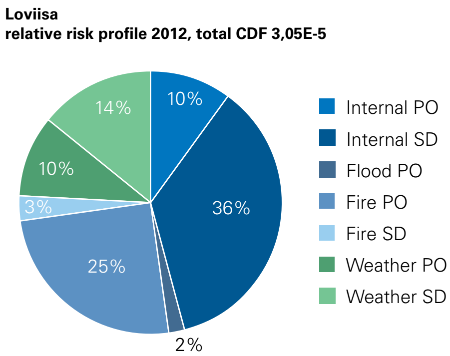


Figure 11. Relative contribution of different initiating event types to the annual core damage frequency in 2012 for Loviisa NPP. The most significant internal initiating events at full power (power operation, PO) are the small interfacing system LOCAs and the loss of instrumentation room ventilation. At shutdown (SD) the most significant internal initiating events are drop of heavy loads and reactivity accident due to boron dilution. Note: "Flood" includes only internal flooding from process systems and external flooding is included in "Weather".

The results of STUK's review show that Fortum has applied in its analyses commonly accepted methods in modelling transient and accident situations of the plant and in collecting and analysing reliability data. The reviews also show that the assessments provide an adequate basis for risk informed decision making.

PRA has been used by the licensee in the risk-informed applications required by the Guide YVL 2.8, for example in evaluation of plant modifications, review of safety classification, development of Risk-Informed In-Service Inspection programme. The risk informed review of the Operational Limits and Conditions, including optimisation of testing intervals, and optimisation of Operational Limits and Conditions (allowable outage times) is under way. The Loviisa NPP has also introduced a Risk-Informed In-Service Inspection programme for piping. The number of inspections was increased but the focus shifted from high safety classes to lower safety classes. This shift is due to the fact that some lower safety class pipings have relatively large risk significance as they belong to vital sup-

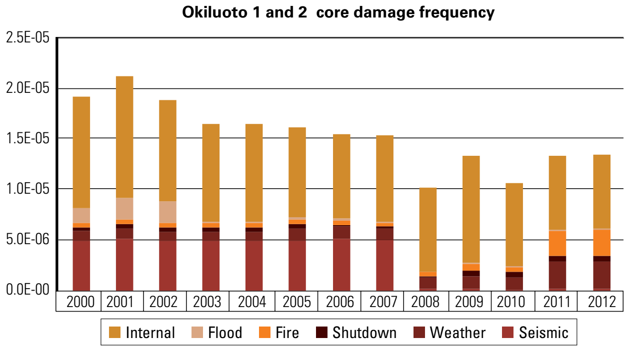


Figure 12. Development of the estimate of annual core damage frequency for Olkiluoto units 1 and 2 in 2000–2012. The decrease in seismic risk in 2009 is due to plant modifications allowing improved handling of spurious activation of isolations due to relay chatter. The risk estimate increase in 2009 is due to a more detailed analysis of the capacity of decay heat removal by diverse systems. The risk estimate increase in 2011 is due to the change of the method used to determine fire ignition frequencies and update of external hazards study that contains a new man-made hazard "marine oil-spill".

port systems, or leaks in lower class pipelines may lead to consequential damage to safety systems. The radiation doses to inspection personnel will decrease as a result of the new inspection programme.

Probabilistic risk assessment of the Olkiluoto units 1 and 2

TVO submitted to STUK the first version of Level 1 PRA in 1989. Since then, the PRA has been updated several times and the scope has been extended. TVO has now practically full-scope PRA covering levels 1 and 2 for full power operation and for low power and shutdown states.

Annual core damage frequency since 2000 is shown in Figure 12. Plant modifications have been carried out continuously at the Olkiluoto plant, including backfitting with severe accident management systems and power uprate and modernisation in the 1990's (see Annex 2).

At the end of 2012 the overall core damage frequency of Olkiluoto units 1 and 2 is approximately $1.3 \cdot 10^{-5}$ per reactor year, including all operating states and all groups of initiating events. The relative contributions to annual core damage frequency from different groups of initiating events are shown in Figure 13.

In 1996, TVO submitted to STUK the Level 2 PRA. The analysis has been updated a few times since then. According to the living PRA model in 2010 the frequency of the large release to the environment (>100 TBq Cs-137) was $3.5 \cdot 10^{-6}$ per reactor year, which was approximately one tenth of the core damage frequency. The large release frequency has decreased in the updates mainly due to the decrease of the core damage frequency, but the severity of the release has decreased significantly mainly due to modifications in procedures.

TVO has used PRA in the risk-informed applications required by the Guide YVL 2.8, for example in evaluation of plant modifications, review of safety classification, development of Risk-Informed In-Service Inspection programme, optimisation of testing intervals, and optimisation of Operational Limits and Conditions (allowable outage times).

Probabilistic risk assessment of Olkiluoto unit 3

The vendor of Olkiluoto unit 3 conducted a design phase PRA, which TVO submitted in 2004 to STUK for the review of the construction licence application as required by the Nuclear Energy Decree. The design phase PRA includes analysis of internal initiating events, internal hazards and external hazards for power operation and refuelling out-

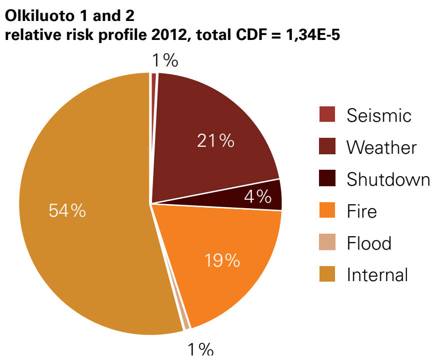


Figure 13. Relative contribution of different initiating event types to the annual core damage frequency in 2012 for Olkiluoto units 1 and 2. The most significant internal initiating events at full power are the loss of off-site power and loss of feedwater. Note: "Flood" includes only internal flooding from process systems and external flooding is included in "Weather".

age. STUK approved the Olkiluoto 3 PRA for the construction licence in January 2005. The PRA of Olkiluoto 3 has been continuously updated by the plant vendor during the construction phase and STUK has closely followed the completion of the PRA.

Olkiluoto unit 3 preliminary PRA covers seismic events and other external events (harsh weather, organic material in seawater etc.). According to the preliminary results, Olkiluoto unit 3 fulfils with a wide margin the probabilistic safety goals set forth in the Guide YVL 2.8. The contribution of seismic events is less than 1 per cent of the total CDF and the contribution of other off-site external events is less than 10 per cent of the total CDF. The most important external events are strong wind with snowfall and the loss of the ultimate heat sink due to oil spill, organic material in seawater or frazil ice.

Preliminary results of level 2 PRA show that large release frequency of Olkiluoto unit 3 is very small. In addition, the distance of the magnitude and frequency of releases from the unacceptable region are clearly large, and only 2 per cent of the releases are in the vicinity of the limit for large release. Thus, future refinement of the analyses is not expected to change the magnitudes of releases.

PRA has been used by TVO and plant vendor in the risk-informed applications required by the Guide YVL 2.8, for example in evaluation of system design, review of safety classification, development of Risk-Informed In-Service Inspection programme, optimisation of testing intervals, optimisation of Operational Limits and Conditions (allowable outage times), and planning of plant commissioning tests.

Assessment of safety as a result of TEPCO Fukushima Dai-ichi accident

Following the accident at the Fukushima Dai-ichi nuclear power plant on the 11th of March in 2011, safety assessments in Finland were initiated after STUK received a letter from the Ministry of Employment and the Economy on 15 March 2011. The Ministry asked STUK to carry out a study on how the Finnish NPPs have prepared against loss of electric power supply and extreme natural phenomena in order to ensure nuclear safety. STUK asked the licensees to carry out assessments and submitted the study report to the Ministry of Employment and the Economy on 16 May 2011. Although immediate actions to ensure safety of public and environment were not considered necessary, STUK required the licensees to carry out additional assessments and present action plans for safety improvements. Assessments were conducted and reported by the Finnish licensees to STUK on 15 December 2011. STUK has reviewed the results of national assessments, and made licensee specific decisions on 19 July 2012 on the suggested safety improvements and additional analyses.

Finland also participated in the EU Stress Tests and submitted the national report to European Commission at the end of 2011. An EU level peer review on the report was completed by April 2012. The recommendations of the EU peer review have been taken into account in the regulatory decisions and will be considered in the development of national regulations. A National Action Plan was prepared addressing the measures initiated on a national level and at the nuclear power plants as a result of the TEPCO Fukushima Daiichi accident. The National Action Plan was sent to the European Nuclear Regulators Group (ENSREG) and peer reviewed in April 2013. In addition, Finland participated in the second Extraordinary Meeting of the Convention of Nuclear Safety (CNS) in August 2012 and prepared a report introducing all Fukushima related actions. All STUK's related decisions, the national report to European Commission, the report to the Extraordinary CNS, and the Finnish National Action Plan have been published on STUK's website.

Based on the results of assessments conducted in Finland to date, it is concluded that no such hazards or deficiencies have been found that would require immediate actions at the Finnish NPPs. However, areas where safety can be further enhanced have been identified and there are plans on how to address these areas. The experiences from the TEPCO Fukushima Dai-ichi accident are also taken into consideration in the ongoing renewal of the legislation and Finnish Regulatory Guides (YVL Guides) and in the nuclear safety research programme SAFIR 2014 (see Articles 7 and 8). Safety improvements under planning and implementation at the Finnish NPPs due to the TEPCO Fukushima Dai-ichi accident are described more detailed under Articles 16, 17, 18 and 19, and in Annexes 2, 3 and 4.

Information collected in connection with external events PRAs has been used in the national and EU stress tests after the TEPCO Fukushima Daiichi NPP accident, although mainly deterministic approach has been used. Seismic events and other off-site external events have been included in the PRAs in the 1990's and the analyses have been updated regularly. The input data and plant response analyses used in the external events PRAs have been reviewed after the TEPCO Fukushima Daiichi NPP accident in connection with the stress tests and no essential shortcomings have been found. Further updates of the analyses and hazard estimates will be continued.

Verification of safety

Verification programmes

Government Decree 733/2008 includes several requirements which concern the verification of the physical state of a nuclear power plant. For instance, in all activities affecting the plant operation and the availability of components, a systematic approach shall be applied for ensuring the operators' continuous awareness of the state of the plant and its components. The reliable operation of systems and components shall be ensured by adequate maintenance as well as by regular in-service inspections and periodical tests. General requirements on verification programmes and procedures are provided in the YVL Guides (e.g. Guide YVL 1.8, YVL 1.9, YVL 3.0, YVL 3.8).

Main programmes used for verification of the state of a nuclear power plant are

- periodic testing according to the Operational Limits and Conditions
- maintenance programme
- in-service inspection programme
- periodic inspections of pressure equipment and piping
- surveillance programme of reactor pressure vessel material
- programmes for evaluating the ageing of components and materials.

Activities for verifying the physical state of a power plant are carried out in connection with normal daily routines and with scheduled inspections, testing, preventive maintenance etc. Activities are performed by the licensee and in the case of certain inspections by contractors approved separately. Detailed programmes and procedures are established and approved by the licensee. They are also reviewed and, when needed, approved by STUK. The results of tests and inspections are documented in a systematic way and used through a feedback process to further develop the programmes. The Operational Limits and Conditions are approved by STUK. In general, the role of STUK is to verify that the licensees follow the obligations imposed on them and carry out all activities scheduled in verification programmes.

Comprehensive evaluations related to the state and operation of the Loviisa and Olkiluoto plants were carried out in the periodic safety reviews by Fortum in 2005–2007 and TVO in 2007–2009. These activities were controlled by STUK.

Inspection qualification

According to international experience and the Guide YVL 3.8, STUK has recognised the qualification of non-destructive testing systems and procedures as an issue of high importance. This issue requires high priority at both nuclear power plants. The implementation of qualified NDT systems has been started in 1990's.

General requirements on inspection qualification are provided in the Guide YVL 3.8. The document "European methodology for qualification" drawn up by the European Network for Inspection and Qualification (ENIQ) shall be used as the minimum requirement level for qualification of inspection systems to be used in in-service inspection, and it shall be complemented by the ENIQ Recommended Practices. In the content of licensees' guidelines published by the qualification body, the requirements presented in the Guide YVL 3.8, in the European Methodology for Qualification (EUR 17299) and in its recommendations have been taken into account.

The licensees Fortum and TVO have established the Steering Committee for Qualification and nominate its members on annual basis. The Steering Committee for Qualification is guiding and supervising the practical qualification work with the help of a separate Technical Support Group nominated and supervised by the Steering Committee.

Based on a contract with the licensees, Inspecta Certification is nominated as the qualification body for qualification management, implementation, control and assessment as well as the issuing of qualification certificates in Finland. The Finnish qualification body is a qualification body of type 1, which is an independent third party organisation as defined by ENIQ Recommended Practice 7. When needed Inspecta Certification uses also experts outside of its own organisation for individual qualifications.

Most of the qualifications have already been performed and approved by STUK.

STUK ordered in 2009 an assessment of the current qualification activities in Finland from an independent expert organisation. The purpose was to assess whether Finnish inspection qualification practice leads to reliable and effective in-service inspection of safety critical components. Review was performed in two parts: 1) review of the inspection qualification system as specified in the Guide YVL 3.8 and the national qualification guideline documents issued by the qualification body and 2) review of the inspection qualification practices. As a conclusion of the assessment it was reported that the qualification system meets the Finnish requirements, is effective and provides confidence in the inspections of safety critical components.

In-service inspections

The condition of the pressure-retaining components of the Loviisa and Olkiluoto NPPs is ensured with regular in-service inspections. The components of the primary circuit are inspected by means of non-destructive examination methods. These regularly repeated examinations are carried out during outages according to the Guide YVL 3.8. The results of the in-service inspections are compared with the results of the previous inspections and of the pre-service inspections which have been carried out before the commissioning.

The in-service inspection plans are submitted to STUK for approval before each individual in-service inspection. Programmes and related inspection procedures are changed when necessary, taking into account the development of requirements and standards in the field, the advancement of examination techniques and inspection experiences as well as operating experiences in Finland and abroad.

Guide YVL 3.8 and the latest revisions of the ASME Code, Section XI are applied as approval bases for the in-service inspection programmes and procedures. ASME Code, Section XI, Appendix R and ENIQ European Framework Document for Risk-informed In-service Inspection are used as approval bases for the risk-informed in-service inspection programmes.

The reliability of the non-destructive examination methods for the primary circuit piping and components has been essentially improved after the commissioning of the both Loviisa and Olkiluoto NPPs. Guide YVL 3.8 calls for the qualification of the entire NDT-system; equipment, software, procedures and personnel. Most of the inspection systems are already qualified at the both plants. STUK follows the development and implementation of the plans.

A risk-informed inspection programme has been introduced and approved by STUK at the Loviisa units 1 and 2 for the inservice inspections of safety-critical pipelines. The deployment of risk-informed inspection methods for targeting inspections has been developed in Finland by STUK, Fortum, Fortum, TVO and VTT. The objective of risk-informed in-service inspection programmes is to allocate inspection resources to the targets that are most critical from the point of view of risk. Using this approach, it is possible to ensure that the current inspection objects are well-justified, identify new objects and omit certain less safety-critical objects from the existing inspection programme. According to experts' view, the programme is the most extensive risk-informed in-service inspection programme so far implemented in Europe.

The length of the inspection period of the regular inspections (e.g. ASME Code, Section XI) is normally ten years. Inspection programmes have been complemented with additional inspections as regards the reactor pressure vessel and the primary circuit piping, and the length of the inspection period of the reactor pressure vessel has been reduced to eight years. The length of the inspection period of the objects susceptible to thermal fatigue is typically three years.

At the Olkiluoto plant, attempts have been made to focus the inspections on areas where faults are most likely to emerge. These include, for example, items susceptible to fatigue due to temperature variations or items susceptible to stress corrosion cracking. The selection of inspection items is under continuous development. For this purpose, a risk-informed in-service inspection procedure has been developed for the Olkiluoto units 1 and 2 and it has been approved by STUK. Inspections and inspection schedules will be optimised on the basis of risk-informed methods when the next inspection interval programmes are drawn up.

The frequency of the non-destructive examinations performed at regular intervals is usually ten years at the Olkiluoto NPP. The inspection frequency for items susceptible to thermal fatigue is three years, and the inspection frequency for items susceptible to stress corrosion cracking is three to five years.

In addition to the inspections mentioned above, physical inspections concerning the condition and reliability of pressure equipment are carried out as regular pressure equipment inspections according to the Finnish pressure equipment legislation. Such inspections are a full inspection, an internal inspection and an operational inspection. These inspections include non-destructive examinations as well as pressure and tightness tests. The inspections of piping have been defined in the system-specific monitoring programmes. These periodic inspections are dealt with in the Guides YVL 3.0, YVL 3.3, YVL 5.3, and YVL 5.7. The periodic inspection programmes of the Loviisa and Olkiluoto NPPs fulfil the requirements of YVL Guides, as regards the number and techniques of inspections.

Ageing management

According to the Government Decree (733/2008), the design and construction of a nuclear power plant shall include provision for the ageing of systems, structures and components (SSCs) important to safety. Their condition shall be monitored to ensure operability and conformity in design-basis conditions. The needed replacements, repairs and modifications, shall be carried out in a systematic manner.

The regulatory oversight of ageing in operating plants focuses on operating licence renewals and Periodic Safety Reviews (PSRs) where the conformance to the relevant Government Decrees and YVL Guides, including experiences with ageing and its management, is investigated. STUK's findings from other regulatory control practices, particularly the periodic inspection programme, are used as verification. The periodic inspections are done on plant site according to annual planning and tackle both the technical aspects of each discipline and the process of ageing management. STUK also receives annual reports from each nuclear power plant unit on ageing management activities within each technical discipline.

An expert group dedicated to ageing management has been established within STUK to oversee how the licensees perform their duties in the ageing management of SSCs. The group, which consists of mechanical, electrical, I&C, civil and human resource experts and resident inspectors, looks into such events and observations at the Finnish nuclear plants that may be related to inadequate ageing management. If shortcomings are found, for example in condition monitoring or maintenance, the group calls the licensee for further claricatіons or corrective actions. The group also follows up findings from other countries and evaluates their possible linkage to the ageing management of the Finnish nuclear plants. In the overall renewal of the STUK's regulatory guides, a dedicated regulatory guide is developed for ageing management, i.e. YVL A.8.

Ageing management at the Loviisa NPP

Radiation embrittlement of the reactor pressure vessel (RPV) and the related surveillance and mitigation actions dominated the ageing management in Loviisa NPP since the early years of operation. This was more relevant to Loviisa unit 1 whose girth weld at the level of the reactor core has a higher content of impurities. In 1996, the brittle weld joint of the Loviisa 1 reactor pressure vessel was heat-treated to improve the ductility properties of the welding material. In this connection the reactor pressure vessel was subject to thorough non-destructive tests. Embrittlement rate has been re-assessed based on the new surveillance programme representing the critical weld. STUK has granted the operating licences of the RPVs for the Loviisa units 1 and 2 until 2027 and 2030, respectively. For both units, deterministic and probabilistic safety analyses will be updated in the PSRs (by end of 2015 and 2023) in order to justify continued servive of the RPVs. In addition, new findings from domestic and international inspection and research programmes may require updating of the RPV analysis results.

In the mid-1990's, Fortum implemented their systematic plant-wide ageing management programme. The SSCs are assigned to categories A through D based on their technical and economical replaceability. SSC failures in category A would limit plant lifetime and thus deserve a part-assembly-wise break-down of ageing related remedies. Category A comprises the main primary components. Data indicative of plant status and trends are collected with operation, maintenance and inspection IT systems, R&D activities and via experience exchange. The consequent ratings of operability, remaining service life and necessary actions for each SSC are stored on the plant database.

In 2006 the operating utility Fortum submitted to the Government an application to continue the operation of Loviisa units 1 and 2 until the end of 2027 and 2030, respectively, meaning a 20-year extension to the original design lifetime. Among the ageing-related justification were the main fatigue analyses, updated to cover the whole 50 years' life span with consideration of the environmental effects. Documents on In-Service Inspection Summary Programme, Ageing Management Programme Principles and Implementation, and SSC Status and Service Life Extensibility were also submitted. For electrical and I&C components it was noted that massive projects are underway to replace cables in containment due to its detected considerable ambient temperature rise, and for plant-wide replacing of obsolete protection and plant I&C systems and components. In its review, STUK made a general point that the state-of-the-art permitted a quantitative life-time evaluation only in case of ageing by fatigue. However, other potential mechanisms have been identified and resources are in place to monitor, inspect, mitigate and repair as needed. The operating organisation has also strong technical support which has convincingly resolved forthcoming ageing issues in the past, and the history records are well preserved. The Government granted the applied operating licences on condition that two PSRs are undertaken during the licence period.

Ageing management at the Olkiluoto NPP

The ageing management activities at the Olkiluoto units 1 and 2 arose from wide-spread indications of inter-granular stress corrosion cracking (IGSCC) in reactor auxiliary system piping. Early replacement of entire piping systems, achievable with modest doses to maintenance staff, considerably mitigated IGSCC and led the way to the utility's strategy of seeing to the critical SSCs so that a remaining plant life-time of 40 years (design lifetime) could be always demonstrated.

Since 1991, the AGE Group, with assistance of several technical discipline related expert groups, has taken care of these activities by gathering information of possibly needed future actions from several sources and by preparing and updating a table of recommended major modifications, replacements, repairs and overhauls. The modernisation and power uprating of the Olkiluoto units 1 and 2 by 16% in 1994–1996 evolved from these recommendations and was completely carried out by the utility's technical support organisation residing on plant site. The associated significant renewal campaigns of obsolete electrical and instrumentation systems and components largely contributed to current 20-year operating licence periods terminating in 2018. Efforts to enhance the reliability and good performance of the plant components, and to ensure the spare part and support service availability have continued until recent years. The major foreseeable modifications until decommissioning have been identified.

Systematic maintenance planning is an integral part of ageing management at the Olkiluoto units 1 and 2. Nominated owners of equipment groups, characterised by a common type or location, analyse the entire maintenance programme and its experiences, and assist in selection of the most effective maintenance works. Annual findings from each equipment group are stored into a relational data base on the plant computer.

STUK reviewed TVO's clarification on the actual condition and ageing implications of the main SSCs in connection to the Periodic Safety Review (PSR) carried out in 2007–2009. Supporting assessment has been done in several periodical inspections on plant site. The main components were generally found to be in good condition, but the appearance of IGSCC in Nickel-based alloys could not be excluded and it possibly explains an indication reported from the safe-end weld of the main feedwater nozzle, made from Alloy 182. The indication has, however, remained unchanged as evaluated by NDT-inspections during annual outages. The PSR also referred to a completed pilot project for updating fatigue analyses of selected systems to incorporate the environmental effect as required in the implementation process of the Guide YVL 3.5. Based on recommendations from expert consultancy of VTT Technical Research Centre of Finland, more refined modelling is employed now that the utility is renewing all fatigue analyses to justify a prospective re-licensing of the Olkiluoto units 1 and 2 for an operating life of 60 years.

At the Olkiluoto unit 3, the ageing management is taken into account at the design phase. The most severe operating conditions and long-term influences, under which an individual component is expected to serve as a part of a process system, are used to determine the design basis requirements for that component. With known design basis requirements and defined life times of SSCs, their materials, fabrication and other ageing management related issues are specified accordingly. This includes precautions against foreseeable degradation mechanisms with state-of-the art technology, and provision for inspections, overhauls, testing and replacements as needed while respecting the ALARA principle. The anticipated life-span of the main technologies and independence from single technologies are particularly considered in I&C system and somponent design. The design and fabrication of SSCs are verified with qualified analyses, inspections and testing, overseen by STUK, in order to demonstrate fulfillment of quality and performance requirements set by the design specifications. During Olkiluoto unit 3 operation, the ageing of SSCs and retaining the design margins will be managed by dedicated programmes and monitoring tools, and by in-service inspections to whose planning risk-informed methods are applied.

In conclusion, Finnish regulations and practices are in compliance with Article 14.

Article 15. Radiation protection

Each contracting Party shall take the appropriate steps to ensure that in all operational states the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonably achievable and that no individual shall be exposed to radiation doses which exceed prescribed national dose limits.

Regulatory requirements regarding radiation protection

The main regulations governing radiation protection of Nuclear Power Plant operation are the Radiation Act (592/1991), Radiation Decree (1512/1991), Government Decree for Nuclear Safety of NPPs (733/2008) and YVL Guides, Part 7 (12 guides). Radiation Decree stipulates that the effective dose caused to a worker shall not exceed an average of 20 millisieverts (mSv) per year in any five years period, nor 50 mSv in any single year. The limit for the annual dose of an individual in the population, arising from the normal operation of a nuclear power plant, is 0.1 mSv. Based on this, STUK shall upon application confirm the release limits for radioactive materials during the normal operation of a nuclear power plant. ALARA requirement is issued in the Radiation Act and more in detail implementation requirements are given in the YVL Guides both for NPP workers and release abatement. During 2010–2012 no changes in the Guides as regards radiation protection were made. New regulatory guides are drafted as part of the overall revision of the regulatory guides.

Radiation doses of NPP workers

An ALARA programme, updated in 2009, exists for workers at the Loviisa NPP. It includes as main objectives the continuous improvement in the collective dose indicator trend: decreasing of a four years average, now being at 0.6 manSv/reactor unit/year. Important measures are e.g. minimisation of antimony 122 and 124 content on primary circuit surfaces and optimised use of additional shielding in the primary coolant circuit area during outages. One of the reactor coolant pump seals was replaced with an antimony-free material during outage in 2012. It has been estimated that the original seals of the coolant pumps are the main reason for activation products of antimony 122 and 124 in the primary circuit. The rest of the seals will be replaced with antimony-free seals during the next years if results from the new seal are acceptable. ALARA programme includes also the goal that no employee at the plant should receive a radiation dose exceeding 15 mSv per year. As a plant modification, rearrangement of controlled area activities for decontamination and operational waste management was made in 2010.

Table 1. Annual radiation doses of workers at the Loviisa NPP in 2010–2012.

Year	Collective dose [manSv]	Maximum personal dose [mSv]	Average dose*) [mSv]
2010	1.57	15.8	2.27
2011	0.71	7.9	1.39
2012	1.68	14.3	2.35

*) Calculated by using the registered radiation doses, which are ≥ 0.1 mSv/month.

Table 2. Annual radiation doses of workers at the Olkiluoto NPP in 2010–2012.

Year	Collective dose [manSv]	Maximum personal dose [mSv]	Average dose*) [mSv]
2010	0.90	9.1	0.72
2011	0.96	9.3	0.76
2012	0.72	9.0	0.90

*) Calculated by using the registered radiation doses, which are ≥ 0.1 mSv/month.

TVO's ALARA programme for the Olkiluoto NPP contains a compilation of major objectives and procedures regarding the radiation protection, reduction of the doses of employees and target values for main radioactive effluents. The ALARA programme was updated in 2010 and it is included in TVO's radiation protection manual, which is regularly updated. The ALARA programme includes the goals that collective dose should not exceed 1 manSv for two reactor units in a normal year (1.5 manSv when major additional maintenance is needed) and that no employee at the plant should receive a radiation dose exceeding 10 mSv per year. In the programme, there are also target limit values for main radioactive effluents like noble gases, iodine isotopes, water-borne releases and tritium, too. The goal is that annual effluents are less than the target values which are based on real amounts of annual releases from the Olkiluoto NPP. In addition, TVO has a specific ALARA group where the topics of the ALARA programme has been discussed regularly 3–4 times per year.

TVO has continued the replacement of cobalt-containing components in the primary circuit with

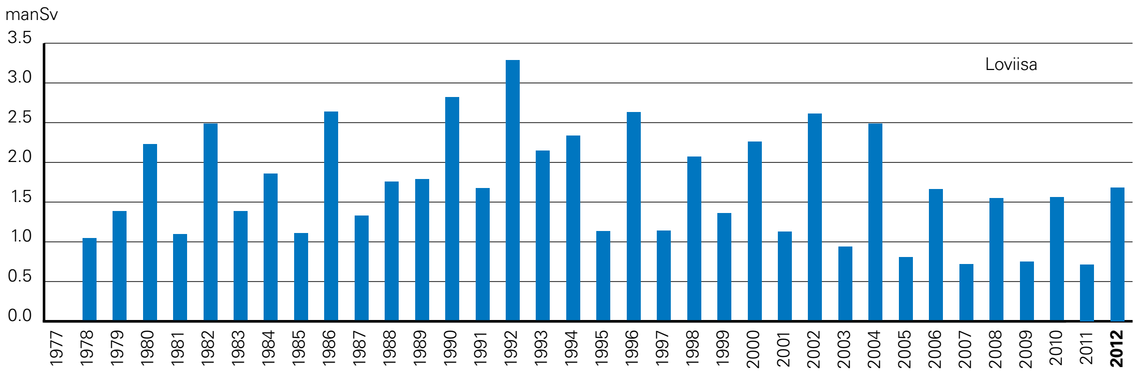


Figure 14. Collective annual occupational doses at the Loviisa nuclear power plant.

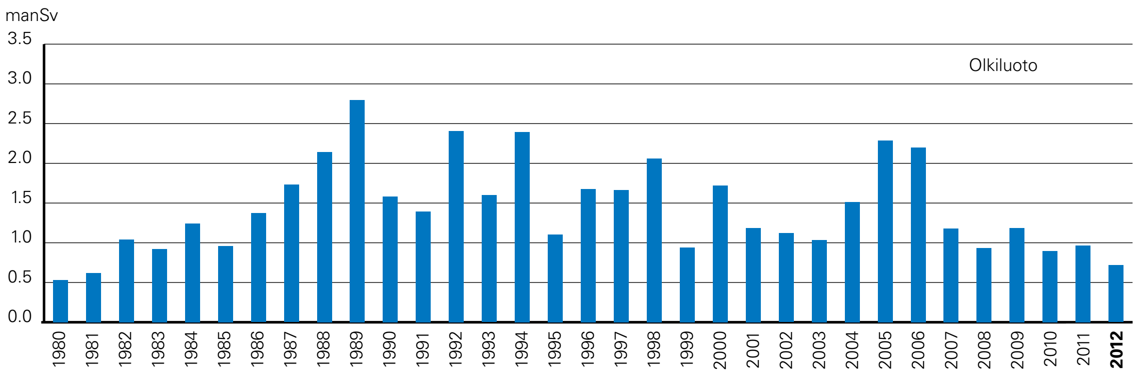


Figure 15. Collective annual occupational doses at the Olkiluoto nuclear power plant.

Table 3. Radioactive effluents from the Loviisa NPP. The proportion of the releases as compared to the limit values is given in parenthesis.

Year	Airborne effluents			Liquid effluents excluding tritium [Bq]
	Noble gases Kr-87 ekv. [Bq]	Iodine I-131 ekv. [Bq]	Aerosols [Bq]	
2010	5.88E+12 (0.03 %)	4.84E+07 (0.02 %)	1.18E+08	1.77E+08 (0.02 %)
2011	6.29E+12 (0.03 %)	8.58E+05 (0.0004 %)	1.10E+08	1.88E+08 (0.02 %)
2012	5.56E+12 (0.04 % *)	2.25E+05 (0.0001 %)	1.03E+08	3.06E+08 (0.03 %)

*) Release limit for noble gases was changed in 2012.

Table 4. Radioactive effluents from the Olkiluoto NPP. The proportion of the releases as compared to the limit values is given in parenthesis.

Year	Airborne effluents			Liquid effluents excluding tritium [Bq]
	Noble gases Kr-87 ekv. [Bq]	Iodine I-131 ekv. [Bq]	Aerosols [Bq]	
2010	5.81E+11 (0.003 %)	9.40E+07 (0.08 %)	1.17E+07	2.39E+08 (0.08 %)
2011	1.24E+12 (0.007 %)	1.74E+06 (0.002 %)	1.50E+07	1.38E+08 (0.05 %)
2012	1.21E+12 (0.01 % *)	1.70E+07 (0.02 % *)	1.63E+07	2.04E+08 (0.07 %)

*) Release limits for noble gases and iodine were changed in 2012.

new ones with low cobalt content. Cobalt-containing components have been reduced from the original value of each plant unit, by more than 40 %. The reduction in moisture of primary steam with the equipment upgrades (new steam dryers) during 2005–2007 at the Olkiluoto NPP has continued the substantial reduction of radiation dose rates at the turbine plant during 2010–2012. The risk-informed procedure was deployed to in-service material inspections in piping and welding for the first time in outages 2012 at the Olkiluoto NPP. This has also contributed towards reducing the amount of work carried out in most radioactive areas, thus reducing the radiation exposure of the employees.

The radiation dose statistics of the workers are presented for the Loviisa and Olkiluoto nuclear power plants in Tables 1 and 2 and Figures 14 and 15. The individual radiation doses have remained well under the set annual and five years dose limits. The maximum combined dose of a Finnish worker at the NPPs for a single year during 2010–2012 was 15.8 mSv. For a 5 years period 2008–2012, the maximum dose was 53.8 mSv and was received by a person working at the Loviisa nuclear power plant.

In international comparison (e.g. the ISOE radiation dose database of the NEA, the Nuclear Energy Association of the OECD countries), the Olkiluoto units 1 and 2 have been among the best boiling water reactors when comparing both individual and collective radiation doses. The long-term planning of annual maintenance operations has made it possible to keep their duration short, which usually reduces the amount of work carried out and hence also the exposure to radiation. Loviisa NPP has succeeded in decreasing the collective dose of the personnel and is well in comparison with different type of PWRs.

Radioactive effluents

STUK confirms upon the licensee's application the release limits for radioactive materials during the normal operation of a nuclear power plant. Operational Limits and Conditions have more stringent requirements applicable for the radioactive substances of primary coolant (fuel integrity), thus practically preventing releases. Fuel rods at the Olkiluoto and Loviisa nuclear power plants have had very low failure rates. Both nuclear power plants have efficiently implemented measures to reduce the releases of radioactive substances into the environment.

The radioactive effluents from the plants in 2010–2012 are shown in Tables 3 and 4. Radioactive releases into the environment from the Finnish nuclear power plants have been well below authorised limits (for important nuclides and pathways, of the order of 0.01% to 0.1% of set values based on the requirements). Calculated radiation exposures to the individual of the critical group living in the environment of the nuclear power plants are shown in Figure 16.

STUK received reports from Fortum (the latest report in 2011) and TVO (the latest report in

2010) on the implementation of the Guide YVL 7.1 concerning the potential solutions (Best Available Techniques, BAT) for further reduction of the radioactive discharges from the Loviisa and Olkiluoto NPPs. Fortum has developed caesium removal technology from liquid releases which is in successful operation. The utility reviewed VVER reactor R & D issues and evaluated their own developments underway. They recognized some techniques worth of further research and development. TVO and the Olkiluoto power plant had previously carried out improvements on water treatment and purification of discharge waters, and no new solutions were presented now. TVO had also an independent assessment, comparing the emissions and operating experience in the Olkiluoto plant units and in equivalent Swedish BWRs. The results indicate that the standard of radiation protection is also in this respect at least of the same level as in the reference plant units surveyed. STUK concluded that the both utilities apply the BAT principle to abatement of radioactive discharges of their power plants.

Environmental radiation monitoring

STUK has approved the operating programme for environmental radiation monitoring in the surroundings of the Loviisa and Olkiluoto NPPs for 2012–2016. The changes in the programme compared with the previous one were related to, inter alia, the use of reference samples, changes in gardening and agricultural product samples, collecting frequencies of samples, measurements of the water treatment plant sludge and the interpretation of measurement results on carbon-14 nuclides.

Environmental Radiation Monitoring Department of STUK has acted as an outside contracted laboratory for the licensee. The outside contracted laboratory collects and analyses about 300 samples (air, fallout, sediment, indicator organisms, milk, etc.) per year from the environment of both Loviisa and Olkiluoto NPPs. Very small quantities of radioactive substances of local origin were detected in 2010–2012 on some samples from the environment of both nuclear power plants. Concentrations of the radioactive substances were very low, and effects on the public are insignificant.

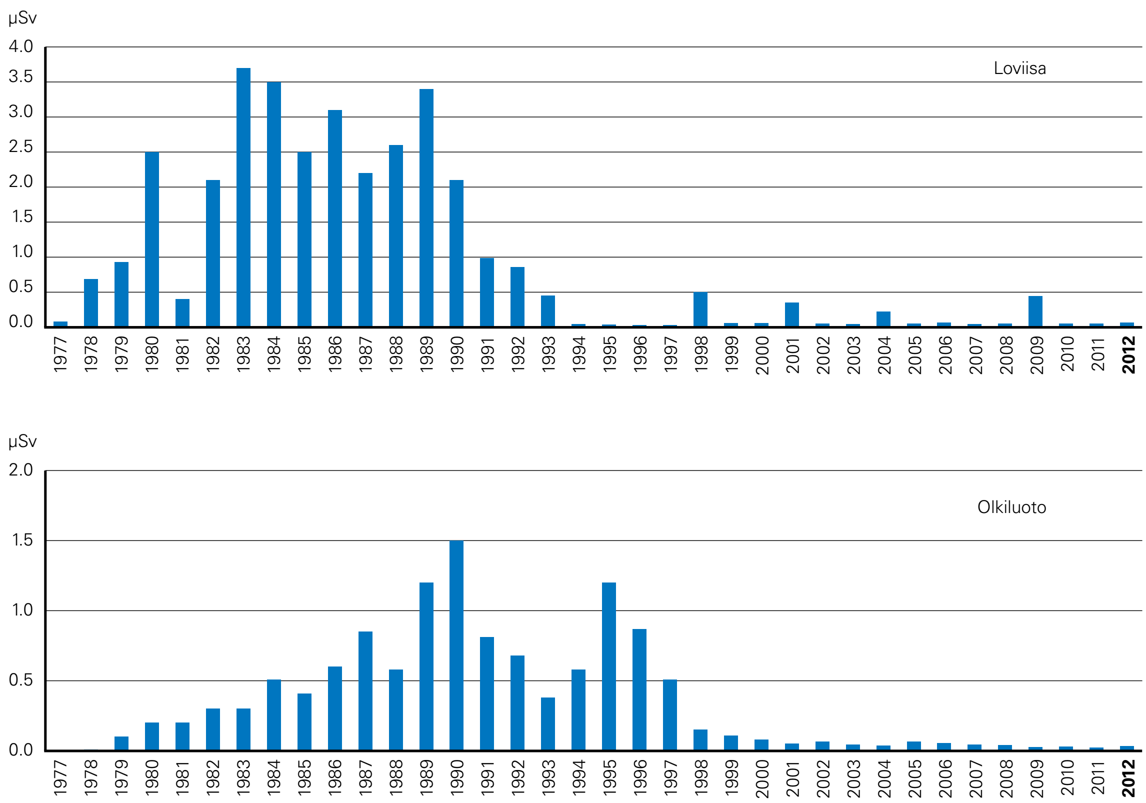


Figure 16. Calculated annual radiation exposures to the members of critical groups in the environment of the Finnish nuclear power plants. Doses have been clearly under the limit 100 μSv.

The IRRS review team identified that STUK should withdraw from the current practice of conducting the environmental monitoring programmes in the vicinity of the nuclear facilities based on commercial contracts with the licensees. Furthermore, STUK should implement an independent monitoring programme for the environment, to verify the results of the off-site environmental monitoring programmes required from the licensees. Based on the IRRS recommendation, there is a plan to change the Finnish Nuclear Energy Act in the near future.

Regulatory oversight

On the basis of documents submitted by the licensees, STUK approved in 2012 the use of the dosimetry service of the Loviisa nuclear power plant and the Olkiluoto nuclear power plant until 2016. As appropriate, the approval also covers the agreement between the licensee and the outsourced services provided by the company Doseco Oy, responsible for routine dosimetry at the Olkiluoto NPP. STUK has audited the dose monitoring service at Doseco Oy.

The dosimeters used for measuring the occupational radiation doses of Loviisa and Olkiluoto plants have underwent STUK's annual tests with acceptable results. These tests comprise irradiating a random sample of dosimeters at STUK's radiation standard laboratory and determination of the doses at the power plant (blind test). Although the test results were acceptable, it was found that the test results of the Loviisa NPP for surface doses were systematically conservative. Closer investigation revealed that the surface doses reported to the dose register in 2011 were relatively higher in relation to deep doses when compared to previous years. As a corrective action, technical and administrative changes were made to the radiation dose determination algorithms at the Loviisa NPP in 2012.

STUK carries out annual radiation protection inspections on-site according to the periodic inspection programme, e.g. covering the resources, expertise and operation of the radiation protection organisation, dosimetry, radiation measurements in the plant, radioactivity measurements of effluents, and monitoring of radiation in the environment. STUK carries out on-site inspections related to radiation protection also during annual maintenances. The inspections at the Loviisa and Olkiluoto NPPs have shown e.g. that the plants have introduced technical and IT administration improvements in the field of radiation protection, which made it possible to enhace the control of occupational radiation doses and contamination.

In conclusion, Finnish regulations and practices are in compliance with Article 15.

Article 16. Emergency preparedness

1. ***Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.***
2. ***Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the States in the vicinity of the nuclear installation are provided with appropriate information for emergency planning and response.***
3. ***Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.***

Emergency preparedness on-site of NPPs

Regulations concerning emergency preparedness and response arrangements at the NPPs are given in the Nuclear Energy Act, the Nuclear Energy Decree and the Government Decree on Emergency Response Arrangements at Nuclear Power Plants (735/2008). Detailed requirements and STUK's oversight procedures are given in the Guide YVL 7.4.

The Government Decree on Emergency Response Arrangements at Nuclear Power plants is under renewal and the new Decree is expected to become effective in 2013. Parallel to that the Guide YVL 7.4 is revised according to the Decree taking also into account the lessons learned from the TEPCO Fukushima Dai-ichi accident. In the new Decree, there is a requirement to take into account the possibility of several reactor units' simultaneous accident in the emergency planning. In STUK's decisions made on the basis of the national assessments and European Stress Tests for nuclear power plants, both TVO and Fortum were required to clarify and update their emergency plans and procedures with respect to issues like qualification of the staff in the emergency organisation, management of access control and contamination control in the case when the normal arrangements are out of function and restoring the access routes and connections to the site in case of massive destruction of the infrastructure. Loviisa and Olkiluoto NPP as well as STUK's emergency centre are now equipped with satellite telephones. The work for developing and improving the emergency preparedness arrangements will continue.

Fortum and TVO have analysed accident and safety-impairing events at the Loviisa and Olkiluoto NPPs. These analyses are documented in the safety analysis reports of the plants and have been used as the basis for planning the Finnish nuclear power plant emergency response arrangements.

Emergencies are classified and described briefly in the plant's emergency plan. The notifications and alarms to plant personnel and authorities required by different classes of emergencies, as well as the scope of operations of the emergency response organisation pertaining to the type of emergency, are described in the emergency procedures.

A person responsible for emergency response arrangements has been appointed both for the Loviisa and Olkiluoto nuclear power plants. Due to the updated Nuclear Energy Act the nominated deputies for the persons responsible for emergency response arrangements have been appointed by the licensees and approved by STUK. The emergency response organisation has been described in the emergency plan and procedures, updated with regard to personnel changes once a year. The more limited staffing of the emergency response organisation required for emergency standby state (alert) is defined in the shift supervisor guides for the emergency response.

The facilities of the emergency response organisation at the Loviisa and Olkiluoto nuclear power plants include a system for displaying data directly from the process computer. Several hundred parameters are transmitted also to the STUK's emergency response centre. The automatic data transfer and display system from the Olkiluoto NPP to STUK was upgraded in 2011 and from the Loviisa NPP to STUK in 2012.

Emergency response training and exercises are annually arranged for the emergency response organisation of the nuclear power plants. The emergency response training has included classroom and group-specific practical training as well as special training, such as first aid, fire and radiation protection training. In addition to severe accidents, emergencies covered by the emergency response exercises also included conditions classified as emergency standby. The content and scope of the training as well as feedback obtained from the training are assessed in the inspections of the STUK's periodic inspection programme.

STUK verifies the preparedness of the organisations operating nuclear power plants in yearly onsite inspections. Emergency preparedness at the Loviisa and Olkiluoto power plants meet the key regulatory requirements. At the Loviisa NPP, the objects of the inspection included the preparedness organisation's personnel resources, facilities and equipment, training and alert arrangements, revision of the structure and content of emergency preparedness instructions, radiation measurements in the surroundings and meteorological measurements on-site. Emergency preparedness exercises and mustering exercises were conducted annually. Also an unannounced exercise was organised starting outside the normal working hours.

At the Olkiluoto NPP, the objects of the inspection included preparedness organisation personnel resources, training, exercises, facilities and equipment, alarm arrangements, radiation measurements in the surroundings, meteorological measurements on-site, emergency preparedness of the Olkiluoto unit 3 construction site and the work for revising the emergency preparedness instructions. An all-site mustering exercise was held in 2012 at the Olkiluoto unit 3 construction site.

Both the Loviisa and Olkiluoto monitoring networks have up to 15 real time environmental dose rate measuring stations, five and four of them close to the plant area and the others in a half circle at 5 km distance from the plant. Three additional measurement stations will be installed in the vicinity of Olkiluoto unit 3 before the plant unit is in operation. At the Loviisa NPP, a new monitoring network including 28 stations is on trial run and will replace the older system in 2013. The design basis of the new measuring stations is at least 3 months autonomic operation in emergency situations with long-term batteries. At the Loviisa NPP, the licensee will renew the weather monitoring system including also the on-site weather mast and including a new measurement point in the marine environment.

Off-site preparedness arrangements

In addition to the on-site emergency plans established by the licensees, off-site emergency plans required by the rescue legislation (379/2011) are prepared by regional authorities. The requirements for off-site plans and activities in a radiation emergency are provided in the Decree of the Ministry of Interior (406/2011). STUK is an expert body to support the Ministry of Interior in the emergency response in the case of nuclear and radiological accidents.

STUK publishes VAL Guides for emergency response. Guide VAL 1 (2012) “Protective Measures in Early Phase of a Nuclear or Radiological Emergency” and VAL 2 (2012) “Protective Measures in Intermediate Phase of a Nuclear or Radiological Emergency” provide detailed guidance. In the case of an accident the local authorities are alerted by the operating organisation of the plant.

The Ministry of Interior has released a new guide “Nuclear or Radiological Emergencies: Roles and Responsibilities of All Actors” (MI publication 38/2012), which contains the detailed information of the arrangements in the Finnish society in the case of a nuclear or radiological emergency.

STUK has an Emergency Preparedness Manual for its own activities in the case of a nuclear or radiological emergency. STUK has an expert on duty on 24/7 basis. The message on an exceptional event (alarm) can be received from the operating organisations of the facilities, or automatically from the radiation monitoring network that is dense in the whole country (approx 250 measuring stations, see Figure 17), or from foreign authorities.

The off-site plans include provisions to inform the population in the case of an accident. Written instructions on radiological emergencies, emergency planning and response arrangements have been provided to the population living within the 20 km Emergency Planning Zone. These instructions are regularly updated and distributed.

The regulations and guides are tested in off-site emergency exercises conducted every third year. Full scale off-site emergency and rescue exercise OLKI11 was carried out in 2011 based on the Olkiluoto nuclear power plant accident scenario. Over 50 different organisations participated in this exercise which combined for the first time a scenario initiated by illegal activities and a technical emergency situation at the plant.

In 2013, the national full command post exercise LOVIISA13 was held. About 60 different governmental, regional and private organisations in Finland took part in the exercise.

As a result of the studies made after the TEPCO Fukushima Dai-ichi accident, no major

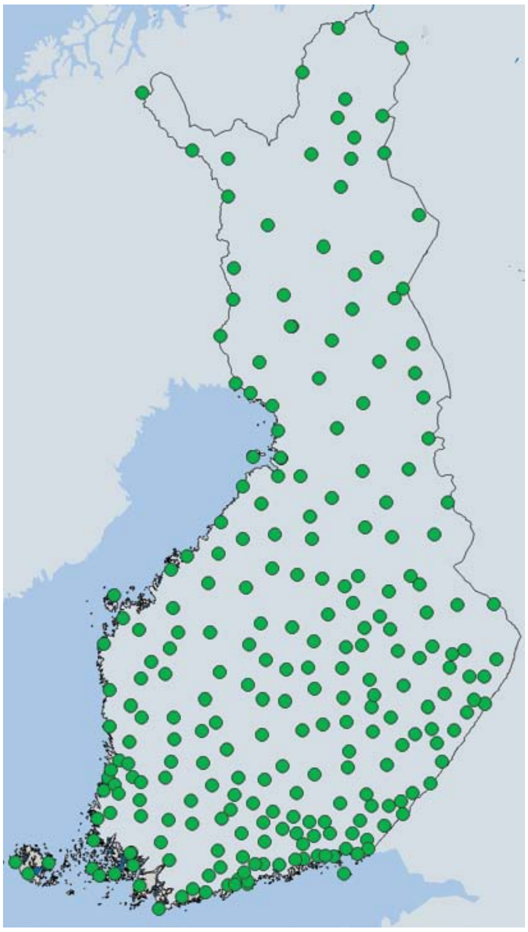


Figure 17. The measuring stations of the radiation monitoring network.

changes have been identified in off-site emergency preparedness so far. However, there is a need to ensure accessibility to the site in case of extreme natural hazards, provide a sufficient amount of radiation protection equipment and radiation monitoring capabilities for rescue services and improve communication capabilities. In addition, there is a need to ensure that the resources of rescue authorities can be reasonably coordinated between radiological and other emergencies, should they happen simultaneously.

The rescue planning is strengthened in a co-operation between the nuclear power plant, regional rescue services, regional police departments and STUK. Permanent coordination groups have been established for both Loviisa and Olkiluoto NPPs in order to ensure coordinated and consistent emergency plans, to improve and develop emergency planning and arrangements and to share lessons from the exercises, regulations and other information. Also extensive training is arranged by these groups. In addition, a National Nuclear Power Plant Emergency Preparedness Forum is under consideration in order to have co-operation and combination between permanent groups. The Ministry of the Interior and the Ministry of Social Affairs and Health, the regional rescue service authorities, STUK and the NPP licensees will be participating in the Forum.

In autumn 2012, an international Integrated Regulatory Review Service (IRRS) mission held at STUK covered also emergency arrangements. As the outcome, the IRRS mission suggested that STUK should, in cooperation with relevant Government authorities, consider improving national arrangements for timely provision of assistance requested by other countries (including through RANET) and for effectively integrating assistance received by Finland into the national response system. As a good practise the IRRS team mentioned that STUK has excellent tools, facilities and organisational arrangements to perform the necessary evaluation of the emergency in a timely manner and to provide appropriate recommendations for protective measures. The organisation and conduct of the emergency exercises and the coordination with other stakeholders was also considered exemplary.

Information to the neighbouring countries

Finland is a party to the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, done in Vienna in 1986. Being a member of the European Union, the Council Decision (87/600/EURATOM) on Community arrangements for the early exchange of information in the event of a radiological emergency applies in Finland, too. In addition, Finland has respective bilateral agreements with Denmark, Germany, Norway, Russia, Sweden and Ukraine. Accordingly, arrangements have been agreed to directly inform the competent authorities of these countries in the case of an accident.

In addition to the domestic nuclear emergency exercises held annually on each nuclear power plant site, STUK has taken part in international emergency exercises. STUK has also participated as a co-player in emergency exercises arranged by the Swedish and Russian nuclear power plant operators and authorities. Neighbouring countries have been actively invited to take part in the Finnish exercises. In 2013, Finland hosted a joint international exercise in which Nordic and Baltic countries and the IAEA took part in. Participants were from Sweden, Norway, Denmark, Iceland, Estonia, Latvia, and Lithuania and also Russian key emergency centres followed the exercise. The international exercise was combined with the full exercise at the Loviisa nuclear power plant. In the exercise e.g. real time communication and coordination of actions among participants were tested.

In conclusion, Finnish regulations and practices are in compliance with Article 16.

Article 17. Siting

Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented:

- *i.* ***for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;***
- *ii.* ***for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment;***
- *iii.* ***for re-evaluating as necessary all relevant factors referred to in sub-paragraphs (i) and (ii) so as to ensure the continued safety acceptability of the nuclear installation;***
  for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the likely safety impact on their own territory of the nuclear installation.

Regulatory approach to siting

Requirements for the siting of a nuclear power plant are provided in the Nuclear Energy Act and the Nuclear Energy Decree. The application for a Decision-in-Principle has to include e.g.:

- a description of settlement and other activities and town planning arrangements at the site and its vicinity
- a description of the suitability of the planned location for its purpose, taking account of the impact of local conditions on safety, security and emergency response arrangements, and the impacts of the nuclear facility on its immediate surroundings
- an assessment report in accordance with the Act on the Environmental Impact Assessment Procedure (468/1994) as well as a description of the design criteria which the applicant will observe in order to avoid environmental damage and to restrict the burden to the environment.

More detailed requirements on the Environmental Impact Assessment (EIA) are provided in the Decree on Environmental Impact Assessment Procedure (713/2006). The Finnish EIA legislation complies with the EU Directive 2001/42/EU on the EIA procedure.

In the design of a nuclear power plant, site-related external events have to be taken into account. Government Decree 733/2008 provides as follows: “The safety impact of local conditions, as well as the security and emergency preparedness arrangements, shall be considered when selecting the site of a nuclear power plant. The site shall be such that the impediments and threats posed by the facility to its environment remain extremely minor and heat removal from the plant to the environment can be reliably implemented.” STUK issued in 2001 the Guide YVL 1.10 “Safety criteria for siting a nuclear power plant”, which describes generally all requirements concerning the site and surroundings of a nuclear power plant, gives requirements on safety factors affecting site selection and covers regulatory control. Requirements on seismic design are set forth in the Guide YVL 2.6. Deterministic analyses are made to assess the impact of various natural phenomena and other external events. The probabilistic risk assessment required for the safety review of Construction and Operating Licence applications provides information on risks caused by external events.

The general principle in the siting of nuclear power plants is to have facilities in a sparsely populated area and remote from large population centres. In the vicinity of the plant, no activities are allowed that could pose an external threat to the plant. Site characterisation is performed based on geological, seismic, hydrological and meteorological factors as well as on transport routes and risks, industrial activities, agriculture, nature and population. Extreme meteorological conditions and consequences (e.g. frazil ice formation) have to be taken into consideration in the site evaluation and plant design.

In connection with the decisions for construction of the Loviisa and Olkiluoto plants in the 1970s, siting requirements related to population density and land use planning were quite easily and practically achievable in a sparsely populated country like Finland. The precautionary action zones have only a few tens of permanent inhabitants. Similar attention was not given to the recreational houses and the transient summertime population in the coastal area (mainland and islands) where the conditions might be demanding for efficient emergency preparedness and rescue action. The number of recreational houses on the seaside within 5 km the existing plants is about 400–500.

Finland is a party to the Convention on Environmental Impact Assessment in a Transboundary Context, done in Espoo in 1991. The Convention is applied for Finnish nuclear facility projects by providing a full participation to all neighbouring countries which announce the willingness to participate in the environmental impact assessment procedure in question. In Finland, the EIA is conducted at an early stage of a NPP project, prior to the selection of the plant design, based on the power range of the plant and on general information on the available designs. This is before the Decision-in-Principle is taken, as the outcome of the EIA procedure is part of the material needed for the Decision-in-Principle application.

Regulatory Guide YVL 1.10 on NPP siting criteria is being revised. The new Guide YVL A.2 will include a description of all relevant legal processes, including those based on non-nuclear legislation. Efficient cooperation between the utility and responsible authorities is emphasised, e.g., for:

- maintaining the land use planning in the plant environment during the plant operational life time in line with the safety goal of avoiding dense population
- taking necessary actions to guarantee efficient road connections to the plant area also in case of a severe accident and all extreme weather conditions.

Quality, competence and comprehensiveness of the site survey and site confirmation are required and the results shall be assessed by STUK in different licensing stages. The basic goals for population safety will not be changed in the revised guide.

The EIA and other site-related studies are conducted by the licence applicant or licensee depending on the context. The safety related reports are reviewed by STUK. The Ministry of Employment and the Economy arranges the national public hearings and the Ministry of the Environment arranges the international hearings.

The bilateral agreements mentioned under Article 16 include provisions to exchange information on the design and operation of nuclear facilities. In the European Union a specific statement is also prepared for each new nuclear power plant unit in a member state before authorisation of the operation (Euratom Treaty, Article 37). This is based on a General Data report submitted by the member state and on its examination in a plenary meeting of Group of Experts. For Olkiluoto unit 3 this process was conducted in 2010. Based on the legislation on land use planning, statements from neighbouring countries must be requested for the land use plans of a nuclear power plant. Sweden, Denmark, Norway, Germany, Poland, Lithuania, Latvia and Estonia were informed of initiating the regional planning process for Fennovoima's two candidate sites in Northern Finland and the opportunity to participate.

The detailed requirements on the determination of site-specific design bases for external events are collected and expanded in the new Guide YVL B.7.

Re-evaluation of site related factors

The operating licence for a nuclear facility is granted for a fixed term. Periodic Safety Review (PSR) shall be conducted either in connection with the license renewal or as a separate review with intervals of about ten years at most.

For the licence renewal of the Loviisa units in 2005–2007 and the Periodic Safety Review of the Olkiluoto units in 2007–2009, comprehensive reassessments of safety, including the environmental safety of the nuclear facility and the effects of external events on the safety of the facility, were conducted by the licensees and reviewed by STUK. The assessments covered meteorology, hydrology, geology, seismology, population and use of land and sea area. During the operation of a nuclear facility, the Final Safety Analysis Report (FSAR), including its site-specific parts, has to be periodically reviewed and updated as needed. A detailed re-evaluation of the site related factors was also carried out in 2007–2009 for the Olkiluoto and Loviisa sites in connection with the Environmental Impact Assessment and Decision-in-Principle procedures for new NPP units. The next PSR for the Loviisa NPP has been started by the licensee and it shall be submitted to STUK by the end of 2015. The next PSR for the Olkiluoto NPP units 1 and 2 will be conducted in connection with the renewal of the operating licences expiring at the end of 2018. Olkiluoto site related factors will be re-evaluated also in connection with the operating licence procedure for the Olkiluoto unit 3.

The capacity of the NPP units to withstand external hazards is evaluated in deterministic safety analyses and in probabilistic risk assessments (PRA). PRAs of the Finnish units cover natural and man-made external hazards such as high seawater level, high wind including tornadoes, lightning, high- and low air temperature, high seawater temperature, frazil ice formation in cooling water intakes, algae and other organic material in seawater, oil spills from oil tanker ship accidents and earthquakes. During the past twenty years the results of external events PRAs have initiated several safety improvements in the plants.

Research on the site related natural hazards is conducted continuously in the Finnish National Nuclear Safety Research Program SAFIR (http://safir2014.vtt.fi/links.htm). STUK has a major role in steering the research and the results support STUK in the review of the reports submitted by the licensees. The research covers seismic hazard and extreme meteorological phenomena and seawater level variations, including the effects of climate variability and change.

In addition to the normal PSRs, an extraordinary review of site related issues was carried out after the TEPCO Fukushima Dai-ichi accident in connection with the so called European stress tests. National studies were initiated immediately after the accident and the EU stress tests were started in June 2011.

The stress tests did not reveal any new site-related external hazards or vulnerabilities of the plants to external events. No need for immediate action was recognized, but some additional studies of external hazards and feasibility studies for plant modifications to improve robustness against external events were found justified.

The following examples of safety improvements and additional analyses of external events at the Loviisa NPP can be mentioned: enhanced protection against high seawater level during annual maintenance shutdown (partly implemented) and power operation (hazard evaluation and feasibility studies on-going), installing cooling towers replacing the service water system in case of blockage of seawater intake (under detailed planning), and detailed structural analysis of spent fuel pools in the case of an earthquake with consequential boiling in the pools.

At the Olkiluoto NPP units 1 and 2, the plans include system modifications to ensure the operation of the auxiliary feed water system in case of the loss of the ultimate heat sink (seawater systems) and structural analysis of the spent fuel pools. Seismic walk-downs of the fire extinguishing water system have been carried out and some improvements will be implemented. The emergency diesel generators will be replaced within the next few years. The new emergency diesel generators will be provided with alternative air and seawater cooling, while the existing diesels have only seawater cooling. In addition, studies are carried out on systems to ensure residual heat removal in the case of total loss of AC power and/or loss of the ultimate heat sink due to external or internal events. The effects of extreme seawater levels on the accessibility of the site will be studied as well.

In conclusion, Finnish regulations and practices are in compliance with Article 17.

Article 18. Design and construction

Each Contracting Party shall take the appropriate steps to ensure that:

i. ***the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defence in depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur;***

ii. ***the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis;***

iii. ***the design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the man-machine interface.***

Implementation of defence in depth

Regulatory requirements regarding nuclear power plant design and construction

According to the Government Decree 733/2008, several levels of protection have to be provided in the design of a nuclear power plant. The design of the nuclear facility and the technology used is assessed by STUK when reviewing the applications for a Decision-in-Principle, Construction Licence and Operating Licence. Design is reassessed against the advancement of science and technology, when the Operating Licence is renewed and in the periodic safety reviews.

In the design, construction and operation, proven or otherwise carefully examined high quality technology shall be employed to prevent operational transients and accidents and to mitigate their consequences. A nuclear power plant shall encompass systems by means of which operational transients and accidents can be quickly and reliably detected and the aggravation of any event prevented. Effective technical and administrative measures shall be taken for the mitigation of the consequences of an accident. The design of a nuclear power plant shall be such that accidents leading to extensive releases of radioactive materials must be highly unlikely.

Dispersion of radioactive materials from the fuel of the nuclear reactor to the environment shall be prevented by means of successive barriers which are the fuel and its cladding, the cooling circuit of the nuclear reactor and the containment building. Provisions for ensuring the integrity of the fuel, primary circuit and containment are included.

In ensuring safety functions, inherent safety features attainable by design shall be made use of in the first place. If inherent safety features cannot be made use of, priority shall be given to systems and components which do not require an external power supply or which, as a consequence of a loss of power supply, will settle in a state preferable from the safety point of view (passive and fail-safe functions).

In order to prevent accidents and mitigate the consequences thereof, a nuclear power plant shall be provided with systems for shutting down the reactor and maintaining it in a subcritical state, for removing decay heat generated in the reactor, and for retaining radioactive materials within the plant. Principles ensuring the implementation of these safety functions even in the event of a malfunction must be applied in designing the systems in question. Such principles are redundancy, separation and diversity. The safety functions necessary for transferring the plant to, and maintaining a controlled state must be accomplished, even if any individual system component needed to fulfil the safety function (including the necessary supporting or auxiliary functions) is inoperable and if any other component needed for the function is simultaneously out of use due to required repair or maintenance. Common-cause failures in safety systems shall only have minor impacts on plant safety. A nuclear power plant shall have reliable on-site and off-site electrical power supply systems. The execution of safety functions shall be possible by using either of the two electrical power supply systems. Due to the TEPCO Fukushima Dai-ichi accident, the Finnish requirements are being supplemented by requiring that the plant shall be provided with systems and procedures by which decay heat removal from the reactor and from the spent fuel pools can be ensured for 72 hours independent of the electricity or water supply from off-site sources in events caused by rare external events or disturbances in the plant internal electricity distribution.

The plant shall also be provided with systems, structures and components for controlling and monitoring severe accidents. These shall be independent of the systems designed for operational conditions and postulated accidents. Systems necessary for ensuring the integrity of the containment building in a severe accident shall be safety-classified and capable of performing their safety functions, even in the case of a single failure of an active component.

Special attention shall be paid to the avoidance, detection and correction of any human errors during design, construction, operation and maintenance. The possibility of human errors shall be taken into account in the design of the nuclear power plant and in the planning of its operation and maintenance, so that human errors and deviations from normal plant operations due to human errors do not endanger plant safety. The impacts of human error shall be reduced by using various safety design methods, including defence-in-depth, redundancy, diversity and separation.

Detailed requirements are given in Guides YVL 1.0, YVL 2.0, YVL 2.4, YVL 2.7, YVL 3.0, YVL 4.3, YVL 5.2, YVL 5.5, and YVL 6.2.

An assessment of the design of the facility and related technologies is made by STUK for the first time when assessing the application for a Decision-in-Principle. Later on, the evaluation is continued when the Construction Licence application is reviewed. Finally, the detailed evaluation of systems and equipment is carried out through their design approval process. The design of Loviisa plant units was reassessed by STUK in 2005–2007 and Olkiluoto plant units in 2007–2009 in the periodic safety review process. Design of the Olkiluoto unit 3 has been assessed for the construction licence (2005) and during the construction phase. It will be reassessed when reviewing the plant's operating licence.

Application of defence in depth concept at the Finnish NPPs

During the time period 2010–2012, no significant faults or signs of wear were detected in the integrity of equipment and structures critical to plant safety. The condition of the multiple barriers containing releases of radioactive substances has remained good both at the Loviisa and Olkiluoto NPPs.

In connection with the Loviisa plant's licence renewal, Fortum prepared a plan on actions aimed at further enhancing the safety of the plant units in the future. The most important ongoing plant modification project related to the Defence-in-Depth concept at the Loviisa plant is the upgrade of the I&C systems of the plant units. The project started in 2004 with the construction of a new I&C building. Safety classified parts of the project are intended to be completed in 2017.

Fortum and TVO have also reviewed all of the analyses of transient and accident situations at the Loviisa and Olkiluoto nuclear power plants in connection with the operating licence renewal and periodic safety review. Deterministic safety assessment is described in more detail under Article 14.

Severe accidents were not taken into account in the original design of the operating Finnish nuclear power plants. However, since the commissioning of the plants, major improvements have been implemented to mitigate the consequences of severe accidents. Mitigations systems of the Loviisa and Olkiluoto NPPs are described in detail in Annexes 2 and 3.

For the Olkiluoto unit 3, application of the Defence-in-Depth principle was presented in the Preliminary Safety Analysis Report (PSAR). The design follows the principles laid down in the Government Decree 733/2008. Compared with the existing reactors, the possibilities for mitigation of the consequences of the severe accidents are taken into account already in the early design phase. This is achieved by implementing features to ensure containment integrity. Design provisions include e.g. core catcher for corium spreading and cooling, hydrogen recombination, and containment heat removal. In addition, aircraft crash protection design requirements for both a military aircraft and a large passenger aircraft are taken into account.

Several plant modifications improving safety have been carried out at the Loviisa NPP during the last few years. Plates preventing vortices were installed in the intake pipes of the Loviisa plant emergency makeup water tanks during the 2009 annual outage. The objective of the modification is to obstruct air suction into the reactor emergency injection system pumps when the tank water level drops. The Loviisa plant improved suction strainers of the low pressure emergency cooling system and the containment spraying system by means of installing higher density mesh elements in them. The modification serves to ensure fuel cooling in accident conditions by means of preventing materials coming loose from, for example, heat insulation from being carried to the reactor core via the emergency cooling system. According to analyses, blockages in the core caused by large amounts of fibres could lead to overheating of the reactor core. The modifications were carried out at the Loviisa unit 2 in 2010 and at the Loviisa unit 1 in 2011.

Based on the safety analyses, it was considered necessary to make modifications in the operation of the Loviisa emergency water tanks of the low pressure emergency cooling system (accumulators). The modification serves to to ensure that heat transfer from the reactor can be reliably provided by preventing the nitrogen in the water tank from getting into the reactor. In order to ensure the tightness of the primary circuit, the sealing grooves of two inner sealing groove zones of the Loviisa units 1 and 2 reactor pressure vessel flange face were repaired. The tightness of the reactor pressure vessel and its lid is based on double seal grooves in which a nickel sealing wire is inserted. The first defects which required local repair were detected in these sealing grooves in periodic inspections at the Loviisa unit 2 in 2005. Similar defects were also detected in subsequent inspections at the Loviisa unit 1. The repairs were done during the annual outage 2010 at the unit 1 and 2012 at the unit 2.

Due to the TEPCO Fukushima Dai-ichi accident, safety improvements have been initiated at the Loviisa NPP. Improvements under planning and implementation for the Loviisa plant include among other things:

- Installation of independent cooling towers for decay heat removal from the reactor core and from the spent fuel pools. The cooling towers would provide an alternative ultimate heat sink in case of loss of sea water cooling. Installation of the towers is planned for 2014.
- Flood protection. The utility has estimated the effects of high sea level to the plant behavior. The utility will submit a detailed plan of improved flood protection in 2014 (protection during annual maintenance shutdown already partly implemented).
- Design plans of diverse cooling water supply to the spent fuel pools have been submitted to STUK in 2013.
- Evaluation of the availability of cooling water and emergency diesel fuel in case of accidents at multiple units.

Fukushima related modifications at the Loviisa NPP are described in more detail in Annex 2.

Several plant modifications improving safety have also been carried out at the Olkiluoto NPP units 1 and 2 during the last few years. The main steam line isolation valves inside the containment were replaced at the Olkiluoto units 1 and 2 during annual maintenances in 2010 and 2011. The function of the valves is to isolate the reactor pressure vessel and prevent the loss of reactor coolant and releases of radioactive substances outside the containment. The valves also function as a backup for the isolation valves outside the containment. One reason for the valve replacement was the tendency of the old valves to close as the steam flow increases. In a situation where one valve closes, the steam flow through the other valves increases and this can make them close, too. The near simultaneous closing of all the steam line isolation valves causes a greater pressure rise and load on the reactor pressure vessel than the closing of a single valve only.

TVO has replaced in 2010 all rubber collar pipe penetrations below elevation +10 in the rooms containing emergency cooling system pumps with type-approved fire and pressure penetrations. All in all, the modification involved over 60 penetrations. STUK had earlier made a remark about the condition of the penetrations. TVO examined all the similar original penetrations at the plant by means of testing and assessing their compliance with fire, ventilation and water-tightness requirements, and analysed the risks to plant safety. Based on the risk analysis results, the impact of the conditions of the penetrations was about 3% of the PSA model annual core damage frequency.

TVO has made a decision to replace all current emergency diesel generators (EDGs) of the Olkiluoto units 1 and 2 with their auxiliary systems to correspond with the changed need for power, taking also into account any increases in the need for power due to possible future plant modifications as well as the lessons learnt from the Fukushima accident in relation to securing the power supply.

Safety improvements due to the TEPCO Fukushima Dai-ichi accident under planning for the Olkiluoto units 1 and 2 include among other things:

- Assessing possibilities for ensuring cooling of the reactor core in case of total loss of AC supplies and systems. Evaluations of feasible solutions are under way.
- Ensuring operation of the auxiliary feed water system pumps independently of availability of the sea water systems. The modification is planned for 2014-2015.
- Design plans of diverse cooling water supply to the spent fuel pools will be completed in 2013.
- The utility is assessing plans for new mobile equipment (aggregates, pumps).
- Evaluation of the availability of cooling water and emergency diesel fuel in case of accidents at multiple units.

Fukushima related modifications at the Olkiluoto NPP units 1 and 2 are described in more detail in Annex 3.

In 2011, STUK has accepted increase of the maximum bundle average burnup up to 57 MWd/kgU for the TVEL 2nd generation fuel used at the Loviisa plant. STUK has also accepted increase of the maximum bundle average burnup up to 50 MWd/kgU for the fuel types used at the Olkiluoto units 1 and 2: GEI4, GNF2, ATRIUM 10XM, SVEA-96 OPTIMA and SVEA-96 OPTIMA2. New type of fuel bundles (so-called TVEL 2nd generation fuel) were taken into use at the Loviisa NPP in 2009. The fuel enrichment is slightly higher which has an impact on shutdown margin of the reactor. Also six rods in the bundle contain burnable poison. Acceptable control rod positions in the Operational Limits and Conditions were also changed in order to keep the shutdown margin of the reactor core at the same level as before.

A minor fuel leak was observed at the Loviisa unit 1 on 2009. One leaking fuel assembly was found in the investigation carried out during the annual maintenance outage of 2010, and the leaking assembly was removed from the reactor. Another minor fuel leak has been observed at the Loviisa unit 2 late 2012. A fuel leak was observed at the Olkiluoto unit 1 about one week before the 2010 annual maintenance. The leak remained small, and the leaking fuel assembly was removed from the reactor during the outage. Olkiluoto unit 2 had two fuel leaks in 2010–2011. The leaking fuel assemblies were identified and removed from the reactor during the 2011 and 2012 annual maintenances.

Inspections of the reactor pressure vessel and piping have revealed no deterioration of the materials at the Finnish NPPs. No significant issues with safety implications were observed in the periodic inspections of the pressure equipment. STUK has renewed the operating licences of the Loviisa units 1 and 2 reactor pressure vessels until the end of the operating licence of the units. However, safety of the pressure vessel operation must be assessed in connection with the Periodic Safety Reviews.

The Loviisa unit 2 primary and secondary circuits were subjected to pressure tests in 2010. The pressure tests are performed every eight years. In the tests, the structural strength and leak tightness of the circuits are tested using a pressure 1.3 times the design pressure, i.e. 178 bar abs for the primary circuit and 73 bar abs for the secondary circuit. Results of the tests were accepted by STUK. The inner parts of the reactor pressure vessel of the Olkiluoto unit 1 were subjected to a visual video inspection during the 2011 refuelling outage. The Olkiluoto unit 1 faults being monitored have remained unchanged, and the inspections did not reveal any new faults with important safety implications.

The steel liner of the Loviisa NPP containment is subjected to a leak tightness test at four-year intervals using the design pressure of 1.7 bar abs. The test has been carried out in 2010 at the Loviisa unit 2 and in 2012 at the Loviisa unit 1. Results of the tests have fulfilled the acceptance criteria. The reactor containment at the Olkiluoto NPP is subjected to a leak tightness test three times during a 12-year period. In addition, leak tightness tests have been made systematically to containment isolation valves, personnel airlocks and containment penetrations during the annual outages. The results show that the leak tightness of the containment building has remained acceptable at the both NPPs. The overall leak tightness of the Olkiluoto unit 2 reactor containment was tested during the annual outage of 2010 and that of the Olkiluoto unit 1 containment during the outage of 2012. Results of the test have fulfilled the acceptance criteria.

During the period 2010–2012, no significant failures were observed at the Loviisa plant in the safety functions or in the systems, equipment and structures executing them. No significant faults or signs of wear have been detected during in the integrity of equipment or structures critical to plant safety.

In accordance with a periodic testing programme, TVO carried out testing of the relief train valves of the blowdown system at the Olkiluoto unit 1 during the 2010 annual maintenance. The purpose of the blowdown system is to limit the pressure in the reactor by letting out steam from the reactor to the suppression pool if the normal route of the steam to the turbine is not available. When tested, two relief valves did not operate as planned. TVO carried out inspection of the electric pilot valves of the relief valves which revealed that three electric pilot valves had jammed. All three jammed valves were of a new type that had been installed at the Olkiluoto unit 1 the year before. The reason for the jamming was the oxidation of the internal coating material of the valve guide bushing. The manufacturer had changed the coating material without informing TVO.

In 2011 maintenance outage at the Olkiluoto unit 2, TVO discovered that there were cracks in the pistons of the blowdown system valves. The inspections revealed other damage as well; for example, the hard chrome plating of the pilot cylinder had been damaged. However, the cracks and other damage had not affected the operation of the valves; they had operated correctly in periodic tests. TVO replaced the parts of the worst damaged valves during the annual maintenance. Based on the requirement by STUK, new spare parts were changed to the valves immediately when a sufficient number of new spares had been received from the manufacturer. STUK also required that TVO must inspect the similar valves at the Olkiluoto unit 1. The events are described in more detail in Annex 3.

Incorporation of proven technologies

It is stated in the Government Decree 733/2008 that proven or otherwise carefully examined high-quality technology shall be employed in the design, construction and operation of a nuclear power plant. The respective detailed requirements are provided in many YVL Guides.

Practical implementation of the new safety requirements and procedures to ensure adequate reliability of software based instrumentation and control systems in the modernisation projects of the operating power plants and in the design of the new nuclear power plant can be considered as one of the major challenges for the next years. This includes also the issues related to the highly integrated control rooms.

At the Loviisa NPP, I&C systems are currently being renewed. The project began in 2002 with basic conceptual design; implementation begun in 2004 with construction of new buildings to accommodate the new systems. Safety classified parts of the project are intended to be completed in 2017. The first phase was implemented at the Loviisa unit 1 during the 2008 annual maintenance, including the upgrade of I&C of reactor preventive and control rod position measurement and control functions, part of reactor in-core monitoring system and I&C of some non-safety auxiliary systems. Control room facilities are also renewed in phases with the system renewal.

At the Olkiluoto units 1 and 2, changes in I&C systems are made gradually. Software based instrumentation and control technology has already been implemented in the modernised systems. The safety systems, with the exception of new protective relays of electrical systems and neutron flux measurement system, are still of conventional technology.

STUK has reviewed the licensing documents related to the modernisation project of the Loviisa units 1 and 2 and the construction project of the Olkiluoto unit 3. The licensing path covers different layers of the design from architectural design of I&C (including Defence-in-Depth, separation and diversity assessments) to system level design and down to I&C platform and equipment suitability and licensing. During the licensing, STUK is reviewing that proven and qualified solutions are used.

The critical part of the licensing is how to demonstrate that the prevention of failure propagation and independency of different defence-in-depth levels are adequate. Proofing that platforms and equipment fulfils requirements can also be laborious work and must be carefully planned if the equipment is not originally designed for safety critical use. Cyber security threats must also be considered.

Design for reliable, stable and manageable operation

Government Decree 733/2008 requires that a nuclear power plant's control room shall contain equipment which provide information about the plant's operational state and any deviations from normal operation as well as systems which monitor the state of the plant's safety systems during operation and their functioning during operational transients and accidents. Furthermore, it requires that a nuclear power plant shall contain automatic systems that maintain the plant in a controlled state during transients and accidents long enough to provide the operators a sufficient time to consider and implement the correct actions. Special attention shall be paid to the avoidance, detection and repair of human errors. The possibility of human errors shall be taken into account both in the design of the nuclear power plant and in the planning of its operation so that the plant withstands well errors and deviations from planned operational actions.

Plant systems reliability and human factors are systematically considered in the probabilistic risk assessments (PRA). The analyses support the efforts to eliminate accidents or to mitigate their consequences. The probabilistic risk assessments are subject to the approval of STUK. Human factors in relation to the monitoring and control of Finnish nuclear power plants area described under Article 12. Significant effort has been devoted by the regulator and utilities involved in the assessment of modern control room concepts. Existing plants are moving towards so-called hybrid control rooms, where normal operation is based on digital controls and video screens, but safety backups are still implemented also using traditional mosaic displays, analogy indicators and switches.

In conclusion, Finnish regulations and practices are in compliance with Article 18.

Article 19. Operation

Each Contracting Party shall take the appropriate steps to ensure that:

i. ***the initial authorization to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning programme demonstrating that the installation, as constructed, is consistent with design and safety requirements;***

ii. ***operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation;***

iii. ***operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures;***

iv. ***procedures are established for responding to anticipated operational occurrences and to accidents;***

v. ***necessary engineering and technical support in all safety-related fields is available throughout the lifetime of a nuclear installation;***

vi. ***incidents significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body;***

vii. ***programmes to collect and analyse operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organizations and regulatory bodies;***

viii. ***the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal.***

Initial authorisation

According to Government Decree 733/2008 Section 22, in connection with the commissioning of a nuclear power plant, the licensee shall ensure that the systems, structures and components and the plant as a whole operate as designed. At the commissioning stage, the licensee shall ensure that an expedient organisation is in place for the future operation, alongside a sufficient number of qualified personnel and instructions suitable for the purpose.

Requirements for the commissioning programme are set forth in the Guide YVL 2.5. According to the Guide YVL 2.5, the purpose of the commissioning programme is to give evidence that the plant has been constructed and will function according to the design requirements. Through the programme possible deficiencies in design and construction can also be observed. The Operating Licence is needed before fuel loading into the reactor. Authorisation for fuel loading is given by STUK after its specific inspection where readiness of the power plant and operating organisation is checked. Furthermore, according to the Nuclear Energy Decree, the various steps of the commissioning, i.e., criticality, low power operation and power ascension, are subject to the approval of STUK.

The commissioning programme is described in the Preliminary and Final Safety Analysis Reports. The participation of the operating staff in the commissioning programme is a requirement of the Guide YVL 1.6. The commissioning programme is to be submitted to STUK for approval. The detailed commissioning test programmes and test reports for systems in safety classes 1, 2 and 3 are submitted separately to STUK for approval. STUK witnesses commissioning tests and assesses the test results before giving stepwise permits to proceed in the commissioning.

Olkiluoto unit 3 commissioning

Commissioning of the Olkiluoto unit 3 has started. On the turbine island, component and system commissioning tests are ongoing. On the nuclear island, commissioning is pending for the installation of operational I&C. Commissioning is divided into four actual commissioning phases followed by a 30-day demonstration run before provisional takeover of the plant. The first commissioning phase consists of component and system testing. This is followed by overall system tests – cold and hot functional tests – before core loading. For fuel loading, Operating licence and STUK's authorisation are required. Hot functional tests with core in subcritical state and first criticality can then follow. After first criticality, the commissioning proceeds with power tests at various power levels up to rated power. During power tests, transient tests are performed. The transient tests will cover at least reactor trip, turbine trip, loss of off-site power, house load operation, trip of one main circulation pump or main feedwater pump, as well as other minor operational transients.

All commissioning documentation is part of Commissioning Manual which includes also organisational procedures. Vendor has prepared an Overall Commissioning Programme as well as system level commissioning documentation and TVO and STUK have approved some of these documents. Preparations for plant level commissioning are still underway, e.g. preparation of detailed commissioning programs for the later phases of commissioning. STUK oversees the commissioning of safety classified systems and related result documentation is provided for STUK's review.

Before commissioning activities of a system can be started, the system goes through a commissioning inspection. This step certifies that components and system are properly installed and all activities preceding commissioning have been completed. This is also part of the pressure vessel requirements.

As the Government Decree 733/2008 states, one aim of the commissioning is to ensure that an expedient organisation is in place for the future operation. TVO's personnel (e.g. future operators and maintenance personnel) are participating in the commissioning activities in order to gain familiarity with the plant. The documentation for operation, like operating and testing procedures, is validated during the commissioning tests. The Operational Limits and Conditions are being prepared, and trained to TVO's personnel. TVO is also preparing itself for the future operation of the plant by planning refuelling outages, data systems, waste management, radiation protection and other issues related to the plant operation.

As part of the construction inspection programme inspections, STUK oversees TVO's actions for ensuring that the plant is commissioned appropriately.

Operational Limits and Conditions

Nuclear Energy Decree requires that the applicant for an Operating Licence must provide STUK with the Operational Limits and Conditions (OLCs). The OLCs shall at least define limits for the process parameters that affect the safety of the facility in various operating states, provide regulations on operating restrictions that result from component failures, and set forth requirements for the testing of components important to safety. Technical and administrative requirements and restrictions for ensuring the safe operation of a nuclear power plant shall be set forth in the plant's OLCs. Guide YVL 1.1 requires that the minimum staff availability in all operational states and the limits for the releases of radioactive substances are also defined in the document.

The OLCs have been established for each nuclear power plant unit and are updated based on operational experiences, tests, analyses and plant modifications. The OLCs are subject to the approval of STUK prior to the commissioning of a facility. Strict observance of the OLCs is verified by STUK's continuous oversight, reporting requirements and through a periodic inspection programme. The OLCs, operating procedures and other plant documentation need to be updated as part of plant modification process.

Fortum has established the OLCs for the Loviisa units 1 and 2, and STUK has reviewed and accepted them. The OLCs are continuously updated, and all the changes need to be approved by STUK. The limitations and conditions of the reactor and plant operation, the requirements for periodic tests and the essential administrative instructions are presented in the OLCs.

The OLCs for the Olkiluoto units 1 and 2 determine the limits of process parameters that affect the plant safety, for different operating modes, set the provisions for operating limits caused by component inoperability and set forth the requirements for the tests that are conducted regularly for components important to safety. Furthermore, the OLCs include the bases for the set provisions.

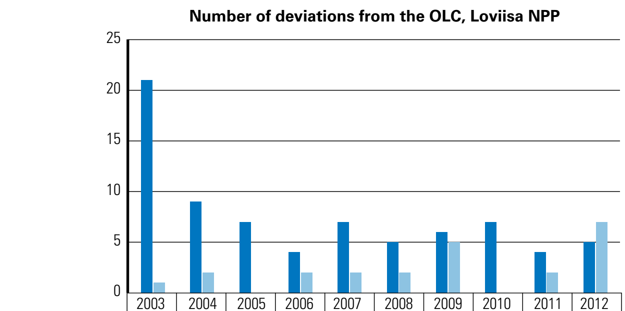
The OLCs for the Olkiluoto unit 3 are still under preparation. STUK received a preliminary version of the OLCs for information in 2011. STUK reviewed the general principles of the OLCs, but not yet the details. The OLCs for the Olkiluoto unit 3 will define safety limits for the plant, limiting conditions and surveillance requirements for plant systems, as well as administrative controls. The OLCs will also include bases and justification for the conditions.

Figure 18 presents the number of exemptions and deviations from the Operational Limits and Conditions. The main reason for the large number of exemptions at the Loviisa NPP in years 2002-2003 was the project to renew the radiation monitors that required exemptions in all operational states. Based on the results of the last 10 years, the Loviisa NPP applied for STUK's approval for exemptions from the OLCs on the average six times per year. Hence, the number of applications in 2010–2012 (total 18) was equal to the average. During the period 2010–2012, most of exemption applications concerned I&C renewal or overdue repairs of component failures. In 2010–2012, there were nine events at the Loviisa plant in which the Operational Limits and Conditions were violated. Seven of these events occurred in 2012, which is notably higher than the average two events per year. Hence, Loviisa NPP has assigned an investigation team to evaluate these events (see Annex 2).

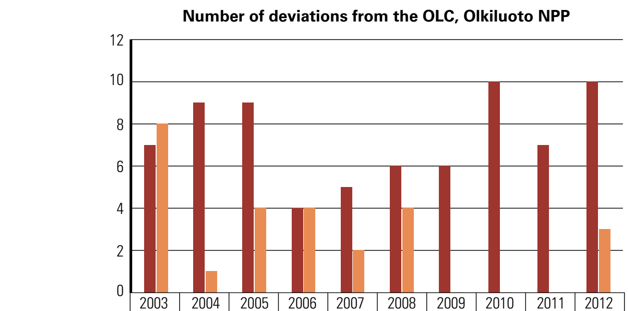
Based on the results of the last 10 years, the Olkiluoto nuclear power plant applied for STUK's approval for exemptions from the OLCs on the average seven times per year. Hence, the number of applications in 2010–2012 (total 27) was a little higher than the average. Most of the applications were related to modifications. In 2004 and 2005, the number of deviations was increased because of work and installations related to the modernisation of Olkiluoto units 1 and 2 and the construction of Olkiluoto unit 3. Similarly, major modifications were carried out during 2010 and 2011. In 2010–2012, there were three events at the Olkiluoto plant in which the Operational Limits and Conditions were violated.

Procedures for operation, maintenance, inspection and testing

Government Decree 733/2008 Section 23 requires that the control and supervision of a nuclear power plant shall utilise written instructions that correspond to the current structure and state of the plant. Written orders and related instructions shall be provided for the maintenance and repair of components. Section 26 requires that the plant shall have a condition monitoring and maintenance programme for ensuring the integrity and reliable operation of systems, structures and components. More detailed requirements are presented in the Guides YVL 1.1, YVL 1.8 and YVL 1.9. The procedures for operation, maintenance, inspection and testing have been established at both Finnish nuclear power plants. The procedures shall be approved by the licensee itself, and most of them are required to be submitted to STUK for information. STUK verifies by means of inspections and continuous oversight performed by resident inspectors that approved procedures are followed in the operation of the facility.



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Exemptions	21	9	7	4	7	5	6	7	4	5
Deviations	1	2	0	2	2	2	5	0	2	7



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Exemptions	7	9	9	4	5	6	6	10	7	10
Deviations	8	1	4	4	2	4	0	0	0	3

Figure 18. Number of exemptions and deviations from the Operational Limits and Conditions in the Loviisa and Olkiluoto NPPs.

Loviisa NPP

A structured system of procedures exists at the Loviisa plant. The procedures cover work processes and functions important to safety and availability. The system of procedures is a part of the quality system of the plant. Strict requirements have been set in the Quality Assurance Manual for the coverage, responsibilities, updating and observance of the procedures. According to the Manual the evaluation of the system of procedures is included in the annual review of the coverage and effectiveness of the quality assurance programme. The state of the plant procedures is acceptable at the Loviisa plant. Procedures are maintained, evaluated and developed systematically and in a controlled way. The most important procedure types are:

- Administrative procedures including Organisational Manual and Administrative Rules,
- Operating procedures and testing procedures,
- Procedures for emergency and transient situations,
- Fuel handling procedures,
- Radiation protection procedures, and
- Maintenance procedures.

Loviisa plant has upgraded computer systems used in managing documentation and permit-to-work system. By means of a work order system it is ensured that the plant operators are aware of the state and configuration of the unit. Fortum has developed, and develops further, its work order system based on accumulated operating experiences. In addition to the work order system the operators in the main control room of the units follow failures, repairs and preventive maintenance of the components referred to in the Operating Limits and Conditions. A shift supervisor gives a permit to start a specific work when he has evaluated the work plans specified in the work order system, taking into account the operability requirements of the systems and components set in the Operational Limits and Conditions.

The maintenance activities of the Loviisa units 1 and 2 cover preventive, predictive and repairing maintenance as well as implementation of modification works, spare part maintenance and activities during outages. The scheduling of the modification planning for the next maintenance outage is fixed in order to get enough time for preparations. Minor modifications are concentrated to every second annual maintenance outage and major works are carried out every fourth year. This is accomplished by starting from a long term investment planning which converts into a long term modification plan.

The functioning of the systems and components is ensured with regular tests. The systems and components to be tested and the time periods of the tests are presented in the Operational Limits and Conditions. At least the respective periodic tests are required after the modification and repairing works and maintenance activities requiring dismounting. The performance test programme to be carried out after an essential modification is required to be approved by STUK in advance. In addition, inspections regarding to the functioning and condition of components are carried out when necessary based on operating experiences from other plants and on the advancement of technical knowledge. Other operating organisations of VVER-type reactors have been essential sources of operating experiences in this respect.

STUK oversees monitoring and maintenance activities as well as repair and modification works with regular inspections and continuous oversight performed by resident inspectors. During inspections it is aimed to make sure that the utility has adequate resources, such as a competent staff, instructions, a spare part and material storage as well as tools for the sufficiently effective implementation of the monitoring and maintenance activities. Special subjects are the condition monitoring programmes for the carbon steel piping and their results. Special attention has also been paid to the reliable activities of subcontractors as well as to the technical competence of external human resources. Both the utility and STUK oversee companies that perform inspection activities and the technical competence of organisations that carry out various duties.

Olkiluoto NPP

The measures that are followed in the operation and maintenance of the Olkiluoto units 1 and 2 are based on written procedures. The administrative and technical procedures needed in the operation of the Olkiluoto units 1 and 2 have been gathered into the Operating Manual. The Operating Manual contains also necessary transient and emergency procedures for unusual conditions. The most important procedures have been reviewed by STUK. Updating and comprehensiveness of the procedures are among the inspection issues included in the STUK's periodical inspection programme. TVO updates the procedures when necessary and checks systematically that the procedures are up-to-date in four-year-intervals.

The Work Request System ensures that the operators of the plant are aware of the plant state. TVO has developed its Work Request System and will continue to do so, on the basis of operational experience. In the main control room of the plant units, the operators follow, in addition to the Work Request System, the failures, repairs and preventive maintenance of the components specified in the Operational Limits and Conditions. The Shift Supervisor grants the permission to begin a single work after inspecting the work plans and taking into account the operability requirements for the systems and components set forth in the Operational Limits and Conditions.

The maintenance activities of the Olkiluoto units 1 and 2 cover preventive and corrective maintenance as well as the design and execution of modifications, spare part service, outage actions and the related quality control. The Maintenance Department plans and implements the annual maintenance outages together with the Operation Department and Technical Support Department. Special attention has been paid to the reliable work of the subcontractors and to the technical competence of the external work force. The technical expertise of testing laboratories and contractors is controlled both by the power company and STUK.

The systems and the components that will be tested as well as the test dates are presented in the Operational Limits and Conditions. Periodical testing that corresponds at least to the aforementioned, is required after maintenance measures that require modifications, repairing or disassembling. STUK's approval is required in advance for a functional test programme that is conducted after a significant modification. Inspections that concern the operability and condition of components are also conducted, if necessary, on the basis of operational experience received from elsewhere and development of technical knowledge. The most significant sources of operational experience, in this sense, have been the Swedish BWR plants.

STUK oversees the condition monitoring and maintenance as well as the modification and repair work by regularly repeated inspections. The inspections aim to ensure that the power company has adequate resources such as a competent personnel, instructions, a spare part and material storage as well as the tools for adequately efficient implementation of condition monitoring and maintenance actions. Special items are the condition monitoring programmes of the carbon steel pipelines and their results.

Procedures for responding to operational occurrences and accidents

Government Decree 733/2008 Section 23 gives basic requirements for operating and emergency procedures.

At both Finnish nuclear power plants, procedures for anticipated operational occurrences and accidents are in use. To the extent found necessary, the procedures have been verified during operator training at the plant simulators. At both nuclear power plants there are also advanced safety panels for monitoring critical safety functions. STUK has independently evaluated the appropriateness and comprehensiveness of the procedures for anticipated operational occurrences and accidents.

Olkiluoto units 1 and 2 have event-oriented operating procedures for events within the scope of the design. To cope with emergency conditions beyond design, including severe accidents, a set of symptom-based emergency operating procedures (EOPs) is available. The focus of the severe accident EOPs is on ensuring the containment integrity. The symptom oriented accident management procedures (included in EOPs) apply to shutdown states, as well, although prevention of core damage is essential especially in situations with open containment. As a lesson learnt from the TEPCO Fukushima Dai-ichi accident, the licensee will improve EOPs to support heat removal from spent fuel pools by pool boiling and supplying make-up water to the pools.

At the Loviisa NPP, immediate SAM measures are carried out within the EOPs. After carrying out immediate actions successfully, the operators concentrate on monitoring the SAM safety functions with SAM procedures. The SAM procedures focus on monitoring the leak tightness of the containment barrier, and on the long-term issues. As a lesson learnt from the TEPCO Fukushima Dai-ichi accident, the licensee will improve EOPs and SAM procedures to support heat removal from spent fuel pools by pool boiling and supplying additional water to the pools. New EOPs for shutdown states, which cover the immediate recovery of SAM systems, have been developed in 2012 and are going through implementation.

Engineering and technical support

Government Decree 733/2008 Section 30 requires that the organisation shall have access to professional expertise and technical knowledge required for the safe operation of the plant, the maintenance of equipment important to safety, and the management of accidents. The requirements in the Guide YVL 1.7 also cover technical support. Competence of the engineering and technical support is supervised by the licensee. In addition, STUK carries out inspections and audits by which also the competence of the support staff is evaluated.

Teollisuuden Voima Oyj is an independent organisation and it has longstanding expertise in nuclear operations. TVO uses external expertise regularly in various design and modification activities when needed.

Fortum has under corporate structure own unit for technical support that provides support to the Loviisa NPP among other projects. There are also on-site experts at the Loviisa NPP for various engineering and technical support functions.

Reporting of incidents significant to safety

Guide YVL 1.5 provides in detail the reporting requirements on incidents. The Guide provides a number of examples of operational disturbances and events, which have to be reported to STUK. It also defines requirements for the contents of the reports and the administrative procedures for reporting, including time limits for submitting of various reports. STUK publishes information concerning significant events (INES ≥ 1) as press releases. Information from other events is published on STUK's website. STUK describes the events also in its quarterly and yearly reports on nuclear safety that are also available to the general public through internet or paper reports in Finnish. STUK's Annual Report on nuclear safety (see Reference 1) summarises events from the whole year and is available to the general public through internet or paper reports both in Finnish and in English.

Figures 19 and 20 present the total number of reported events and INES classified (≥ 1) events at the Finnish nuclear power plants.

INES-classified events

At the Loviisa NPP, three events in 2010, two events in 2011 and twelve events in 2012 were classified on the International Nuclear Event Scale (INES). Five of these events were rated at level 1, others being of level 0:

- Radioactive resin found in ventilation system in 2010 (IRS report 8088)
- Spread of contamination in conjunction with transfers of spent fuel in 2010
- Deficiencies observed in the testing of radiation monitors at Loviisa unit 2 in 2012
- Excess fire load in the main coolant pump room at Loviisa unit 1 in 2012
- Incorrect settings in electrical motor protection relays at Loviisa unit 2 in 2012.

These incidents are described in more detail in Annex 2.

STUK discussed the increased number of incidents with the licensee during the fall 2012. The licensee has started to assess the reasons behind the incidents. The assessment will be finalised during 2013 after which the corrective actions will be implemented and followed at the Loviisa NPP.

At the Olkiluoto NPP, five events in 2010, three events in 2011 and six events in 2012 were classified on the International Nuclear and Radiological Event Scale (INES). Five of these events were rated at level 1, others being of level 0:

- Blowdown system failure at Olkiluoto 1 and repair outage at Olkiluoto unit 2 in 2010
- Use of a wrong fresh fuel delivery lot in fuel transfer planning at Olkiluoto unit 1 in 2010
- Defects in the internal parts of the valves of the system required for overpressure protection of and residual heat removal from the primary circuit at Olkiluoto units 1 and 2 in 2011
- Deficiencies in the functioning of one outer isolation valve of the reactor main steam system at the Olkiluoto unit 1 in 2012
- Deficiencies in the functioning of one outer isolation valve of the reactor main steam system at the Olkiluoto unit 2 in 2012.

These incidents are described in more detail in Annex 3.

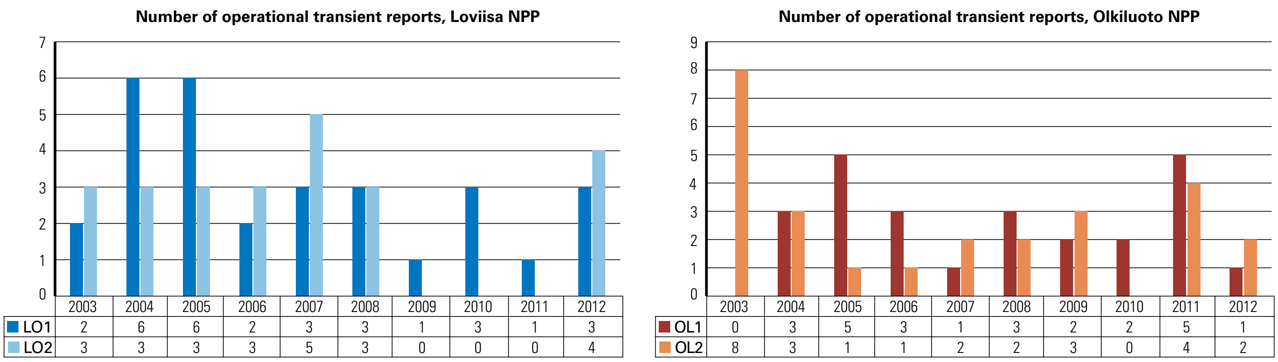
Operational experience feedback

According to the Section 24 of the Government Decree 733/2008, nuclear power plant operational experience feedback (OEF) shall be collected and safety research results monitored, and both assessed for the purpose of enhancing safety. Safety-significant operational events shall be investigated for the purpose of identifying the root causes as well as defining and implementing the corrective measures. Improvements in technical safety, resulting from safety research, shall be taken into account to the extent justified on the basis of the principles laid down in Section 7 a of the Nuclear Energy Act.

STUK requires that all incidents at nuclear facilities and activities are analyzed and reported to STUK according to the reporting criteria and the reports are assessed by STUK. Based on the analysis, corrective actions are planned and implemented by the operators. Regulatory requirements are given in STUK's Regulatory Guides YVL 1.5 (Reporting NPP Operation to STUK), YVL 1.11 (Nuclear power plant operational experience feedback), and YVL 1.9 (QA during operation of NPPs). The Guide YVL 1.11 provides detailed requirements and administrative procedures for the systematic evaluation of operating experiences, and for the planning and implementation of corrective actions. Operational events at other nuclear power plants and foreign operational occurrences have to be systematically assessed as well, from their applicability and their significance for the nuclear facilities in Finland.

The licensees have developed the required procedures for analysing operating experiences and root causes for events. The licensees are using WANO and IRS reports as basic material to be screened for external OEF and they have OEF groups for screening, analysing of OE entry into processing and following the corrective actions. The licensees have also their internal audit programme and OEF is one topic in these programmes.

STUK verifies by means of inspections and by reviewing licensee's event reports that the activities of the licensees as regards incident evaluation



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
LO1	2	6	6	2	3	3	1	3	1	3
LO2	3	3	3	3	5	3	0	0	0	4

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
OL1	0	3	5	3	1	3	2	2	5	1
OL2	8	3	1	1	2	2	3	0	4	2

Figure 19. Annual total number of event reports (operational transient reports) submitted by Loviisa and Olkiluoto nuclear power plants.

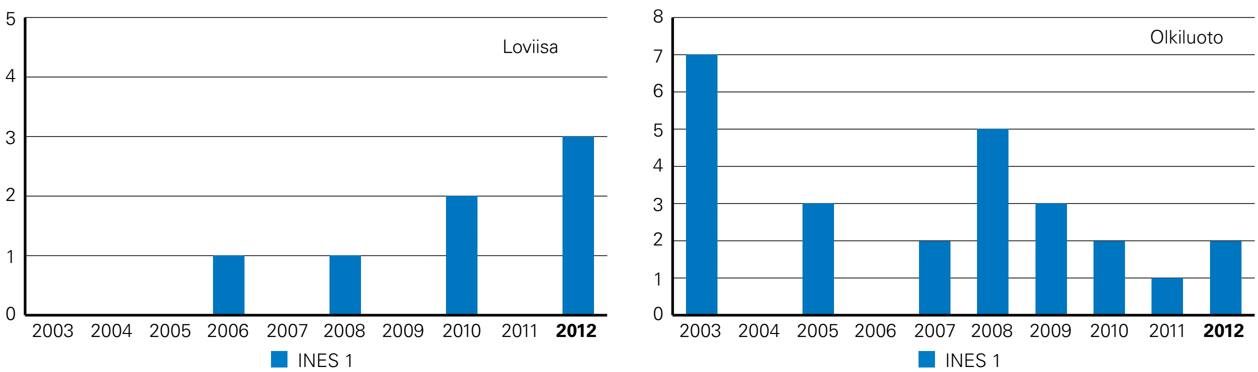


Figure 20. Annual total number of events at INES Level 1 and above at the Finnish nuclear power plants.

are effective. In STUK's periodic inspection programme there are two inspections related to OEF, namely C1 Operations and B4 Operational experience feedback. When necessary, a special investigation team is appointed by STUK to evaluate a certain incident or group of incidents. The evaluation of foreign operational occurrences and incidents is based on the reports of the IRS Reporting System (IAEA/NEA) and on the reports of other national regulatory bodies.

For review and assessment of OE information abroad STUK has an internal IRS Group with a coordinator and sixteen technical experts covering all expertise areas of Nuclear Reactor Regulation and Nuclear Waste and Materials Regulation departments. The group meets monthly and based on the expert assessment in STUK's own IRS database the group members make together an judgement whether there is a need for regulatory or licensee measures on the basis of lessons learned assigning the IRS report into categories with respect to actions to be taken (categories 1 to 3), or not needed (category 0). In the case that an expert to whom the report is assigned for review cannot immediately say if an event requires actions at Finnish plants the report is classified into category 1 (particular issues need clarification) and clarifications of the applicability are initiated with the plant contact persons. After clarifications the event is reclassified. Classification into category 2 (Lessons learned need to be taken into account in certain activities) means that concrete actions are not required but the report contains information which should be considered in inspections by STUK. If actions are required at the Finnish nuclear power plants in operation or under construction the report is classified into category 3 (Actions required). Examples of such events are unexpected failures of components being installed also into the systems or equipment of Finnish plants, or events revealing deficiencies in procedures of the plants. Category 4 (Good practise in Finland) means that actions to prevent an event have already taken or an occurrence of such an event has taken into account in the original design of the plant, or there are procedures and regulatory requirements in place (YVL Guides) preventing a similar event.

Figure 21 shows the distribution of IRS reports into different categories in STUK's review and assessment from 2009 to 2012. Altogether 212 IRS-reports were assessed during that period and most of them (73%), 155 reports, fell into category 0 requiring no actions. 10 % (22 IRS reports) of reviewed reports were classified into category 2 and applicability of lessons learned were checked in the inspections of STUK's periodic inspection programme. In the case of 14 reported events (7% of all reviewed reports) caused actions at the Finnish nuclear power plants. Nearly in the equal number of cases (13 events) it was realised that similar kind of events were prevented by technical or administrative arrangements.

One example of foreign IRS reports which caused actions at the Finnish plants in 2012 was 'Reactor Pressure Vessel Flaw Indications at Doel 3, Belgium' (IRS report number 8244). STUK asked clarifications by a mandatory request (letter on 19th March 2012), with deadline end of May 2013 for TVO and end of August 2013 for Fortum. Number of IRS reported events classified in category 2 (Lessons learned need to be taken account in certain activities) is increasing: 14 events in 2012.

A fire that took place during a containment leak test carried out at the 2011 annual outage of Ringhals unit 2, as well as the obstructions in the containment spray systems of Ringhals units 2 and 4 observed during the cleaning and inspections carried out after the fire, were identified as issues relevant to the Finnish nuclear power plants eventhough not reported to IRS. STUK received the first information on the fire in the meeting with the Swedish Radiation and Nuclear Safety Authority (SSM) in mid of June 2011. STUK took the event and licensees' actions as one item in its periodic inspection program inspection on "Utilization of International OE". The Finnish nuclear power plants have decided

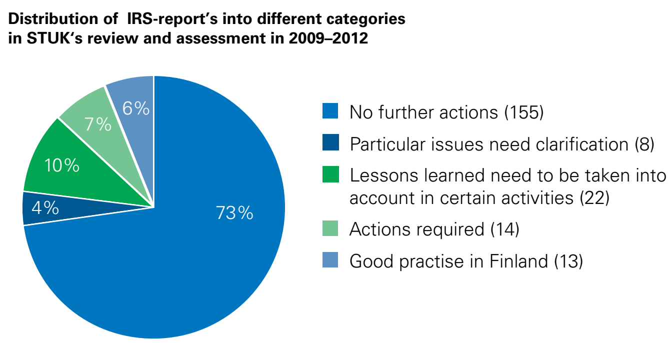


Figure 21. Distribution of IRS-reports into different categories in STUK's review and assessment in 2009–2012.

on several corrective actions based on this event considering containment leaktightness test procedures (control of fire load in the containment), movable and pressure-resistant fire detectors in the containment, inspection of pipes with x-ray or endoscope procedures, and re-evaluation of periodic testing methods in general (scope, criteria, conditions).

Reports for the IRS System on safety-significant occurrences at the Finnish nuclear power plants are written by STUK. STUK's international OEF group oversees the utilisation of international OE by licensees.

STUK has also participated in co-operation between international organisations such as the IAEA, the OECD/NEA and the EU, which exchange information on safety issues and operating events. Other forums that STUK uses to obtain information are WENRA, the VVER Forum and the NERS Forum as well as some bilateral agreements. A special exchange of information between Rostechnadzor and STUK on the operation of the Kola and Leningrad nuclear power plants and of Finnish nuclear power plants is also ongoing activity. The similar information exchange is arranged between SSM and STUK on the operation of the Swedish and Finnish NPPs.

At the Loviisa NPP, VVER reactor operating experience is collected, screened and evaluated by a dedicated operating experience feedback group composed of engineers from the plant operation organisation and from Technical Support. The main information to be handled comes from WANO (World Association of Nuclear Operators) Moscow Centre which links all the VVER reactor operators. Additional reports are received from the IAEA, OECD/NEA and NRC (U.S. Nuclear Regulatory Commission). The activities of the operating experience feedback group are not limited only to VVER reactors. The plant managers of VVER-440 reactors have periodic meetings. The plant operation problems, modernisation, back-fitting, plant life management and safety questions are handled and experiences are exchanged in these meetings and in further individual contacts.

TVO has also an operating experience feedback group. This onsite group gives recommendations to the line organisation that makes decisions on eventual corrective actions. The industry operating experience from similar reactor types is followed by several means. The main sources of information are ERFATOM (the owners group for Nordic BWR operators), KSU (Swedish nuclear training centre), WANO and the Swedish Forsmark NPP. Information is also coming directly from several sources (IAEA and OECD/NEA, IRS), Loviisa power plant (e.g. operating experience meetings and reports), vendors (Westinghouse Atom, Alstom Power Sweden AB), component manufacturers, the WANO Network, BWROG (BWR Owners Group) and BWR Forum (FANP).

IRS reports are also received directly by the licensees via WBIRS and evaluated by them. Almost all plant modifications, as improvements in systems, structures, and components, which have emerged from foreign experience originate from plants that are of the same type as the Finnish plants.

Management of spent fuel and radioactive waste on the site

Management of the operational low and intermediate nuclear level wastes and the final disposal of these wastes takes place at the NPP sites. Final disposal facilities for low and intermediate level waste are in operation at Loviisa and Olkiluoto sites. Since the disposal facilities are operated by the nuclear power plant operators, the technical feasibility and economic motivation to minimise the generation of radioactive waste are evident.

The detailed requirement for radioactive waste minimisation is included in the Guide YVL 8.3. It calls for a limitation of waste volumes in particular from repair and maintenance works, and segregation of wastes on the basis of activity. Clearance of wastes from regulatory control, prescribed in the Nuclear Energy Decree and in the Guide YVL 8.2, aims at limiting the volumes of waste to be stored and disposed of. The Guide YVL 6.2 provides for prevention of fuel failures, which also contributes to the limitation of activity accumulation in waste from reactor water cleanup systems.

The Guide YVL 8.3 also requires that besides the short-term radiation protection objectives, also the long-term properties of waste packages with respect to final disposal shall be taken into account in the conditioning and storage of waste. The Guide includes also more specific requirements for the conditioning and interim storage of wastes. The Guide YVL 8.1 calls for a waste type description, to be approved by STUK, for each category of reactor waste to be disposed of. In the description of waste type, the most important characteristics of waste with respect to the safety of disposal are defined.

Low and intermediate level waste

In 2007–2009 the policy to minimise the waste production at the Olkiluoto NPP has included the high quality requirements for the fuel, careful planning of the maintenance work and decontamination. The segregation and monitoring of the operational wastes have been effective, enabling the clearance from the regulatory control of waste below the clearance limits. In 2010, TVO transported moisture separator reheaters removed from Olkiluoto units 1 and 2 during refurbishment in 2005 and 2006 to Studsvik Nuclear AB for treatment.

At the Loviisa NPP, the design, construction and commissioning activities of the liquid waste solidification plant has continued. The plant is designed for conditioning and disposal of liquid low and intermediate level waste. Based on the results of the commissioning tests of the plant some system modifications were designed and implemented during 2011–2012. The commissioning continues in 2013 with operating personnel training activities and updating the plant design documentation and procedures. The tests of modified systems will be finalised in 2013. The target date for the start of the solidification plant operation is spring 2014 after the regulatory commissioning inspections and approval. The management of solid low and intermediate level waste has been developed by building new facilities for the treatment, activity monitoring and interim storage of waste. New facilities were commissioned in 2010.

At the Loviisa NPP site, the repository for the low and intermediate level waste is located at the depth of 110 meters in granite bedrock. It consists of three tunnels for solid low level waste and a cavern for immobilised intermediate level waste. The third tunnel was built during 2010–2012 for the sorting and temporary storing of a low level maintenance waste. Construction was completed in 2012. The commissioning of the third tunnel will be done in 2013, after the commissioning inspection made by STUK.

The repository for the low and intermediate level waste at the Olkiluoto NPP site consists of two silos at the depth of 60 to 95 meters in tonalite bedrock, one for solid low level waste and the other for bituminised intermediate level waste.

The original plan presented in the construction licence application for unit Olkiluoto 3 was to dispose all the low and intermediate level waste in the existing repository in Olkiluoto. However, the waste packages of the conditioned intermediate level waste have different dimensions compared to the waste packages from operating units in Olkiluoto. Therefore TVO will in the operating licence application propose that the conditioned intermediate level waste is first stored on-site in the existing waste storage facility, and later disposed of in the extension of the repository. The solid low level waste from Olkiluoto unit 3 can be disposed of in the existing repository.

At the end of 2012, 5965 cubic meters of low and intermediate level operating waste has accumulated at the Olkiluoto NPP and 3545 cubic meters at the Loviisa NPP. About 94 % of Olkiluoto waste and 52 % of Loviisa solid waste has been disposed of in the on-site repositories. Low and intermediate level waste not yet disposed of is stored inside the plants.

Decommissioning

The Guide YVL 1.0 requires that provision for a nuclear power plant's decommissioning shall be made already during the plant's design phase. One criterion when deciding the plant's materials and structural solutions shall be that volumes of decommissioned waste are to be limited. The Guide YVL 7.18 calls for selection of such construction materials that limit the degree of activation and spread of contamination and makes decontamination of surfaces feasible.

According to the Nuclear Energy Decree the licence applications must include the plans for decommissioning. The utilities are obliged to keep the decommissioning plans up-to-date and submit them to the Ministry of Employment ant the Economy every six years, last in 2008. STUK reviewed the plans and submitted its opinion to the Ministry in 2009. A new decommissioning plan for Loviisa NPP was submitted in the end of 2012.

The assumption in the decommissioning plan of the Loviisa NPP is that both units will be shut down after 50 years operation in 2027 and 2030. The dismantling starts immediately and lasts until 2035. Olkiluoto units 1 and 2 are planned to be shut down after 60 years operation in 2038 and 2040. The dismantling starts after 30 years delay. The final planning and building of disposal facilities will start already during the safe storage period and all together the decommissioning project will last about 15 years. The reason for delayed dismantling is the radiation protection of the personnel. Olkiluoto unit 3 is planned to shut down after 60 years operation in 2070's. The dismantling will start after the dismantling of the older units has been completed.

According to STUK's opinion expressed to the Ministry of Employment and the Economy, the decommissioning plans at this phase of the NPP operation are reasonably comprehensive and detailed. The decommissioning can be carried out as planned, and the plans are sufficient to be used in the cost estimations.

Spent fuel

Spent fuel from the Loviisa NPP was transported back to Russia until 1996. Amendment of the Nuclear Energy Act issued in 1994 requires that spent fuel generated in Finland has to be treated, stored and disposed of in Finland. Accordingly, spent fuel shipments to Russia were terminated, and the necessary extension of the wet type spent fuel storage facility was commissioned in 2001. The installation of the dense racks into the storage facility started in 2007 and continues until 2018. The capacity of the storage facility will be adequate for the total amount of the spent fuel 1100 tU allowed in the operating licence issued in 2007.

After the stress tests due to the TEPCO Fukushima Dai-ichi accident some safety improvements were identified for the Loviisa NPP spent fuel interim storages. The improvements concerned the availability of external cooling water and connections to feed the cooling water from external sources. The water level and temperature monitoring of the fuel pools were planned to be modified to function in all conditions. Also exhaust routes for the vapour were considered to be modified.

At the Olkiluoto NPP, the wet type spent fuel interim storage facility was commissioned in 1987. The current capacity about 1200 tU is adequate until 2014. TVO has started the construction works for enlarging the Olkiluoto interim storage in summer 2010. The extension includes construction of three new pools and it will be done according the updated safety requirements (Government decision 733/2008). Extension has been included in Olkiluoto NPP units 1 and 2 operating licence and has been handled as plant modification. STUK reviewed TVO's application and gave approval for construction during first half of the 2010. Extension has been planned to be ready in the end of 2013.

After the stress tests some safety improvements for the Olkiluoto NPP spent fuel interim storage were identified. The possibility to feed the cooling water from external source and to monitor spent fuel pool water level and temperature in all cases were the most important safety features to be implemented. The connection for feeding the cooling water from external source was already included in the design of enlargement of the Olkiluoto spent fuel interim storage before Fukushima accident.

At the end of 2012, the spent fuel accumulation at the Olkiluoto NPP was 1388 tons of uranium and at the Loviisa NPP 542 tons of uranium.

The power companies Fortum and TVO established in 1995 the joint company Posiva to take care of spent fuel final disposal. Research, development and planning work for spent fuel disposal is in progress and the disposal facility is envisaged to be operational in about 2022. The Decision-in-Principle on the spent fuel disposal facility in deep crystalline bedrock was made by the Government in 2000 and ratified by the Parliament in 2001. It covers the final disposal of the spent fuel from the Olkiluoto units 1 and 2 and Loviisa units 1 and 2. Two separate Decision-in-Principles for the disposal of the spent fuel from the Olkiluoto units 3 and 4 were made in 2002 and 2010, consequently. The spent fuel disposal facility will be constructed in the vicinity of Olkiluoto NPP site. To confirm the suitability of the site, construction of the underground rock characterization facility ONKALO was started in 2004. The excavation of ONKALO was almost completed during 2012, but some extensions will be excavated during 2013-2014.

Posiva submitted a construction licence application for an encapsulation and final disposal facility for spent nuclear fuel to the Ministry of Employment and Economy in the end of 2012. The detailed technical documentation of the application is planned to be reviewed by STUK during 2013–2014 and based on the review STUK will give a safety assessment for the Ministry of Employment and Economy during 2014. The construction licence application includes both the encapsulation plant and the underground disposal facility. The capacity of the repository in the application is 9000 tU and it covers the spent nuclear fuel from the NPP units in operation (Olkiluoto 1 & 2, Loviisa 1 & 2), under construction (Olkiluoto 3) as well as a new reactor unit (Olkiluoto 4) for which the Decision-in-Principle was ratified by the Parliament in July 2010.

Fennovoima presented in their Decision-in-Principle application similar general principles as Posiva for the spent nuclear fuel disposal. The positive Decision-in-Principle for a new reactor unit ratified by the Parliament in 2010 included a requirement for Fennovoima either to negotiate a contract with the other Finnish NPP operators under waste management obligation to use the same repository, or to start an environmental impact assessment process for another disposal facility for the spent nuclear fuel from Hanhikivi 1 unit. Based on the Decision-in-Principle, Fennovoima has six years to fulfill this requirement. During 2012 the Ministry of Employment and Economy formed a working group to start the discussions on the waste management co-operation options. Participants of the working group were from Ministry of Employment and Economy, Fennovoima, Posiva, Fortum and TVO. The working group produced a report which compared expanding the repository in Olkiluoto for Fennovoima's spent fuel and building a second disposal facility for spent nuclear fuel, and recommended that companies continue negotiations about cooperation in waste management to implement a optimal solution. Fennovoima has also started planning the environmental impact assessment process for a separate disposal facility.

A new separate favourable Government resolution (DiP) is anyway required for either the possible expansion of the Olkiluoto spent fuel disposal facility for Fennovoima´s spent fuel disposal or alternatively for a separate spent fuel disposal facility. For both options before the DiP a recommendation on constructing the facility by the municipality intended as the site, and an assessment by STUK on the safety of implementation are required. Furthermore, Parliament may either adopt or repeal the resolution. After that, a construction licence and operating licence are needed for the chosen option.

Safety regulation for spent fuel disposal is included in the Government Decree on the safety of disposal of nuclear waste 736/2008 and STUK's Guides YVL 8.4 and YVL 8.5.

A detailed description of spent fuel and radioactive waste management and related regulation is included in the 4th Finnish National Report as referred to in Article 32 of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (STUK-B 138, October 2011).

In conclusion, Finnish regulations and practices are in compliance with Article 19.

ANNEX 1 List of main regulations

Legislation (as of 15th April 2013)

1. Nuclear Energy Act (990/1987)
2. Nuclear Energy Decree (161/1988)
3. Act on Third Party Liability (484/1972)
4. Decree on Third Party Liability (486/1972)
5. Radiation Act (592/1991)
6. Radiation Decree (1512/1991)
7. Government Decree on the Safety of Nuclear Power Plants (733/2008)
8. Government Decree on the Security in the Use of Nuclear Energy (734/2008)
9. Government Decree on Emergency Response Arrangements at Nuclear Power Plants (735/2008)
10. Government Decree on the Safety of Disposal of Nuclear Waste (736/2008)
11. Act on the Finnish Centre for Radiation and Nuclear Safety (1069/1983)
12. Decree on the Finnish Centre for Radiation and Nuclear Safety (618/1997)
13. Decree on Advisory Committee on Nuclear Safety (164/1988)

YVL Guides

General guides

Guide YVL 1.0 Safety criteria for design of nuclear power plants, 12.1.1996

Guide YVL 1.1 Regulatory control of safety at nuclear facilities, 10.2.2006

Guide YVL 1.2 Documents pertaining to safety control of nuclear facilities, 11.9.1995

Guide YVL 1.3 Mechanical components and structures of nuclear facilities. Approval of testing and inspection organizations, 17.3.2003

Guide YVL 1.4 Management systems for nuclear facilities, 9.1.2008

Guide YVL 1.5 Reporting nuclear facility operation to the Radiation and Nuclear Safety Authority, 8.9.2003

Guide YVL 1.6 Nuclear power plant operator competence, 5.10.2006

Guide YVL 1.7 Functions important to nuclear power plant safety, and training and qualification of personnel, 28.12.1992

Guide YVL 1.8 Repairs, modifications and preventive maintenance at nuclear facilities, 2.10.1986

Guide YVL 1.9 Quality assurance during operation of nuclear power plants, 13.11.1991

Guide YVL 1.10 Requirements for siting a nuclear power plant, 11.7.2000

Guide YVL 1.11 Nuclear power plant operating experience feedback, 22.12.1994

Guide YVL 1.12 INES classification of events at nuclear facilities, 16.1.2002

Guide YVL 1.13 Nuclear power plant outages, 9.1.1995

Guide YVL 1.14 Mechanical equipment and structures of nuclear facilities. Control of manufacturing, 4.10.1999

Guide YVL 1.15 Mechanical components and structures in nuclear installations. Construction inspection, 28.4.2008

Guide YVL 1.16 Regulatory control of nuclear liability insurances, 22.3.2000

Systems

Guide YVL 2.0 Systems design for nuclear power plants, 1.7.2002

Guide YVL 2.1 Nuclear power plant systems, structures and components and their safety classification, 26.6.2000

Guide YVL 2.2 Transient and accident analyses for justification of technical solutions at nuclear power plants, 26.8.2003

Guide YVL 2.4 Primary and secondary circuit pressure control at a nuclear power plant, 24.3.2006

Guide YVL 2.5 The commissioning of a nuclear power plant, 29.9.2003

Guide YVL 2.6 Seismic events and nuclear power plants, 19.12.2001

Guide YVL 2.7 Ensuring a nuclear power plant's safety functions in provision for failures, 20.5.1996

Guide YVL 2.8 Probabilistic safety analysis in safety management of nuclear power plants, 28.5.2003

Pressure equipment

Guide YVL 3.0 Pressure equipment of nuclear facilities, 9.4.2002

Guide YVL 3.1 Nuclear facility pressure vessels, 1.7.2005

Guide YVL 3.3 Nuclear facility piping, 26.6.2006

Guide YVL 3.4 Approval of the manufacturer of nuclear pressure equipment, 14.1.2004

Guide YVL 3.5 Ensuring the firmness of pressure vessels of a NPP, 5.4.2002

Guide YVL 3.7 Pressure equipment of nuclear facilities. Commissioning inspection, 26.9.2008

Guide YVL 3.8 Nuclear power plant pressure equipment. In-service inspection with non-destructive testing methods, 22.9.2003

Guide YVL 3.9 Nuclear power plant pressure equipment. Construction and welding filler materials, 5.11.2004

Buildings and structures

Guide YVL 4.1 Concrete structures for nuclear facilities, 22.5.1992

Guide YVL 4.2 Steel structures for nuclear facilities, 19.12.2001

Guide YVL 4.3 Fire protection at nuclear facilities, 1.11.1999

Other structures and components

Guide YVL 5.1 Nuclear power plant diesel generators and their auxiliary systems, 23.1.1997

Guide YVL 5.2 Electrical power systems and components at nuclear facilities, 24.6.2004

Guide YVL 5.3 Nuclear facility valve units, 28.4.2008

Guide YVL 5.5 Instrumentation systems and components at nuclear facilities, 13.9.2002

Guide YVL 5.6 Air-conditioning and ventilation systems and components of nuclear facilities, 25.11.2004

Guide YVL 5.7 Nuclear facility pump units, 28.4.2008

Guide YVL 5.8 Hoisting and transfer functions at nuclear facilities, 26.9.2008

Nuclear materials

Guide YVL 6.1 Control of nuclear fuel and other nuclear materials required in the operation of nuclear power plants, 19.6.1991

Guide YVL 6.2 Design bases and general design criteria for nuclear fuel, 1.11.1999

Guide YVL 6.3 Regulatory control of nuclear fuel and control rods, 28.5.2003

Guide YVL 6.4 Transport packages and packagings for radioactive material, 4.4.2005

Guide YVL 6.5 Transport of nuclear material and nuclear waste, 4.4.2005

Guide YVL 6.7 Quality management of nuclear fuel, 17.3.2003

Guide YVL 6.8 Storage and handling of nuclear fuel, 27.10.2003

Guide YVL 6.9 The national system of accounting for and control of nuclear material, 23.9.1999

Guide YVL 6.10 Reports to be submitted on nuclear materials, 23.9.1999

Radiation protection

Guide YVL 7.1 Limitation of public exposure in the environment of and limitation of radioactive releases from a nuclear power plant, 22.3.2006

Guide YVL 7.2 Assessment of radiation doses to the population in the environment of a nuclear power plant, 23.1.1997

Guide YVL 7.3 Calculation of the dispersion of radioactive releases from a nuclear power plant, 23.1.1997

Guide YVL 7.4 Nuclear power plant emergency preparedness, 9.1.2002

Guide YVL 7.5 Meteorological measurements of a nuclear power plant, 28.5.2003

Guide YVL 7.6 Monitoring of discharges of radioactive substances from a nuclear power plant, 22.3.2006

Guide YVL 7.7 Radiation monitoring in the environment of a nuclear power plant, 22.3.2006

Guide YVL 7.8 Environmental radiation safety reports of a nuclear power plant, 22.3.2006

Guide YVL 7.9 Radiation protection of workers at nuclear facilities, 21.1.2002

Guide YVL 7.10 Monitoring of occupational exposure at nuclear facilities, 29.1.2002

Guide YVL 7.11 Radiation monitoring systems and equipment of a nuclear power plant, 13.7.2004

Guide YVL 7.18 Radiation safety aspects in the design of a nuclear power plant, 26.9.2003

Radioactive waste management

Guide YVL 8.1 Disposal of low and intermediate level waste from the operation of nuclear power plants, 10.9.2003

Guide YVL 8.2 Clearance of nuclear waste and decommissioned nuclear facilities, 18.2.2008

Guide YVL 8.3 Treatment and storage of low and intermediate level waste at a nuclear power plant, 29.6.2005

Guide YVL 8.4 Long-term safety of disposal of spent nuclear fuel, 23.5.2001

Guide YVL 8.5 Operational safety of a disposal facility for spent nuclear fuel, 23.12.2002.

The guides are available at http://plus.edilex.fi/stuklex/en/lainsaadanto/luettelo/ydinvoimalaitosohjeet/ (not all published in English).

ANNEX 2 Loviisa NPP units 1 and 2 under operation

The Loviisa plant comprises of two VVER units that are operated by Fortum Power and Heat Oy (Fortum). The plant units were connected to the electrical grid in February 8, 1977 (Loviisa 1) and November 4, 1980 (Loviisa 2). The nominal thermal power of both of the Loviisa units is 1500 MW (109% as compared to the original 1375 MW). The increase of the power level was licensed in 1998. The Operating Licences of the units are valid until the end of 2027 (unit 1) and 2030 (unit 2). According to the conditions of the licences, two periodic safety reviews are required to be carried out by the licensee (by the end of the year 2015 and 2023).

Most significant plant modifications at the Loviisa NPP during the plant lifetime

Several plant changes have been carried out during Loviisa NPP plant lifetime. The most important projects since the plant commissioning have been modifications made for protection against fires, modifications based on the development of the PRA models, severe accident mitigation programme, reactor power uprating, and contruction of training simulator, interim storage for spent fuel and repository for reactor operational waste.

In some of the earliest modifications in 1982, a hydrogen removal system was installed in the containment building in order to eliminate the risk of explosion during an accident when hydrogen is released from the core. The system consisted of 60 glow plugs that can ignite a controlled hydrogen burn.

In 1993, strainer area in the floor sumps of the emergency cooling system and the containment spray system was significantly enlarged by new design, and the sump systems were improved so as to provide more reliable pumping of the water accumulated in the two sumps during a loss of coolant accident (when the emergency make-up water tank is empty) back into the reactor and to the spray nozzles. The sumps were equipped with several hundreds of strainer units, a nitrogen flush system to blow any insulation debris off the strainers, and control instrumentation. The amount of debris the strainer system can cope with increased ten-fold.

In connection with the PRISE project in 1994–1995 (protection from primary to secondary leaks), the plant protection system was modified to provide automatic isolation of the damaged steam generator at high water level (the steam and feed water lines are closed), and to stop the respective reactor coolant pump. The aim was to protect the steam line from water hammer. Also new measuring equipment, based on the detection of nitrogen-16 isotope, was installed in the steam lines in order to ensure the detection of any leaks from the primary circuit.

Protection against fires at the Loviisa NPP

The possibility of fires and nuclear accident risks caused by them were not adequately taken into account initially in the functional design and the layout design of the Loviisa plant. Therefore, fire compartments were not implemented so that the plant safety functions could be maintained during all fire situations considered possible. For this reason the significance of an active fire fighting (fire alarm and extinguishing systems as well as operative fire fighting) is important along with structural fire protection arrangements.

Fire safety has been improved with several measures at the Loviisa plant after its commissioning. These measures have been implemented in various fields of fire protection. As a result, the plant safety against the effects of fires has been essentially improved.

For a provision against oil fires in the turbine hall several measures have been taken. Fire insulators of the load-bearing steel structures of the turbine building have been installed. The turbine hall has been equipped with an automatic sprinkler system and the significant parts of the turbines have been protected. Later on, the fire wall of the turbine hall has been built up to protect components important to reactor decay heat removal. Furthermore, the additional emergency feedwater system has been built for the case that all feedwater and emergency feedwater systems would be lost in a turbine hall fire. At the Loviisa NPP the decay heat removal systems are in the turbine hall. That´s why a separate building for additional decay heat removal system outside turbine hall was built in 2005. The new system is needed for cooling the plant to cold shutdown, if normal systems are not operable.

The main transformers have been protected with a sprinkler system which essentially reduces the risk that a fire would spread into the surrounding buildings, especially into the turbine hall. The risk to lose the AC-power (station blackout) during transformer fires has been reduced by protecting the diesel generators against fires. The 110 kV net connection has been physically separated from the 400 kV connection so that the loss of both connections as a result of a transformer fire is improbable. Several improvements against fires have been done in off-site power supply arrangements and in diesel generators. The original fire water pumps are supplied only from the off-site electrical network. Therefore, an additional fire water pump station has been constructed at the plant. It has been equipped with diesel-driven fire water pumps and with a separate fire water tank. Fire water piping and fire extinguishing systems as well as their coverage have been improved. A new addressed fire alarm system was completed in 1999 at Loviisa 1 and in 2001 at Loviisa 2. Several structural improvements for fire safety have been done, or are under design.

The level of the operative fire protection has been improved by establishing a plant fire fighting crew which is permanent, constantly ready to depart and has the proper equipment. As regards fire protection and fire risks also plant instructions have been complemented.

Severe Accident Management implementation at Loviisa NPP

The Loviisa severe accident programme, which includes plant modifications and severe accident management procedures, was initiated in the end on 1980's in order to meet the requirements of STUK. For Loviisa NPP, the severe accident management approach focuses on ensuring the following top level safety functions:

- depressurisation of the primary circuit
- absence of energetic events, i.e. hydrogen burns
- coolability and retention of molten core in the reactor vessel
- long term containment cooling
- ensuring subcriticality
- ensuring containment isolation.

The developed severe accident management (SAM) strategy lead to a number of hardware changes at the plant as well as to new severe accident guidelines and procedures.

The primary system depressurisation is an interface action between the preventive and mitigation parts of SAM. If the primary feed function is operable, the depressurisation may prevent the core melt (primary system cooling by feed and bleed). If not, it sets in motion the mitigation actions and measures to protect the containment integrity and mitigate large releases. Manual depressurisation capability has been designed and implemented through motor-operated high capacity relief valves. Depressurisation capacity will be sufficient for bleed & feed operation with high-pressure pumps, and for reducing the primary pressure before the molten corium degrades the reactor vessel strength. Depressurisation is to be initiated from indications of superheated temperatures at core exit thermocouples. The depressurisation valves were installed at the same time with the replacement of the existing pressuriser safety valves in 1996.

The cornerstone of the SAM strategy for Loviisa is the coolability of corium inside the reactor pressure vessel (RPV) through external cooling of the vessel. Since the RPV is not penetrated, all the ex-vessel phenomena such as ex-vessel steam explosions, direct containment heating and core-concrete interactions can be excluded. Some of the design features of the Loviisa plant make it most amenable for using the concept in-vessel retention of corium by external cooling of the RPV as the principle means of arresting the progress of a core melt accident. Such features include the low power density of the core, large water volumes both in the primary and in the secondary side, no penetrations in the lower head of the RPV, and ice condensers which ensure a passively flooded cavity in most severe accident scenarios. On the other hand, if in-vessel retention was not attempted, showing resistance to energetic steam generation and coolability of corium in the reactor cavity could be laborious for Loviisa NPP, because of the small, water filled cavity with small floor area and tight venting paths for the steam out of the cavity.

An extensive research programme regarding the thermal aspects was carried out by Fortum. The work included both experimental and analytical studies on heat transfer in a molten pool with volumetric heat generation and on heat transfer and flow behaviour at the RPV outer surface. Based on experiments, the in-vessel retention concept for Loviisa was finalised. STUK approved the conceptual design in December 1995. The modifications were completed in 2002. The most laborious one of them was the modification of the lower neutron and thermal shield such that it can be lowered down in case of an accident to allow free passage of water in contact with the RPV bottom. Also a strainer facility was constructed in the reactor cavity in order to screen out possible impurities from the coolant flow and thereby prevent clogging of the narrow flow paths around the RPV.

Based on plant-specific features, the only real concern regarding potential energetic phenomena is due to hydrogen combustion events. The Loviisa NPP reactors are equipped with ice-condenser containments, which are relatively large in size (comparable to the volume of typical large dry containments) but have a low design pressure of 0.17 MPa. The ultimate failure pressure has been estimated to be well above 0.3 MPa. An intermediate deck divides the containment in the upper (UC) and lower compartments (LC). All the nuclear steam supply system components are located in the lower compartment and, therefore, any release of hydrogen will be directed into the lower compartment. In order to reach the upper compartment, which is significantly larger in volume, the hydrogen and steam have to pass through the ice-condensers.

In the 1990's an extensive research programme was carried out at Fortum to assess the reliability and adequacy of the existing igniters system. The experiments and the related numerical calculations demonstrated that the global convective loop around the containment for ensuring well mixed conditions will be created and maintained reliably provided that the ice-condenser doors will stay open. A new hydrogen management strategy for Loviisa was formulated which concentrates on two functions: ensuring air recirculation flow paths to establish a well-mixed atmosphere (opening of ice condenser doors) and effective recombination and/or controlled ignition of hydrogen. Plant modifications included installation of autocatalytic hydrogen recombiners, modifications in the igniters system (igniters were removed from the upper compartment and left only in the lower compartment) and a dedicated system for opening the ice-condenser doors. The modifications were completed in 2003.

The studies on prevention of long term over pressurisation of the containment showed that the concept of filtered venting was not possible at the Loviisa NPP because the capability of the steel liner containment to resist subatmospheric pressures is poor. An external spray system was then designed to remove the heat from the containment in a severe accident when other means of decay heat removal from the containment are not operable. Due to the ice condenser containment, the time delay from the onset of the accident to the start of the external spray system is long (18–36 hours). Thus the required heat removal capacity is also low, only 3 MW (fraction of decay power is still absorbed by thick concrete walls). The system is started manually when the containment pressure reaches the design pressure 1.7 bar. Autonomous operation of the system independently from plant emergency diesels is ensured with dedicated local diesel generators. The active parts of the system are independent from all other containment decay heat removal systems. The containment external spray system was implemented at the two units in 1990 and 1991.

The SAM strategy implementation included also a new, dedicated, limited scope instrumentation and control system for the SAM systems, a dedicated AC-power system and a separate SAM control room which is common to both units. These were implemented mainly in year 2000 for Loviisa unit 1 and in 2002 for Loviisa unit 2.

In addition to the hardware modifications, severe accidents guidance for the operating personnel has been implemented. It consists of SAM procedures for the operators and of a so-called Severe Accident Handbook for the Technical Support Team. The SAM procedures are entered after a prolonged uncover of the reactor core indicated by highly superheated core exit temperatures. The procedures are symptom oriented and their main objective is the protection of containment integrity through ensuring the top level severe accident safety functions.

Modernisation and power uprating of Loviisa NPP in 1994–1997

The key aspects in the project for the modernisation and power uprating of Loviisa NPPs were to verify the plant safety, to improve production capacity and to give a good basis for the extension of the plant's lifetime to 50 years, which corresponds to the additional 20 years of operation applied for both units of the Loviisa NPP in 2006.

In the first phase, before starting the project, a feasibility study for uprating of the reactor thermal power was carried out. The main result was in short that no technical or licensing issues could be found which would prevent the raising of the reactor thermal output up to 1500 MW from the original level of 1375 MW. The feasibility study gave also a good picture of the necessary plant modifications. It focused on the following tasks: the optimisation of the power level and definition of the new parameters of the main process, reactor core and fuel studies, including RPV irradiation embrittlement, safety analyses and licensing, the main components and systems, and project planning and risk assessment.

The reactor power uprating from 1375 MW to 1500 MW was planned on the basis of optimising the need for major plant modifications. In the primary side and the sea water cooling system, the mass flow rates were not affected, but the temperature difference has been increased in proportion to the power upgrading. In the turbine side, the live steam and the feedwater flow rate were increased by about 10%; the live steam pressure was not changed.

The reactor fuel loading was considered on the basis of the previous limits set for the maximum fuel linear power and fuel burn-up. The increase in the reactor thermal output was carried out by optimising the power distribution in the core and the power of any single fuel bundle was not increased above the maximum level before power upgrading. In parallel with this work, more advanced options related to the mixing rate of the cooling water in the fuel subchannels and the increasing of fuel enrichment were investigated. The dummy elements installed on the periphery of the core at the Loviisa units 1 and 2 were preserved to minimise irradiation embrittlement of the reactor pressure vessel.

The VVER 440 design margins in the primary side are rather large and the hardware modifications needed there were quite limited. Replacement of the pressuriser safety valves was indicated already during the feasibility study as a necessary measure because of the power upgrading. Most of the other substantial measures in the primary side were carried out on the basis of the continuing effort to maintain and raise the safety level of the plant, and they were not directly included in the power upgrading.

It was necessary to carry out more extensive measures in the turbine plant and to the electrical components. Steam turbines were modified to a higher steam flow rate. Because of these measures, also the efficiency and operation reliability has improved. Certain modifications were carried out in the electrical generators and the main transformers to ensure reliability in continuous operation with the upgraded power output.

The implementation of the modernisation project was carried out in co-operation between Loviisa NPP and Fortum Nuclear Services (former Fortum Engineering). In addition, many other organisations such as the Technical Research Centre of Finland (VTT) participated in the work. The last step in the process to uprate the reactor thermal power was the long-term trial run to verify the main process parameters as well as plant operation in both steady state and transient situations. Normal operation and in a limited way also transient behaviour of the plant were studied in the trial tests. Studies were made by means of the plant simulator and the results of transient analyses were used in the planning of the trial test programme. Due to the small number of plant modifications required for the power increase of the Loviisa plant, a simple trial test programme supported by the simulator studies was considered as appropriate and acceptable.

The first trial run at 103% reactor power could be started in January 1997. Test runs continued step by step during the year, and the last transient test at final reactor power 109% was completed successfully in December 1997. Transient tests defined in the test programme were performed with a reactor thermal power of 105% and 109%. The test results corresponded very well with all analyses and calculations. All the acceptance criteria for the tests were fulfilled. Measures to improve the efficiency of the steam turbines continued in the annual maintenance outages until the year 2002.

STUK was closely involved at every stage of the project, from the early planning of the concept to the evaluation of the results from the test runs. STUK examined all the modification plans that might be expected to have an impact on plant safety. Individual permits were granted stage by stage, based on the successful implementation of previous work.

The renewal of the operating licence for the increased reactor power was carried out according to the nuclear safety legislation. First the Ministry of Employment and the Economy (former Ministry of Trade and Industry) gave a permission to make plant modifications and test runs with upgraded reactor power under the existing operating licence and under the control of STUK. Then the assessment of the environmental impact (EIA-procedure) of the project was carried out. STUK approved the Final Safety Analyses Report (FSAR), the safety-related plant modifications, and the test programmes and the results. Finally the Government granted the renewed operating licence in April 1998. The licence was awarded to 1500 MW nominal reactor thermal power until the end of the year 2007.

The revision of emergency operating procedures (2000–2005)

The emergency operating procedures of Loviisa nuclear power plant were revised in the so called HOKE project, launched in 2000. The project encompassed the drawing up of diagnosis procedures for transients and emergencies arising from primary and secondary leaks, procedures for operators and the safety engineer as well as action sheets for onsite measures.

In accordance with the new procedures, nuclear power plant operators follow their own separate procedures and initiate the necessary actions in their fields of responsibility in the event of an emergency or a transient. The shift manager co-ordinates these actions and reviews the main actions and parameters using his own procedures. The safety engineer in parallel with the operators independently oversees safety functions using separate procedures to ensure that plant behaviour is as planned.

The revised procedures consist of guidelines and instructions presented as flow charts. The guidelines define strategy and give grounds for operator actions during emergencies and transients. It serves as a basis for actual control room procedures containing operator procedures. The guidelines are used for training purposes as well.

The validation and verification of the procedures and their background material ascertains authenticity of the procedures i.a. by comparison with the plant and by simulator tests. Verification authenticates i.a. correlation and functioning of the new procedures with other plant procedures. The project included training given to the control room personnel of the Loviisa plant in the use of the new procedures. Due to the revision's significance STUK required that shift supervisors and operators working in the control room have given shift-specific proof of workmanship prior to the introduction into use of the revised procedures.

In December 2005, STUK authorised the introduction into service of the revised emergency operating procedures.

Examples of latest plant modifications at the Loviisa NPP (2010–2012)

Improvement of safety system suction strainers

The suction strainers of the low pressure emergency cooling system and the containment spraying system, which are required in accident conditions, were improved by means of installing higher density mesh elements in them. In accident conditions caused by a pipe break, fibres coming loose from pipe heat insulation can accumulate in the suction strainers. The aim is to prevent fibres from entering the reactor core via the emergency cooling system, because blockages caused by large amounts of fibres could lead to overheating of the reactor core.

Higher density mesh elements improve the filtering capacity of the suction strainers, thus reducing significantly the amount of fibres being carried into the reactor core compared with the old suction strainer structure.

Modernisation of the primary system pressure management

Modernisation of the pressuriser system at the Loviisa unit 1 was carried out in 2012. The modification was done because of restrictions to use the emergency spray of the pressuriser in a pressure higher than 12 bars. At the same time, the valves of the pressuriser spray system were replaced and the spray lines coming from the high pressure emergency core cooling system were moved to the low pressure core cooling system. In addition, the capacity of the relief train of the pressuriser was increased. The modification also envolved I&C, electrical and piping changes. The same modification is planned for implementation at the Loviisa unit 2 during the 2014 annual maintenance outage.

Construction of new off-site diesel power plant

Construction of a new diesel powered off-site generator plant was carried out in 2011-2012. The power of the plant is 10 MW and it can be used as a peak power plant for electrical grid or as a power supply for the nuclear plants. It is not safety classified, but it can feed power as a last resort to the safety and non-safety classified systems of the nuclear plants.

Examples of latest incidents at the Loviisa NPP (2010–2012)

Radioactive resin found in ventilation system

Resin tanks and their overflow lines were being rinsed with pure water at the radioactive liquid waste solidification plant of the Loviisa power plant in March 2010. The tanks and overflow lines had minor resin residues from previous use. Resin is used, among other things, for purifying the primary circuit coolant water. This makes the resin radioactive. The level measurement of one of the tanks was unreliable, which is why the tank was overfilled as a result of human error and slightly radioactive water-resin mixture entered the gas exhaust line of the tank and from there to the auxiliary building ventilation system. The entry of water in the ventilation system was quickly discovered because maintenance work was in progress in the corridor along which the ventilation channel runs. A temporary bypass line had been made in the ventilation channel for the maintenance operation. The maintenance workers noticed that water was seeping from the joint between the regular and temporary channels and reported this to the control room.

The corridor in the auxiliary building was cordoned off and actions were initiated in the area for limiting the spread of radioactivity. The ventilation system was set in filtering mode, the area was cleaned and the resin-containing water was collected.

The power company performed radiation measurements on the ventilation lines, even further away from the location of the event. Small quantities of radioactive resin were found in the ventilation system in places unaffected by the migration of resin and water that had now taken place. This led to the conclusion that radioactive resin had already entered the auxiliary building ventilation system on some previous occasion. The scope of cleaning operations at the power plant was extended and all dry resin was also collected from the ventilation systems.

The total activity of the mildly radioactive resin and water entering the ventilation channel was estimated to be less than 100 MBq. The total volume of water collected from the system was about 100 litres, and about 5 litres of wet resin and 8 litres of dry resin were also collected. The employees accumulated a collective radiation dose of 0.2 mmanSv in the course of the cleaning operation, which means that the operation did not cause a risk to personnel safety.

Because the auxiliary building ventilation system leads the exhaust air to the vent stack, the filters in the vent stack sampling lines were measured. No radioactive particles were found in them, nor were there any indications that radioactive particles would have spread into the environment.

The power company performed comprehensive measurements outside the plant buildings in order to verify that particulate resin had not escaped into the environment through the vent stack. The measurements concentrated on the natural drainage routes of melting waters and rain water.

The measurements did not reveal any radioactive particles. However, the power company did find small amounts of radioactivity (Co-60) from the samples of grit used for sanding the parking lot. The quantity was 0.2 Bq/kg. The quantity allows for the conclusion that the quantity of activity possibly released into the environment in connection with the event is so small that it is insignificant for the vicinity of the plant and the people living in it.

The event showed that liquid substances may escape through the venting lines as a result of various process measures and erroneous actions and end up in places where they do not belong. The operation of the liquid waste solidification plant has not been continued after the event. Fortum performed a root cause analysis of the event. Fortum will investigate the process planning and instructions at the plant. The entry of liquids into the ventilation system through the venting lines will be prevented by modifications to process technology. The liquid level measurement in the tanks will be improved so that overfilling of the tank can no longer occur. The operating instructions for the solidification plant will also be further specified.

On the seven-level International Nuclear Event Scale (INES), the event was rated at level 1. STUK has also prepared an IRS report concerning the event.

Spread of contamination in conjunction with transfers of spent fuel

Radioactive particles fell on the security-fenced yard of the Loviisa NPP from an inadequately cleaned transport vessel for spent nuclear fuel during the period 10 May to 9 June 2010 when spent fuel was being moved to the spent fuel interim storage from the Loviisa unit 1. The storage is located at the Loviisa unit 2. The power plant discovered the event on the evening of 9 June 2010 when measuring radioactivity on the transfer route. The power plant notified STUK of the event the following morning.

Spent fuel is moved from the reactor hall to the fuel storage using a purpose-built transfer container. The radioactive particles found on the transfer route were small metal particles that are present in the fuel storage pool water in the reactor hall. The particles had been deposited on the surface of the transfer container while it was in the pool, and because the container was not properly cleaned, they fell to the ground when the container was being transported.

About 50 radioactive particles were found in the vicinity of the transfer route on the plant yard when the power plant carried out measurements on 9–10 June 2010. The measurements were continued on the yard area using a more accurate method, and 35 particles more were found around the transfer route. The particles mainly contained Co-60, Mn-54, Co-57 and Co-58 nuclides. The total activity of the particles was determined and found to be about 10 MBq. This is a small amount of activity, but it should not be present outside the controlled area at all.

The storage and transfer route of spent nuclear fuel are in the controlled area of the power plant where radioactivity is regularly monitored. Particles were only found near the transfer route and at the landfill site. The yard was cleaned of any radioactive particles in connection with the radioactivity measurements. The event did not cause any hazard to people or the environment.

The Loviisa power plant took corrective action in order to prevent similar events. The methods and instructions for the transfers will be revised, and advanced radiation protection training will be organised for the fuel team. In addition, improvements will be made to the container transfer trolley in order to prevent the spread of contamination. STUK will follow the implementation of these actions. The event was classified at INES Level 1.

Deficiencies in the testing of radiation monitors

In May 2012, the Loviisa power plant informed STUK that it had found deficiencies in the testing procedure of certain radiation monitors at the Loviisa unit 2. The monitors in question are used to measure the radioactivity of the water let out of the secondary circuit and discharged into the sea. The procedures had not been fully observed when testing the monitors, resulting in the process control function being left untested in some tests. In addition, some periodic tests had been completely ignored.

The testing requirements of radiation monitors are recorded in the operational limits and conditions (OLC) that the power plant must comply with. According to the OLC, a general inspection of the monitors must be performed every two weeks, a functional test every month, and a calibration check every six months. Based on the investigations of Fortum, there have been deficiencies in all these.

After the detection of the deficiencies, the radiation monitors and the related process control functions were tested in accordance with the procedures. The tests showed that the equipment functioned in the normal manner. Radiation monitors have a self-diagnostics function in case of failures and, in addition to periodic testing, the operation of the monitors is followed in the process computer trend displays. As the equipment functions in the normal manner, deficient testing had no immediate importance to the safety of the plant or the environment.

The preliminary classification of the event on the INES scale was 0. Fortum delivered a special report of the event to STUK, describing the reasons and corrective measures for the event. As the event involved deficient quality management and unjustified ignoring of procedures, STUK rated the event as an anomaly belonging to INES category 1.

Excess fire load in the containment

On STUK's oversight rounds during the Loviisa unit 1 annual outage on 7th September 2012, ten one-litre plastic bottles containing flammable solvent were found in a plastic bag at the shoe boundary of a reactor pit access opening located in the containment's reactor coolant pump room. The solvent was intended for the washing of the reactor pit's steel lining. According to the plant procedure, three litres of flammable solvents may be kept in the open at once. Other tools meant for the cleaning of the reactor pit, including cleaning cloths, were also stored at the same location.

The reactor coolant pump room has plenty of fixed fire load, such as 5,000 kg of cable insulation. Washing agents do not essentially increase the fire load but together with flammable materials, they create the preconditions for a rapidly progressing fire that ignites cables. When PVC cables burn, the temperature in the containment can increase to 200 times the normal value, and high quantities of hydrogen chloride would be released.

The fire safety of the Loviisa power plant's containment is partially based on keeping fire loads as low as possible and minimising the ignition potential. This is particularly important in spaces which have no fixed fire extinguishing systems, such as the containment's reactor coolant pump room, and where the success of first aid extinguishing is uncertain.

STUK also observed a similar event at the Loviisa unit 1 during the 2010 annual outage, with a considerably higher quantity of connectors being stored. Since the 2010 event, the power plant has improved the procedures and supervision of the work.

Due to the repeated nature of the event, STUK rated it as a INES category 1 event.

Incorrect settings of protective relays of motors

At the Loviisa unit 2, thermal relays (overload protections) were replaced in the electrical motors of pumps important to safety in the annual outage in autumn 2012. Approximately one month after the completion of the annual outage, Fortum observed that wrong settings had been entered for the relays, potentially resulting in the pumps stopping in the case of low motor supply voltage. The thermal relays are used as overload protection for the electrical motor, meant to protect the motor and to cut the motor's power supply if the motor overheats.

STUK's inspection in November revealed irregularities in the protections of the electrical motors of certain pumps important to safety. Further investigations by Fortum showed that incorrect settings existed in the new thermal relays installed into motors during the 2012 annual outage at the Loviisa unit 2. There were incorrect thermal relay settings in a total of ten different pump motors in the emergency cooling and feed water circuits, with the normal supply voltage values used instead of undervoltage values. The incorrect relay settings could have led to stopping of the pumps in undervoltage situations.

The safety significance of the event was low, and the event caused no immediate risk for the safety of the plant unit or the personnel. The pumps were operational in normal voltage conditions, but could have stopped in undervoltage situations. Undervoltages and pump malfunctions are indicated in the control room, which allows operators to take the necessary measures following the procedures. The plant unit is designed to cope with undervoltage of the external 400/110 kV power grids using its four emergency diesel generators.

According to Fortum, the root cause behind the event was a design error in the definition of thermal relay settings. The plant documentation used as a basis of design work does not include undervoltage information for the pump motors in question. The design error was not observed in connection with the modification work or the inspection.

After the incorrect thermal relay settings had been detected, Fortum informed the control room personnel of the proper procedures in undervoltage situations. As an immediate corrective measure, Fortum implemented the appropriate thermal relay settings. The power company will also add further details to the setting and testing procedure, develop the plant information system and documentation, and make additional checks to ensure that the thermal relay settings used in the plant unit's electrical motors are correct. Fortum also inspected the corresponding thermal relays of pump motors at the Loviisa unit 1, and no erroneous settings were found.

The event was rated as category 1 on the international INES scale, because the erroneous relay settings simultaneously affected the reliable undervoltage operation of several systems important to safety.

Several reported incidents during 2012

Increasing number of incidents occured at the Loviisa NPP during 2012. Three of them were classified at INES Level 1 and seven of them at INES Level 0. Several of them occurred during the plant outage. Incidents included deficiencies in the periodic testing of equipment included in the Operational Limits and Conditions (2 incidents), incorrect separations and repairs (4 incidents), additional fire load inside the containment, indistinct operability of the renewed valves of the pressuriser system during the plant start-up, incorrect set-ups in the motor relays of the safety related pumps, and deficiencies in the testing periods of preventive maintenance. Several incidents included deficiencies in the operations and procedures of the plant.

STUK discussed the increased number of incidents with the licensee during the fall 2012. The licensee has started to assess the reasons behind the incidents. The assessment was finalised in the end of May 2013 after which the corrective actions will be implemented and followed at the Loviisa NPP.

Periodic safety reviews at the Loviisa NPP

During the years 1996–1998 the overall safety review of the Loviisa plant was carried out by the licensee and independently by STUK in connection to the renewal of operating licences of nuclear power plant units. The safety documentation, including safety assessments done by the licensee, was submitted to STUK at the end of 1996. In addition to the review of the licensing documents such as Final Safety Analysis Report, STUK also made an independent safety assessment. The statement of STUK was given to the Ministry of Employment and the Economy (former Ministry of Trade and Industry) in March 1998. As regards radiation and nuclear safety, the main conclusions in the statement were that the conditions of the Finnish nuclear energy legislation are complied with.

The latest overall safety review of the Loviisa plant took place in 2005–2007 in connection of the relicensing of the operation of the plant. The operating licence application was addressed to the Government and was handled by the Ministry of Employment and the Economy. Fortum filed the application to the Ministry of Employment and the Economy in November 2006. Legislative and regulative requirements for the application of the operating licence are described in the Nuclear Energy Decree (161/1988) Sections 33, 34, 36 and in the Guide YVL 1.1 Regulatory control of safety at nuclear facilities.

The Loviisa plant was reaching its original design age in 2007–2010, but the technical and economical lifetime of the plant is estimated to be at least 50 years according to the current knowledge of the plant ageing. Due to consistent plant improvements, the safety level of the plant has been increased as shown by the probabilistic risk assessment (PRA).

Based on the application, STUK carried out a comprehensive review of the safety of the Loviisa plant. The review was completed in July 2007 when STUK provided the Ministry of Employment and the Economy with it's statement on the safety of the plant. The Finnish Government granted in July 2007 to Fortum new licences for unit 1 until the end of 2027 and for unit 2 until the end of 2030. The length of the operating licences corresponds to the current goal for the plant's lifetime, which is

50 years. Two periodic safety reviews (by the end of the year 2015 and 2023) are to be carried out by the licensee as a licence condition.

The statement of safety included also STUK's safety assessment which provided a summary of the reviews, inspections and continuous oversight carried out by STUK. Based on the assessment, STUK considered that the Loviisa Nuclear Power Plant meets the set safety requirements for operational nuclear power plants but there are some reservations related to the redundancy and separation of components needed for performing safety functions (e.g. fire compartmentalisation). These reservations are originating from the design basis laid down during the 1970s. However, substantial modernisations have been carried out at the Loviisa NPP since its commissioning to improve safety. Risk factors have been systematically identified and eliminated using operating experience, research and development and probabilistic risk analysis. Examples of such plant modifications include the development of fire detection and fire extinguishing systems, as well as operative fire protection in parallel with structural fire protection. The most recent risk reducing modifications include also improvements to the plant residual heat removal and emergency cooling systems and ensuring the cooling of reactor coolant pump seals. Fortum has also many ongoing projects for enhancing safety and reducing the accident risk. They include e.g., improvements aiming at prevention reactor coolant pump seal leaks with regard to fire and flood conditions, precautions against oil accidents in the Gulf of Finland, and improvements aiming at reducing the risk arising from heavy load lifting with the structural reliability of the polar crane and developing the procedures relating to lifting. This is in line with the principle of continuous improvement of safety provided in section 7 a of the Nuclear Energy Act.

As a summary of the review of the issues and documentation pertaining to the periodic safety review and the continuous oversight results, STUK noted that the prerequisites for safe operation of Loviisa NPP have been met.

Reactor pressure vessel relicensing

Plant lifetime management includes credible procedures for following the plant ageing. The conditions of components which are practically impossible to be replaced by new ones (pressure vessel, steam generators, etc.) are monitored most actively.

Several modifications have been made at the both Loviisa plant units to reduce the risk of reactor vessel brittle fracture. In 1980, 36 fuel bundles at the outer edge of the reactor core were replaced with by stainless steel elements (dummies) to reduce the risk of reactor vessel brittle fracture in the long term. The purpose was to reduce the impact of neutron radiation on the reactor pressure vessel thereby preventing premature embrittlement of the pressure vessel. The reactor pressure vessel of Loviisa unit 1 was heat treated in 1996 to restore quality of one of the mostly affected weldings.

Fortum stated during the last operating licence renewal process that the brittle fracture risk can be managed until the end of the 50 years plant lifetime. The primary circuits of both Loviisa plant units are still in good condition. The validity of the operating licence of the reactor pressure vessel of the Loviisa unit 2 was extended in 2010 until the end of 2030, i.e, to the end of the plant unit's current operating licence. Similarly, STUK assessed the renewal of the reactor pressure vessel operating licence for the Loviisa unit 1 in 2012 and the validity of the operating licence of the reactor pressure vessel of the Loviisa unit 1 was extended until the end of the plant unit's current operating licence. In the future, the safety of the reactor will be assessed in connection with the plant's periodic safety reviews.

Planned and ongoing activities to improve safety at the Loviisa NPP

In Finland, the continuous safety assessment and enhancement approach is presented in the nuclear legislation. Actions for safety enhancement are to be taken whenever they can be regarded as justified, considering operating experience, the results of safety research and the advancement of science and technology. The implementation of safety improvements has been a continuing process at the Loviisa nuclear power plants since its commissioning and there exists no urgent need to upgrade the safety of this plant in the context of the Convention.

For continued safe operation, plant improvement projects are still necessary. The largest ongoing investment is the complete renewal of the plant

I&C system. Also some improvement measures will be done based on the lessons learnt from the TEPCO Fukushima Dai-ichi accident.

Safety assessments and improvements based on the lessons learnt from TEPCO Fukushima Dai-ichi accident

Based on the results of assessments conducted after the TEPCO Fukushima Dai-ichi accident on 11 March 2011, it is concluded that no such hazards or deficiencies have been found as would require immediate actions at the Loviisa NPP. However, the areas where safety can be further enhanced have been identified and there are plans on how to address these areas. Main changes are aimed at decreasing the dependency on plant's normal electricity supply and distribution systems as well as on the sea water cooled systems for residual heat removal from the reactor, containment and spent fuel pools. The licensee has also been required to submit plans to improve protection against external flooding by the end of 2013.

Natural hazards

According to the PRA results, the risk caused to the operating units by external events is a relatively small fraction of the total risk. However, there are areas where possibilities for further risk reduction exist, for example improving the protection against high seawater.

Safety margins were assessed by the licensee and reviewed by STUK. Based on the results, STUK required further clarifications on the following main points:

- seismic resistance of spent fuel pools including situations with water temperature exceeding the design bases;
- seismic resistance of fire fighting systems; and
- plans for improving flooding margin for the Loviisa plant by end of 2013.

Seawater level variations in the Baltic Sea are moderate. Due to geological conditions and the shallow water strong tsunami type phenomena are not considered possible in the Baltic Sea. At the Loviisa NPP, the observed maximum seawater level is +1.77 m above the mean sea level (N60 reference system). The design basis of the Loviisa NPP is about +3 m during power operation and about +2.1 m during refueling shutdown. Based of extreme value distribution fitting, the annual probability of exceeding the level +3 m is about $4 \cdot 10^{-7}$. The refueling shutdowns are scheduled for summer and early autumn when the seawater level variations are small. The design basis of the Loviisa NPP is considered sufficient in the short term. Although the estimated annual probability of exceeding the design value is very small, the consequences of flooding of the basement of the Loviisa NPP would be severe, as all cooling systems might be lost. Therefore, to ensure safe operation in the long term, the possibilities for decreasing the risk of seawater flooding have to be examined.

Loviisa NPP has improved in 2012 flood protection during certain annual shutdown states with open hatches in the condenser cooling seawater system; the design water level was increased from +2.1 m to +2.45 m and further increase to +2.95 m is considered.

The licensee has been required to submit plans to improve protection against external flooding by the end of 2013. The licensee is examining site area protection with levees and the protected volume approach and also their combination to improve of the flooding resistance of the Loviisa plant. The licensee will make decisions based on updated flooding hazard estimates contracted from the Finnish Meteorological Institute.

Design issues

At the Loviisa NPP, the systems needed for residual heat removal from the reactor, containment and fuel pools require external power and the ultimate heat sink is the sea. A reliable supply of electrical power to the systems providing for basic safety functions at the Loviisa NPP is ensured by the Defence-in-Depth concept. As a result of multiple and diversified electrical power sources at different levels, the probability of loss of all electrical supply systems is considered very low. However, as a result of the studies made after the TEPCO Fukushima Dai-ichi accident, further changes are expected to be implemented. Main changes are aimed at decreasing the dependency on plant's normal electricity supply and distribution systems as well as on the sea water cooled systems for residual heat removal from the reactor, containment and spent fuel pools.

At the Loviisa NPP, the availability of an alternate heat sink depends on the plant state and feed water availability. If primary circuit can be pressurised (i.e. reactor vessel head is in place), atmosphere can be used as an alternate heat sink as long as there is enough water available for dumping steam into atmosphere from the secondary circuit. There is a separated diesel driven auxiliary emergency feed water system with two pumps which feeds water to the steam generators in case of loss of AC power. It is also possible to transfer heat to spent fuel cooling system and hence to intermediate cooling system, giving time for restoring ultimate heat sink.

The licensee at the Loviisa NPP considers a plant modification to ensure the long-term decay heat removal in case of loss of seawater by implementing an alternative ultimate heat sink. The modification consists of two air-cooled cooling units per plant unit powered by an air-cooled diesel-generator. The other cooling unit would remove decay heat from the reactor and the other one ensures the decay heat removal from in-containment spent fuel pool and from the spent fuel storage pools. The cooling unit is connected to the intermediate cooling circuit, and it backs up the seawater cooled heat exchangers. The cooling units for the reactors are dimensioned to be able to remove the deacy heat after 72 h, and until then the heat removal can be carried out by steam dumping into the atmosphere from the steam generator secondary side. The modifications in consideration would create a possibility to closed-loop operation also in case of loss of ultimate heat sink. The conceptual design plan is ready and the cooling towers are planned to be realised in 2014.

In addition, the licensee has evaluated measures needed to secure the availability of the auxiliary emergency feedwater system in the case of loss of electrical power, water supply for the diesel driven auxiliary emergency feed water pumps, and electricity supply for instrumentation needed in accidents. The modifications will be realised during 2012 and 2013, with the exception of improving the instrumentation by 2015.

The experiences from the Fukushima Dai-ichi accident will be taken into consideration in the ongoing renewal of the Finnish Regulatory Guides (YVL Guides). For example there will be a new requirement for arrangements that enable the decay heat removal from the reactor out of the containment and arrangements to ensure sufficient cooling of the fuel in fuel storages. In spite that there are fixed severe accident management systems installed at Loviisa operating units, STUK required the licensee to investigate needs and possibilities to use mobile power supply and mobile pumps in accidents. Loviisa NPP has studied the possibilities to utilise mobile power supply and mobile pumps to support safety functions.

At the Loviisa NPP, the current AC power supply systems include connections to 400 kV and 110 kV power grids, main generator (house load operation), four emergency diesel generators per unit, a diverse diesel power plant and a dedicated connection to a nearby hydropower plant, two SAM diesel generators, and the possibility to supply electricity from the neighbouring NPP unit. No modifications are planned to the current design concerning AC power supply.

At the Loviisa NPP, there is enough diesel fuel in the emergency diesel generator (EDG) tanks for at least 72 h of operation, and with realistic loads in case of an accident, the duration is evaluated twice as long. Currently the emergency diesel generators (EDGs) at the Loviisa NPPs use conventional diesel fuel, which is available only in limited scope. An investigation of replacing conventional diesel with widely available biodiesel is being performed by the licensee and the diesel engine manufacturer. In 2012, the licensee of the Loviisa NPP purchased a container to transfer diesel fuel at the site. The purpose of this container is to make fuel transfer between the tanks on-site easier and faster. In addition, the licensee has started an investigation to build a new fuel storage tank, from which it is possible to deliver fuel to the diesel generators' day tanks.

At the Loviisa NPP, some DC batteries depletion times are considered to be rather short. The duration of DC power supply is considered to be enhanced. Especially the reactor coolant pump seal water system functionality must be ensured. The licensee will submit a plan to STUK. There is also an ongoing automation renewal project in which the depletion time of the batteries will be lengthened substantially. It is possible to charge the batteries using the AC power sources. The licensee will install two new separate underground cables from the new diesel power plant to the 6.3 kV diesel busbar in 2012–2013, which will furthermore ensure and enhance battery charging possibilities.

Regarding spent fuel pools, the approach in Finland is to “practically eliminate” the possibility of fuel damage. The licensee have evaluated alternative means of decay heat removal from fuel storage pools in case of loss of existing systems, and to supply coolant to fuel storage pools (including potential need for new instrumentation). The plant modifications will require further analysis before starting the detailed design work. The more detailed analysis will be performed in 2013. Furthermore, the licensee will improve EOPs and SAM Guidelines to support heat removal from spent fuel pools by pool boiling and supplying additional water to the pools. Licensee is also studying the seismic resistance of the fuels pools as well as the influence of pool water boiling to the pool structures.

Severe accident management

A comprehensive severe accident management (SAM) strategy has been developed and implemented at Loviisa 1&2 plant units during 1990’s after the accidents in TMI and Chernobyl (see above). These strategies are based on ensuring the containment integrity which is required in the existing national regulations. STUK has reviewed these strategies and has made inspections in all stages of implementation.

As a result of the studies made after the TEPCO Fukushima Dai-ichi accident, no major changes at the plants are considered necessary. However, the licensee is expected to consider spent fuel pools in the SAM procedures as well as any implications on them possibly arising from simultaneous multi unit accidents. In addition, there are many actions related to the update of the emergency plans.

At the Loviisa NPP, 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 I&C from SAM control room or main control room. The SAM strategies and their implementation at the Loviisa NPP follow the requirements set in the Government Decree 733/2008 and the YVL Guides. The approach and the plant modifications have been approved by STUK. Since the systems for management and mitigation of severe accidents have already been implemented at Loviisa operating units and the corresponding procedures are in place, no further measures for this purpose are foreseen at the moment. However, the soundness and adequacy of the accident management schemes is being constantly assessed against the latest knowledge and experience obtained from different international sources.

Loviisa NPP is investigating possibilities to implement additional injection points for mobile pumps to provide more flexibility to the water supply of the containment external spray. These connections could provide capability to inject enough water for both units with one pump. The different possibilities will be analysed in more detail in 2013. Currently, the containment external spraying for heat removal from the containment can be carried out by fire trucks, individually for both of the units, in case of failure of the fixed pumps. Investment decision for mobile power supply and mobile pumps will be made after related assessments on the need and purpose of mobile devices have been completed. Implementation is planned to be made in 2013.

At the Loviisa NPP, immediate SAM measures are carried out within the Emergency Operation Procedures (EOP). After carrying out immediate actions successfully, the operators concentrate on monitoring the SAM safety functions with SAM procedures. The SAM procedures focus on monitoring the leak tightness of the containment barrier, and on the long-term issues. At the Loviisa NPP, licensee will improve EOPs and SAM procedures to support heat removal from spent fuel pools by pool boiling and supplying additional water to the pools. New EOPs for shutdown states, which cover the immediate recovery of SAM systems, have been developed in 2012 and are going through implementation.

I&C renewal project at Loviisa NPP

I&C systems of the Loviisa nuclear power plant units are being renewed stepwise in a project that will continue for several years. Some modifications will also be made to the functions of the plant systems. Furthermore, a new emergency control room will be provided for each unit to replace the emergency control panels currently located mutually in the main control rooms of the other unit. I&C renewal will be implemented in several project phases so that each phase will be adopted during maintenance outages.

Preliminary planning of the renewal project started several years ago and in the beginning of 2005 the licensee signed the delivery contract with the consortium of Framatome and Siemens. New buildings at the plant site have been constructed and will accommodate the main equipment of the safety and operational I&C. The first phase of the project included e.g. the renewal of the reactor preventive protection I&C and was implemented in the outage 2008 at Loviisa unit 1 and at Loviisa unit 2 in the outage 2009. The second phase of the project including the renewal of the reactor protection system is planned to be implemented at the Loviisa unit 1 during the outage 2015. Safety classified parts of the project are intended to be completed in 2017.

Construction and commissioning of a liquid waste solidification facility

A solidification facility for liquid radioactive waste has been constructed on the Loviisa plant site. The solidification facility processes the evaporation residues generated at the power plant and the radioactive ion exchange resins from the purification filters. The power company initiated the commissioning phase of the solidification facility implementation project during 2006 by carrying out system and plant level tests using inactive substances. Plant level tests continued in 2008 using radioactive evaporation residues and in 2009 with radioactive ion exchange resins. Based on the results of the commissioning tests of the plant some system modifications were designed and implemented during 2011–2012. The commissioning continues in 2013 with operating personnel training activities and updating the plant design documentation and procedures. The tests of modified systems will be finalised in 2013. The target date for the start of the solidification plant operation is spring 2014 after the regulatory commissioning inspections and approval.

ANNEX 3 Olkiluoto NPP units 1 and 2 under operation

The Olkiluoto plant comprises of two BWR units that are operated by Teollisuuden Voima Oyj (TVO). The plant units were connected to the electrical network in September 2, 1978 (Olkiluoto 1) and February 18, 1980 (Olkiluoto 2). The nominal thermal power of both Olkiluoto units is 2500 MW, which was licensed in 1998. The new power level is 115.7% as compared to the earlier nominal power 2160 MW licensed in 1983. The original power level of both units was 2000 MW. The Operating Licences of the units are valid until the end of 2018. According to the conditions of the licences, the licensee carried out a periodic safety review and submitted it to the regulator in the end of 2008.

Most significant plant modifications at the Olkiluoto NPP during the plant lifetime

Several plant changes have been carried out during Olkiluoto NPP plant lifetime. The most important projects since the plant commissioning have been two reactor upratings, severe accident mitigation programme, modifications based on the develoment of the PRA models, contruction of training simulator, interim storage for spent fuel and repository for operational waste, and investigation programme for disposal of spent fuel. The first power uprating project was carried out in 1983–1984. Thermal power was uprated from 2000 MW to 2160 MW (8%). The plant modifications included for example a new relief valve that was installed in the reactor primary system, changes in the reactor protection system, and increase of cooling capacity of some heat exchangers.

Severe Accident Management implementation at the Olkiluoto NPP

Several new research programmes were launched in the beginning of 1980's, whose objective was both to clarify the character and magnitude of loads arising from a severe accident and to find means for controlling the loads on the containment. The main provisions for severe accident management were installed at the Olkiluoto units 1 and 2 during the SAM project which was finished in 1989. The measures implemented were

- containment overpressure protection
- containment filtered venting
- lower drywell flooding from wetwell
- containment penetration shielding in lower drywell
- containment water filling from external source
- containment instrumentation for severe accident control
- Emergency Operating Procedures for severe accidents.

The means for managing severe accidents had to be adjusted to the existing design, and so an optimal implementation of all chosen solutions was not possible. Subsequent development of the accident management procedures and additional minor plant modifications at Olkiluoto plant have taken place during the years after that when new aspects on the issue have emerged.

To secure depressurisation of the reactor primary system in severe accident situations and to prevent a new pressurisation of the reactor, two valves of the relief system were modified. It is now possible to keep the valves open with the help of nitrogen supply or water supply from outside the containment.

One of the most significant deficiencies at the Olkiluoto plant containments, from the standpoint of controlling severe accidents, has been the small size of the containment, which may cause the containment to pressurise due to the hydrogen and steam generation during an accident (common feature for BWRs). Another deficiency is the location of the reactor pressure vessel inside the containment, which is such that the core melt erupting from the pressure vessel may expose the structures and penetrations that ensure the tightness of the containment, to pressure loads and thermal stresses. To eliminate these deficiencies, the containment was e.g. provided with a filtered venting system. Gases that pressurise the containment can be removed through a filter designed for the purpose, if the pressure inside the containment threatens to increase too much. The part of the containment underneath the reactor pressure vessel can be flooded with water in order to protect the containment bottom and penetrations from the thermal effect of core melt. Some penetrations of the containment have been protected from the direct effect of core melt also by structural means. To ensure the cooling of reactor debris, the plant units are also provided with a water filling system, by the means of which the water level inside the containment can be raised all the way to the same level with the upper edge of the reactor core.

The cooling of reactor core melt and the protection of containment penetrations requires that the lower dry well of the containment is flooded at such an early stage of the accident that if the pressure vessel melts through, the erupting core melt falls into a deep water pool. When the core melt falls into the water a so-called steam explosion, which causes a strong and quickly propagating pressure wave in the water pool, may occur. A lot of research has been done on steam explosions. The results show that the core melt discharged through the pressure vessel cools down as it travels through the water pool and cannot create a steam explosion. However, the structures of the lower equipment hatch have been enforced to decrease the risk for loss of containment integrity due to loads caused by limited steam explosions.

Research results have demonstrated that in unfavourable conditions iodine may form organic compounds that are not easily absorbed in the containment or in the filter. Such conditions may occur at the Olkiluoto plant, if the water inside the containment is acidified due to chemicals released during the accident. Organic iodine may also be generated in the primary circuit, if iodine reacts with the hydrocarbons that are released, when the boron carbide contained in the control rods becomes oxidised during the core damage. To improve the possibilities for retaining organic iodine in the filtered venting system, chemicals have been added to the water in the scrubber tank of the system. To minimise the formation of organic iodine, it is also possible to control the pH of the containment water volume by a specific system. The function of the system is based on addition of NaOH to the fire fighting water reservoir which is used for filling of the containment in post-accident conditions. The lower drywell will be flooded from the wetwell prior to the NaOH supply and the lower drywell water pool pH will be kept above 7.

Protection against fires at the Olkiluoto NPP

The possibility of fires and the risks of nuclear power plant accidents arising from fires have been taken into account in the functional and layout design of the existing Olkiluoto plant. Fire safety has been improved in different areas of the fire protection at the existing Olkiluoto plant after commissioning. Although the loss of external electrical supply has been taken into account in the plant design, both units were provided with e.g. second start-up transformer, based on the experience gained from the fire of the electric supply unit in 1991, to improve the independency of plant's external grid connections. Furthermore, the main transformers, in-house transformers and start-up transformers are protected with a sprinkler extinguishing system, which reduces essentially the risks arising from transformer fires. The use of halon is forbidden in Finland since the year 1999 with the exception of some special items. Due to this the halon extinguishing systems at the existing Olkiluoto plant were replaced with other extinguishing systems by the year 2000. Fire risks have been assessed in a probabilistic risk assessment that concentrates on fire issues. Based on this the fire protection of cables, that are crucial to safety, have been improved by renewing fire detectors and improving fire extinguishing systems in cable tunnels. On the basis of the probabilistic risk assessment these improvements reduce the risks arising from fires considerably.

Modernisation and power uprating of Olkiluoto NPP in 1994–1998

The main goals of the modernisation project at the Olkiluoto NPP were the reviewing of safety features and enhancing safety, when feasible, improving the production related performance, finding factors limiting the plant lifetime and eliminating them, when feasible, and enhancing the expertise of the own staff and improving productivity. In order to achieve the safety goal, the existing plant design was reviewed and compared by the TVO to the present and foreseeable safety requirements. Compliance with the European Utility Requirements (EUR) was also reviewed. The feasibility of fulfilling new requirements set for the new nuclear power plants was considered case by case. The living PRA model of the plant was utilised in this context.

The most important safety related modifications included in the modernisation programme are listed below:

- Reactor pressure relief system was diversified by installing two additional relief valves.
- ATWS behaviour was improved by modifying some trip signals and making boron injection automatic and more effective.
- Additional severe accident mitigation measures were implemented.
- Earthquake resistance of the plant was checked and related modifications were made.
- Partial scram function was strengthened.
- Generator breaker was replaced with a new one, which is able to break also short circuit current.
- Protection against frazil ice at the seawater intake was improved.
- Protection against snowstorms at the air intake of the emergency diesels was improved.

Modification of the safety features in connection with the modernisation programme as a whole reduced the severe core damage frequency estimate by a factor of three.

The radiation exposure of the population was reduced in accordance with the ALARA principle. Liquid releases were reduced by a factor of ten by improving the liquid waste handling systems. Also occupational doses were reduced. In practice, this meant minimising the cobalt content in the primary circuit. Renewal of steam dryers reduced the occupational doses remarkably, because the moisture of the steam was reduced.

The development of the BWR technology, margins revealed by operational experience, and plant modifications due to other reasons made also power uprating possible. Thermal power was uprated from 2160 MW to 2500 MW (15.7%). The most important changes were made in fuel technology. The operation was changed from with 8×8 bundles to 10×10 bundles. The new bundles have 40 percent lower average linear heat rating than the old ones. Some additional design changes implemented due to the uprating were the increasing of inertia of the main circulation pumps electrically, steam separators replacement, high-pressure turbine and feed water system modifications, decay heat removal system capacity increasement, and generator and main transformers replacements. The low pressure turbines were also replaced and in that way about 30 MW additional production capacity in each unit was achieved.

The modernisation programme of the Olkiluoto plant units 1 and 2 was started in 1994 and completed in 1998. The installations were performed during the refuelling outages of the years 1996–1998. Some later installations were realised during outages in 1999. In spite of large modifications the refuelling outage times were reasonable, between 15 and 20 days. The test programme was quite the same as in the case of a new plant.

Test operations were conducted in stages at different power levels under STUK's supervision and within the frames permitted by STUK. Before uprating the reactor power to a higher power level STUK conducted a safety review concerning the test operation for the power level in question and asked the Nuclear Safety Advisory Committee for a statement concerning the review before granting the test operating licence.

Test operation programmes that included the entire plant units and were drawn up by TVO, were based on the original commissioning programmes that were run through during the start-up phase and that were modified taking into account the test requirements caused by the modernised systems. For the long-term test operation of the plant units the thermal power of reactor units were uprated step by step from the nominal power of 2160 MW to 2500 MW.

The most significant plant transient tests of the test operation were the load rejection test, turbine trip test and the by-pass test of the high-pressure preheaters. STUK considered it necessary to continue the test operation at the 2500 MW power level for about two months before issuing a statement in favour of continuing the operation of the plant units at the 2500 MW power level.

Licensing steps related to the modernisation programme included an uprated Safety Analysis Report (PSAR, for example) and an uprated Probabilistic Safety Assessment (level 1 PSA), which were reviewed and approved by STUK. Design modifications and test runs were accepted by STUK before implementation. The Final Safety Analysis Report (FSAR) and the related Topical Reports were rewritten. It meant also that almost all transient and accident analyses were redone taking into account the uprated power level and modified plant design. The FSAR and Topical Reports were submitted to STUK at the end of 1996. An operating licence renewal application, covering design modifications and the power uprating, was submitted to the Government at the end of 1996. The licence was granted in 1998. The power uprating was reviewed also according to the Environmental Impact Legislation.

Modernisation and power uprating project contained several safety, ageing and efficiency remedies. Mostly influences of modifications have been positive. A negative finding has been a slight increase of steam moisture. To improve this in both units steam dryers were replaced in outages 2005–2007. Another slightly negative finding was increase of condensate clean up temperature, which decreased the life cycle of clean up resins. To avoid this problem the location of condensate clean up system was changed in the process. In this context even the first LP-preheaters were replaced and modernised.

The modernisation of turbine plant was continued with replacement of steam reheater moisture separators (MSR). They were replaced with modern two stage MSR's. This replacement required modernisation of HP-turbine as well. These replacements were performed in outages 2005 and 2006. In the same outages the I&C system of the turbine plant process was be replaced with a modern digital one.

Turbine plant process automation system renewal (2004–2006)

A new computerised turbine plant automation system was installed in the Olkiluoto unit 2 in 2005 annual maintenance outage (equivalent modification was performed at Olkiluoto unit 1 in 2006). One reason to switch from analogue to programmable technology was the obsolescence the old system. In addition, the modifications made in the turbine plant process in 2005, and in 2006, required some additional modifications to the automation system. The new system improves information management and control of the turbine plant as well as facilitates component maintenance. Another system renewal objective is increased reliability and reduced susceptibility to malfunctions by added redundancy.

The new automation system is implemented by programmable technology. This allows an increased number of process status measurements and versatile information handling possibilities. As regards turbine automation, it facilitates for turbine operators improved information management, process control at operating work stations, trend monitoring and setting of safety limits. Safety limit settings enable turbine operator reaction to even minor process changes. The control desk for the turbine side in the control room was replaced with a safety function control desk and a turbine systems control and monitoring board with operator's work stations. The control room was also fitted with a screen display. In addition, the process computer system capacity had to be upgraded in connection with the control system renewal to handle the large volume of data yielded by the turbine automation. The automation interface was introduced at the Olkiluoto units 1 and 2 training simulator in September 2004, which made possible the training of operating personnel in its use.

Examples of latest plant modifications at the Olkiluoto NPP (2010–2012)

During the years 2010 and 2011, the Olkiluoto nuclear power plant implemented large modifications improving plant safety and the availability of the plant. During the maintenance outage 2010 at the Olkiluoto unit 1, the implementation of the PELE project (Plant Efficiency improvement Lifetime Extension) started with the replacement of the inner isolation valves of the main steam system, upgrade of the low pressure turbines, modernisation of the main service water pumps and the upgrade of the generator cooling water system. The project continued in the following years with the upgrade of the generator and the low voltage switchgear. At the Olkiluoto unit 2, a corresponding upgrade project started during the 2011 outage.

Replacement of the inner isolation valves of the main steam pipes

The main steam line isolation valves inside the containment were replaced at the Olkiluoto unit 1 during annual maintenance in 2010 and at the Olkiluoto unit 2 during annual maintenance 2011. The function of the valves is to isolate the reactor pressure vessel and prevent the loss of reactor coolant and releases of radioactivity outside the containment. The valves also function as a backup for the isolation valves outside the containment.

One reason for the valve replacement was the tendency of the old valves to close as the steam flow increases. In a situation where one valve closes, the steam flow through the other valves increases and this can make them close, too. The near simultaneous closing of all the steam line isolation valves causes a greater pressure rise and load on the reactor pressure vessel than the closing of one valve only.

The new valves are wedge gate valves, which operate on a medium (steam) and on pressurisation principle. This type of valve does not have the risk of self closing caused by a steam flow increase. The factory acceptance test of the valves revealed that the partial stroke function intended for periodic testing did not operate as planned, and the partial stroke related parts were removed from the valves before their installation at the power station. Provisions have been made for reinstalling the partial stroke function, and it will be possible when the manufacturer has demonstrated through extensive factory acceptance tests that partial stroke functions as planned.

STUK reviewed and assessed the valve design documentation before manufacturing, oversaw that manufacturing was in compliance with requirements, oversaw the factory acceptance tests at the manufacturer's site, installation and test runs at the power plant. The test runs of the valves were carried out in June according to the test programme. Leak-tightness tests, valve movement tests in cold and hot state, and testing with steam flow at 60% power of the plant were carried out acceptably.

Upgrade of the plant radiation measurement systems

In a radiation measurement equipment upgrade project, practically all stationary radiation measurement equipment will be replaced at the Olkiluoto units 1 and 2. The first new devices were installed and operational in 2008. Apart from the existing measurements, some completely new measurements will be installed in the project. The purpose of the test operation is to compare the measurement results of the new devices with the measurement results of the old devices. The aim has been to place the new devices in more representative places according to operating experience gained. Another aim has been to find alarm limit set values that would be optimal in terms of radiation safety and plant process monitoring. The radiation measurement system upgrade will still continue in the next few years.

Low-voltage switchgear replacement project

TVO has initiated a project (the SIMO project) for replacing the switchgears of the low-voltage distribution systems at the Olkiluoto units 1 and 2. The primary reason for replacing the switchgears is the increase in maintenance costs due to the ageing of original equipment, as well as the need to modernise the switchgear to correspond to the current requirements regarding plant and personnel safety. The replacement mainly concerns the switchgears and associated transformers of electrical systems important to safety. TVO has already replaced the medium-voltage switchgear (6.6 kV) in 2005 and 2006. The voltages in the low-voltage networks of the units vary from 24 V DC to 660 V AC. The switchgears are used to supply the required electrical power to the I&C systems and components of the units.

TVO made the first switchgear installations of the project in the 2010 annual maintenance. They concerned an electrical system less important to safety. During the 2011 annual maintenance outage of the Olkiluoto unit 2, TVO implemented the first switchgear replacement to systems important to safety so that the low-voltage switchgear in one of the plant's four subsystems was replaced with the associated transformers. TVO continued the project at the Olkiluoto unit 1 during the 2012 annual maintenance outage by replacing the switchgear of one subsystem.

Examples of latest incidents at the Olkiluoto NPP (2010–2012)

Blowdown system failure at Olkiluoto 1 and repair outage at Olkiluoto 2 in June 2010

The purpose of the blowdown system is to limit the pressure in the reactor by letting out steam from the reactor to the containment building if the normal route of the steam to the turbine is not available. The system consists of a total of 14 pipelines. Each pipeline has a valve, controlled by the I&C system of the reactor, that opens when the reactor pressure must be reduced. The valves can be opened either by an electric pilot valve or a pressure-operated pilot valve.

In a test carried out just before the shutdown of the Olkiluoto unit 1 for the annual maintenance outage in May 2010, two blowdown valves did not function as planned, so TVO decided to inspect their electrical pilot valves during the annual maintenance outage. The inspections revealed that three electrical pilot valves were jammed. All jammed pilot valves were of a new type. Five of these valves had been installed at the Olkiluoto unit 1 a year before. The five other electrical pilot valves were of the old type that has operated well for several years. Originally the decision to replace the valves was taken for the purpose of making their maintenance easier.

The jamming was caused by oxidation of the plating material inside the guide bushes that reduced the clearance between the valve piston and the guide bush and jammed the valve. TVO removed the electrical pilot valves of a new type during the annual maintenance outage of the Olkiluoto unit 1 and reinstalled the old-type valves. Operation of the blowdown system (overpressure protection of the reactor) was not at risk due to the faults detected, because the pressure-operated pilot valves were in operating condition.

Ten electrical pilot valves of a new type were installed at the Olkiluoto unit 2 in the annual maintenance in early May before the faults at the unit 1 were discovered. TVO verified the operability of the installed valves by tests carried out during the start-up of the Olkiluoto unit 2. As the valves installed at the unit 2 were similar to the ones at the Olkiluoto unit 1, the experience from the unit 1 suggested that there was a risk of the valves failing during the 2010–2011 operating cycle. TVO decided to replace eight valves with old-type valves. Two valves were replaced with new-type valves that had been modified after the fault was discovered. These two valves have a different coating on the guide bush, and the piston has a bigger clearance. The valves operated during start-up of the plant unit as well as in the tests performed in November 2010.

The fault did not endanger the safety of the plant or its surrounding environment. On the INES scale, the event was rated at level 1.

Use of a wrong fresh fuel delivery lot in fuel transfer planning at Olkiluoto unit 2

About one-fifth of the reactor fuel was to be replaced during the annual maintenance outage of Olkiluoto unit 2 in 2010. The fresh fuel assemblies had been moved to the fuel pool in the reactor hall earlier in the spring to wait for their transfer to the reactor core. In early June 2010, TVO realised that 36 fuel assemblies of the wrong delivery lot had been transferred to the pool. These assemblies were left in the fuel pool, and the correct assemblies were transferred from the store to the reactor.

The fuel assemblies are not of identical composition, because different lots may differ from each other, for example, with respect to their uranium 235 content and neutron-moderating materials. It is important from the point of controlling reactivity that the different properties of fuel assemblies are taken into account. In this case, the properties of the wrong fuel assembly lot did not significantly differ from those of the correct lot, which is why the reactor safety would not have been compromised even if the subject lot of fuel had ended up in the reactor. As a corrective action TVO developed its procedures so that similar events can in the future be prevented. The event was caused by an error in the document concerning the transfers of fresh fuel.

The safety of the reactor or the employees was not compromised. On the INES scale, the event is rated at level 1.

Defects in the internal parts of blowdown system valves at Olkiluoto 2 and repair outage at Olkiluoto 1

TVO discovered in the inspections performed during the annual maintenance outage of the Olkiluoto unit 2 in 2011 that there were cracks in the valve pistons of the system required for overpressure protection of and residual heat removal from the primary circuit. The inspections revealed other damage as well; for example, the hard chrome plating of the pilot cylinder had been damaged. However, the cracks and other damage had not affected the operation of the valves; they had operated correctly in regular tests.

TVO replaced the parts of the worst damaged valves during the annual maintenance. Not all damaged parts could be replaced due to an insufficient inventory of spare parts. On the basis of results from tests carried out during the preceding operating cycles, the valve manufacturer's assessment and analyses performed by VTT, TVO assessed that these valves were operable as well. Immediate replacement of the parts was not deemed necessary. Nevertheless, STUK found, on the basis of the reports produced by TVO regarding the faults discovered, that the original pistons and pilot cylinders of the valves were approaching the end of their life span. It was nevertheless not likely that the valves would quickly become inoperable, which is why STUK gave, on in June 2011, permission to start up the Olkiluoto unit 2 after the annual maintenance outage. STUK required that new spare parts should be changed to the valves immediately when a sufficient number of new spares has been received from the manufacturer. The requirement was to carry out the replacement by 15 September.

Olkiluoto unit 1 is using similar valves, which is why STUK required that TVO must also inspect them. During the repair outage of 26–29 June 2011, damage was observed in the pistons of four valves and in the pilot cylinders of 11 valves. TVO replaced them with flawless spare parts.

The faulty valves were part of a system intended for protecting the nuclear reactor against overpressure and for removing its residual heat in a situation where the steam generated in the reactor cannot enter the turbine plant. The necessary number of valves is opened, and the steam generated in the reactor is led along the system's pipelines to a condensation pool in the reactor containment building. From the condensation pool, the heat is transferred to the sea by other systems.

On the INES scale, the event was rated at level 1.

Deficiencies found in the operation of main steam isolation valves at Olkiluoto 1 and Olkiluoto 2

During the 2012 annual outage of Olkiluoto 1, TVO found that one of the reactor's main steam isolation valves would not have closed as planned when required. A missing valve control conductor was revealed as the cause of the deficiency. The conductor had been removed when four inner main steam isolation valves had been replaced in the 2010 annual outage. The conductor had not been replaced due to a modification design error. TVO carried out additional checks and tests at both plant units after the observation, and found the same deficiency also at Olkiluoto 2. In a turbine automation renewal carried out in 2005, a conductor had been unnecessarily removed. As a result, the same isolation valve as at Olkiluoto 1, and another isolation valve beside it, would not have closed automatically when required.

Olkiluoto 1 and Olkiluoto 2 both have four steam lines for conveying the steam generated in the reactor to the turbine plant. Each steam line has two isolation valves, one inside the containment wall and one on the outside. Their purpose is to close the steam lines in certain transient and accident situations, thus isolating the reactor and its containment in order to retain radioactivity within the containment. The missing control conductors did not belong to these main valves. Instead, the concerned isolation valves were located side by side outside the containment on a pipeline that is used to let the steam released from under the valve piston of closing pressure-operated isolation valves into the containment condensation pool. These two external isolation valves are located on a closed circuit, which means that steam and radioactive substances carried by the steam could not have been released outside the containment even if the valves had been left open.

The events did not put the safety of the plant or the environment at risk, but revealed deficiencies in modification planning and the coverage of testing. TVO installed the missing conductors immediately after the events were detected. TVO will also investigate the coverage of testing more extensively and improve the process used to ensure that modifications are ready to be implemented.

The events of both plant units were rated as INES category 1. The classification is based on a modification error.

Periodic safety reviews at the Olkiluoto NPP

During the years 1996–1998 the overall safety review of the Olkiluoto plant was carried out by the licensee and independently by STUK in connection to the renewal of operating licences of nuclear power plant units. The safety documentation, including safety assessments done by the licensee, was submitted to STUK at the end of 1996. In addition to the review of the licensing documents such as Final Safety Analysis Report, STUK also made an independent safety assessment. The statement of STUK was given to the Ministry of Trade and Industry in June 1998. As regards radiation and nuclear safety, the main conclusions in the statement were that the conditions of the Finnish nuclear energy legislation are complied with.

The latest overall safety review of the Olkiluoto plant took place in 2007–2009 in connection of the periodic safety review. The operating licence for Olkiluoto NPP units 1 and 2, required that a comprehensive periodic safety review (PSR) shall be carried out by the end of 2008. The operating licence also covers the interim storage facilities for spent fuel and medium and low activity operational waste, so these facilities were also included in the PSR. Regulatory guide YVL 1.1 specifies the contents of the PSR. For a separate periodic safety review, STUK shall be provided with similar safety-related reports as in applying for the operating licence.

TVO began preparations for the periodic safety review a few years after the current operating licence was granted. The PSR documentation was submitted to STUK for approval in the end of 2008. STUK made a decision concerning the PSR in October 2009. In the STUK's decision the licensee's PSR was approved as a comprehensive periodic safety review according to the licence condition. The decision included also STUK's safety assessment which provided a summary of the reviews, inspections and continuous oversight carried out by STUK.

The issues addressed in the assessment and the related evaluation criteria are set forth in the nuclear energy and radiation safety legislation and the regulations issued thereunder. Based on the assessment, STUK considered that the Olkiluoto Nuclear Power Plant units 1 and 2 meet the set safety requirements for operational nuclear power plants, the emergency preparedness arrangements are sufficient and the necessary control to prevent the proliferation of nuclear weapons has been appropriately arranged. The physical protection of the Olkiluoto nuclear power plant was not yet completely in compliance with the requirements of Government Decree 734/2008, which came into force in December 2008. Further requirements concerning this issue based also on the principle of continuous improvement were included in the decision relating to the periodic safety review.

The safety of the Olkiluoto nuclear power plant was assessed in compliance with the Government Decree on the Safety of Nuclear Power Plants (733/2008), which came into force in 2008. The decree notes that existing nuclear power plants need not meet all the requirements set out for new plants. Most of the design bases pertaining to the Olkiluoto 1 and 2 nuclear power plant units were set in the 1970s. Substantial modernisations have been carried out at the Olkiluoto 1 and 2 nuclear power plant units since their commissioning to improve safety. This is in line with the principle of continuous improvement of safety provided in section 7 a of the Nuclear Energy Act. The safety of the plant will be further improved during the current operating licence period. Based on the periodic safety review, TVO submitted to STUK action plans for the observed points requiring improvement. STUK included also some additional requirements in the decision relating to the periodic safety review. Systematic assessment and development of the diversity principle was required, including investigation of possibilities for residual heat removal to be independent of seawater. TVO submitted a report regarding the adequacy of the diversification at the plants and an action plan for developing the plants at the end of 2010. STUK approved the report in 2012. Another requirement considered plant modifications to improve safety in situations involving spurious opening of the turbine bypass valves. TVO has submitted required report and STUK has approved TVO's disquisition and action plans to improve the situation.

As a summary of the review of the issues and documentation pertaining to the periodic safety review and the continuous oversight results, STUK noted that the safety of the Olkiluoto nuclear power plant units 1 and 2 is sufficient and the licensee utilises the necessary arrangements to continue the safe operation of the plants.

Planned and ongoing activities to improve safety at the Olkiluoto NPP

In Finland, the continuous safety assessment and enhancement approach is presented in the nuclear legislation. Actions for safety enhancement are to be taken whenever they can be regarded as justified, considering operating experience, the results of safety research and the advancement of science and technology. The implementation of safety improvements has been a continuing process at the Olkiluoto nuclear power plant units 1 and 2 since their commissioning and there exists no urgent need to upgrade the safety of these plant units in the context of the Convention.

There are several ongoing and planned safety upgrading measures at the Olkiluoto nuclear power plant. For example diversification of reactor water level measurements and construction of an emergency control room are under design. In addition, in the last periodic safety review, STUK requested TVO to perform a comprehensive survey on the sufficiency of diversification at the Olkiluoto units 1 and 2 and a plan on measures to develop diversification by the end of 2010.

The reactor water level measurement system consists of four parallel subsystems, two of which are sufficient for implementing the protection function (from high and low level). The subsystems are based on differential pressure measurement. TVO has studied possibilities to supplement the currently used low level measurement system with another system based on a different measuring principle. TVO's plans to implement the modification has been delayed. The current plan is to install the new devices for test use in annual outages 2015 and 2016.

Safety assessments and improvements based on the lessons learnt from TEPCO Fukushima Dai-ichi accident

Natural hazards

Safety margins were assessed by the licensee and reviewed by STUK. Based on the results, STUK required further clarifications on the following main points:

- seismic resistance of spent fuel pools including situations with water temperature exceeding the design bases; and
- seismic resistance of fire fighting systems.

The licensee of the Olkiluoto NPP was also requested to carry out a more detailed assessment on the effects of exceptionally high seawater level on the cooling systems of the spent fuel interim storage and their electric power supply. Cooling system pumps are situated at the +0.5 m level. The spent fuel interim storage is designed as watertight up the seawater level +1.2 m. At higher seawater levels some seepage of water through the soil to the drainage system is anticipated. According to the licensee, the seepage would be stable and slow and the water could be removed with submersible pumps. Fast flooding of the interim storage would be possible through the doors if the seawater level exceeds +3.5 m and through the seam between the seawater pumping station and seawater pipe culvert at the level +2.5 m. The licensee has submitted plans for tightening the aforementioned seam and submitted by the end of 2012 plans for further improving the protection of the interim storage against flooding, including increase of the capacity of the submersible pumps.

Design issues

At the Olkiluoto units 1 and 2, sea water is the primary ultimate heat sink and an alternative heat sink exists only partially. Both units can evaporate residual heat from the reactor core to atmosphere by conducting the steam produced inside the reactor pressure vessel to the condensation pool through the safety relief valves, by 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 the sea water based component cooling systems or on the condensation pool water, which means that the complete loss of sea water as the ultimate heat sink will eventually prevent the supply of water to the reactor pressure vessel.

Licensee is planning plant modifications on the current residual heat removal chain to decrease the dependence on the sea water cooling. A modification in the auxiliary feed water system is planned to enable cooling of the components by demineralised water in addition to sea water based cooling chain. By this modification system can remain operational for a significant period of time even during the loss of the primary ultimate heat sink (sea water). Modifications are scheduled for 2014-2015. In addition, an independent way of pumping water to the reactor pressure vessel is being planned by the licensee in case of loss of AC power. The arrangement will be based on the fire fighting water system with additional booster pumps and an own diesel aggregate. Also a steam driven pump is considered for the early phases of the accident to cool reactor in high pressure.

At the Olkiluoto units 1 and 2, the current AC power supply systems include connections to 400 kV and 110 kV power grids, main generator (house load operation), four emergency diesel generators per unit, a gas turbine, a dedicated connection to a nearby hydropower plant, and the possibility to supply electricity from the neighbouring NPP unit. The licensee has decided to renew all the eight emergency diesel generators. Several plans, surveys and studies have been prepared for this project and the investment decision was made in May 2013. The renewal plan includes several safety improvements. First of all, the new EDGs would be equipped with two diverse component cooling systems. The primary EDG cooling would be provided by the sea water based cooling system, similar to present EDGs units. An alternative, automatically activated air based cooling system would be added to cope with the loss of sea water situations. This would provide extra protection against external hazards, internal hazards such as fires, as well as component failures. Also one extra diesel generator is under consideration to supply water to reactor in case of loss of other AC power.

At the Olkiluoto units 1 and 2, the depletion times of DC batteries are well above 10 h, in some cases tens of hours. It is possible to charge the batteries using the AC power sources. DC batteries supplying the severe accident monitoring systems can be also charged by mobile generators. The licensee is investigating the possibilities for fixed connection points for recharging of all safety important batteries using transportable power generators.

At the Olkiluoto units 1 and 2, the licensee has evaluated that water injection into the pool and boiling of the pool water could be used as an alternative means to remove decay heat from the pools inside the reactor building. To support monitoring of the water level in the reactor building spent fuel pools, there is a plan to equip the fuel pools with a level measurement system. Possibilities for adding makeup water from the fire fighting system to the pools from safe locations will be provided. The pool water level indications will also be routed to those locations. Modifications will be done during 2013-2014. External junctions to the interim spent fuel storage pool (outside the reactor buildings) water system will be added at the Olkiluoto NPP during the enlargement project of spent fuel storage in 2013. Feed of water to the fuel storage pools will be possible from fire-fighting vehicle via those junctions.

At the Olkiluoto units 1 and 2, the licensee started the investigation of needs and targets for mobile power supply in autumn 2011. Investigation includes also renewal of the present mobile SAM diesel generators. Five aggregates stored on the site are under consideration. Enhancing charging of batteries has also been found feasible to improve the availability of DC power. The licensee is investigating the possibilities for fixed connection points for recharging of the safety important batteries using transportable power generators. Investigation of needs and targets for mobile power supply has been started in autumn 2011 and is expected to be completed by the end of 2012. Procurement of the devices and needed modifications are expected to begin in 2013.

Severe accident management

A comprehensive severe accident management (SAM) strategy has been developed and implemented at the Olkiluoto units 1 and 2 during 1980's and 1990's after the accidents in TMI and Chernobyl (see above). These strategies are based on ensuring the containment integrity which is required in the existing national regulations. STUK has reviewed these strategies and has made inspections in all stages of implementation.

As a result of the studies made after the TEPCO Fukushima Dai-ichi accident, no major changes at the plants are considered necessary. However, the licensee is expected to consider also spent fuel pools in the SAM procedures as well as any implications on them possibly arising from simultaneous multi unit accidents. In addition, there are many actions related to the update of the emergency plans.

Hydrogen leakages out of the containment during severe accidents has been analysed for all Olkiluoto NPP units, and the results show that design leakages do not cause a threat to the containment integrity. For spent fuel pools, the approach in Finland is to "practically eliminate" the possibility of fuel damage. The possibility of top venting of reactor hall will be designed at the Olkiluoto units 1 and 2 in 2013 for the steam release in case of spent fuel pool boiling. Hydrogen possibly formed in the spent fuel pools could be exhausted through this route as well.

Enlargening of the spent fuel storage

TVO is in the process of expanding capacity of the the spent fuel interim storage (the so-called KPA storage) at Olkiluoto by three additional pools, and the storage structures will also be modified at the same time to comply with the current safety requirements. The current KPA storage capacity in Olkiluoto will be sufficient until 2014, and the expansion will increase the capacity for the spent fuel coming from the Olkiluoto plant units 1, 2 and 3. TVO submitted the documentation regarding expansion of the storage to STUK for approval at the end of 2009. The extension of the storage is designed to fulfil the current safety requirements, the most significant of which are its ability to withstand the crash of a large airliner and its seismic resistance. At the same time, the structures of the existing part of the storage will be modified with a view to the current requirements. In conjunction with assessing the safety of the expansion, STUK inspected the needs to update the earlier design basis and safety analyses, the resources and operational methods of TVO's project organisation, the structural design basis of the storage, as well as the methods with which TVO will ensure the safety of the storage in operation. Following its inspections, STUK found that the storage expansion meets the safety requirements. STUK has also reviewed the plans for the systems that will change with the expansion. The design and implementation of construction engineering structures are overseen by an inspection organisation approved by STUK. STUK has been overseeing and guiding the work of the inspection organisation.

Renewal of the diesel generators

TVO has investigated the possibilities for replacing all current emergency diesel generators (EDGs) of the Olkiluoto units 1 and 2 with their auxiliary systems to correspond with the changed need for power, taking also into account any increases in the need for power due to possible future plant modifications as well as the lessons learnt from the TEPCO Fukushima Dai-ichi accident in relation to securing the power supply. The nuclear safety requirements dictate that a power margin of at least 10% is available in all load conditions. Furthermore, both main components of the EDGs (the diesel engine and the generator) are old models, whose development and manufacture has been discontinued, and the availability of spare parts and the supplier's technical support are declining.

The purpose of the emergency diesel generators and their associated auxiliary systems is to supply electrical power to the 660 V emergency power system in case of loss of supply from the 6.6 kV main bar. Both plants have four subsystems, and each subsystem has its own standby diesel generator. Replacement of the diesel generators will also mean that the main switchgear in the 660 V emergency power network has to be replaced; this will be done as part of the replacement of low-voltage switchgear as a modification project separate from the replacement of the EDGs.

The intention is to implement the EDG replacement project during the normal operation of the plant units as far as possible. According to the plan, the new EDGs will be installed and commissioned during power operation so that one new EDG is installed to both plant units during one power operation cycle. For this purpose, a ninth EDG unit has to be constructed to replace any one of the current EDGs of the Olkiluoto units 1 or 2. In the future, the ninth EDG can be connected to replace an EDG undergoing periodic maintenance at the Olkiluoto units 1 or 2, or it can replace a failed EDG. A new building will be constructed for the ninth EDG, while the replacement EDGs will be installed at the same premises where the current units are located.

In late autumn 2011, TVO submitted a conceptual design plan regarding the replacement of EDGs to STUK for approval. The conceptual design plan was approved by STUK. According to the preliminary schedule, the EDGs will be installed and commissioned during 2016–2020.

Construction of an emergency control room

Pursuant to a Government Decree, a nuclear power plant shall have an emergency control room independent of the main control room, and the necessary local control systems for shutting down and cooling the nuclear reactor, and for removing residual heat from the nuclear reactor and spent fuel stored at the plant in a situation where operations in the main control room are not possible.

TVO is in the process of constructing emergency control rooms for the Olkiluoto units currently in operation in compliance with the requirements set out in STUK's implementation decision regarding Guide YVL 5.5 and in the periodic safety review of the Olkiluoto NPP. The project is currently in its pre-planning phase, and STUK has reviewed and approved the conceptual design plan of the emergency control rooms in 2012.

ANNEX 4 Olkiluoto NPP unit 3 under construction

Licensing steps

Decision-in-Principle procedure was carried out during the period November 2000 – May 2002 when Teollisuuden Voima Oyj (TVO) applied a Decision-in-Principle for the fifth NPP unit in Finland and the Government approved it and the Parliament confirmed the approval. Construction Licence application for the Olkiluoto unit 3 was submitted by TVO to the Ministry of Trade and Industry (predecessor of the Ministry of Employment and the Economy) in January 2004. The new unit, Olkiluoto 3 is a 1600 MWe European Pressurised Water Reactor (EPR), the design of which is based on the French N4 and German Konvoi type PWR's. A turn key delivery is provided by the Consortium Areva NP and Siemens. The technical requirements for Olkiluoto unit 3 were specified by using the European Utility Requirements (EUR) document as a reference. TVO's specifications complemented the EUR mainly in those points where Finnish requirements are more stringent. STUK gave its statement and safety assessment in January 2005 based on the review of the licensing documentation and the Government issued the Construction Licence in February 2005.

Construction of the Olkiluoto unit 3 still continues. In the turbine island, Siemens has started cold commissioning of the systems after finalising

Figure 22. Olkiluoto NPP unit 3 construction site in April 2013. Source: TVO.

construction and installation works. In the nuclear island, erection of systems, structures and components continues. Next major licensing step is the Operating Licence. Operating Licence is needed prior to loading nuclear fuel into the reactor core. IAEA has agreed to carry out a pre-OSART (Operational Safety Review Team) mission to Olkiluoto NPP before core loading.

Challenges

Currently, the licensee and the vendor don't have commonly approved schedule for the project. The licensee has given a notice that the start of the commercial electricity production of the Olkiluoto unit 3 may be postponed until year 2016. There are certain factors that have affected greatly the project progress. Olkiluoto unit 3 is the first European Pressurised Reactor (EPR) being constructed. Construction of the unit started after a long break in nuclear power plant construction in Europe, which had resulted in loss of experienced and qualified engineering and manufacturing resources. Lack of knowledge on Finnish regulatory framework and safety requirements, insufficient completion of the design prior to construction, some difficulties with advanced manufacturing and construction technologies and lacks in safety culture in the earlier phase of construction works at site have been challenging aspects in the project and caused delays. On the other hand parties have succeeded to find deviations induced during the project and the end products have finally fulfilled quality, performance and safety requirements.

The issue which at the moment set also the timeline of the project is the licensing of I&C architecture and systems. Using of integrated, software based I&C platforms sets new requirements for designing, safety analyses as well as for implementation and testing of the systems. Configuration and requirement management and verification & validation actions are more essential role during these phases than earlier when analog systems were used. The main issues where STUK has asked more clarification concern defining and management of interfaces of different I&C systems so that failure of one system can't disturb other systems. STUK has also asked more clarification how possible spurious actions are taken into account in the design and corresponding safety analyses. The vendor and the licensee are now finalising plans for I&C system architecture as well as answers for STUK's clarification requests.

Regulatory oversight

During the construction, STUK oversees the project very comprehensively. The licensee's performance is evaluated via Construction Inspection Program. The purpose of the program is to verify that the performance and organisation of the licensee ensure high quality construction and implementation in accordance with the approved designs while complying with the regulations and STUK's decisions. Under Construction Inspection Program STUK has performed around 15 inspections every year. Some of the inspections are unannounced inspections.

In addition to Construction Inspection Programme, STUK has strong on-site presence by the resident inspectors at the construction site. There are three to four resident inspectors dedicated for Olkiluoto unit 3 project. This provides STUK constant flow of information and oversight capabilities and gives additional information on licensee's activities. STUK has therefore also very quick ability to response to any immediate safety concern or incident with short notice. Findings made by resident inspectors are also important inputs for the construction inspection programme inspections.

The construction of a nuclear facility shall not begin before the Government has granted the Construction Licence. After that, prior to start manufacturing, installation or commissioning of the system, structure or component, STUK's approvals for the detailed design or plans are needed. STUK also approves manufacturers of nuclear pressure equipment for their duties and inspection organisations and testing organisations for duties pertaining to the control of pressure equipment at nuclear facilities. During the Olkiluoto unit 3 project, STUK has reviewed more than 14000 documents – about 9000 of them are submitted to STUK for approval.

STUK also inspects the compliance of the design and manufacturing of mechanical components and structures. Inspections are performed during and after the manufacturing in manufacturers' premises and at the site after installation and during commissioning. In lower safety classes these inspections are conducted by Inspection Organisations.

Based on the findings made during the technical inspections, inspections under construction inspection programme, document reviews and other visits during construction, STUK prepares annually a comprehensive safety evaluation how safety aspects are fulfilled and taken into account during the construction. The experience has shown that STUK's practice to oversee the project in all level of activities has been effective way to find possible weak points and deviations in early phase of the project. Translations of annual report can be found from the STUK's website.

Safety assessments based on the lessons learnt from TEPCO Fukushima Dai-ichi accident

Following the accident at the TEPCO Fukushima Dai-ichi nuclear power plant on the 11th of March in 2011, safety assessment of Olkiluoto unit 3 was initiated. The topics included the preparedness against loss of electric power supply, loss of ultimate heat sink and extreme natural phenomena. As being a unit under construction, any immediate actions were not necessary, but STUK required the licensee to carry out additional assessment and present an action plan for safety improvements. Assessment was conducted and reported by the licensee to STUK on 15 December 2011. STUK reviewed the assessment and made decision on 19 July 2012 on the suggested safety improvements and additional analyses.

Figure 23. STUK's resident inspector performing construction inspection for primary circuit piping.

External conditions in Finland are moderate. No destructive earthquakes or tsunami waves have been observed. Storms are not comparable to tropical cyclones and strong tornadoes are quite rare. Olkiluoto unit 3 fulfils the current regulatory requirements concerning external events. The design basis of Olkiluoto unit 3 for external events has been selected conservatively in the design phase. The design basis covers earthquakes, internal and external flooding, extreme weather and other natural hazards (like snowstorms, frazil ice formation and impurities in the seawater) as well as human induced hazards. The design values correspond to return periods of up to 100 000 years and much longer for events with "cliff edge" type consequences. As the estimated conditions corresponding to such long return periods involve large uncertainties, considerable physical margins to the largest values observed in the neighbourhood of the site have also been ensured.

The ultimate heat sink of the Olkiluoto unit 3 is the sea. In case of the total loss of the availability of sea water for cooling, the residual heat from the reactor core would be released to the atmosphere via the steam generators. During refuelling outage the containment filtered venting could be used. Filtered venting system is not an original safety feature of EPR concept but it was required by STUK in an early phase of the conceptual design of Olkiluoto unit 3 to ensure the pressure management of the containment during severe accidents. The licensee has assessed possibilities to implement external feed water connections to the steam generator secondary side, connections to external AC power supply and external make-up water injection into the reactor cooling system during refuelling outages in order to have independent means to fulfil residual heat removal function in case plant's normal systems are lost. STUK is currently evaluating licensee's plans.

In the fuel building, the spent fuel pools could be cooled by evaporation. The possibility to use fire water systems and boiling of the pool water has been evaluated. Additional mobile pumps to provide water injection into the fire fighting water system are to be acquired before the start of operation of the Olkiluoto unit 3. The needed external connection points, as well as temperature and level measurements are included in the design of the fuel building systems. Additional measurements to monitor the water level in the pools are to be implemented.

The current AC power supply systems of the Olkiluoto unit 3 include connections to 400 kV and 110 kV power grids, main generator (house load operation), four emergency diesel generators (EDGs), two station black out (SBO) diesel generators, a gas turbine and the possibility to supply electricity from the neighbouring NPP units via 400 kV switchyard. To ensure long autonomy of SBO diesels the licensee has planed to add possibilities to move fuel from EDG storage tanks to SBO diesels.

For uninterrupted power supplies, there are separate and diversified 2 h and 12 h battery backed power supply systems. The first set of batteries supplies all electrical equipment which require uninterruptible power in the nuclear island and the second set of batteries supplies loads which are important in case of a severe accident. The licensee evaluates that there is no need for upgrading the battery capacity.

Severe accidents have been considered in the original design of the Olkiluoto unit 3. STUK has reviewed the overall SAM strategy and the approach has been accepted. No changes to this approach are expected based on current knowledge from the TEPCO Fukushima Dai-ichi accident.

ANNEX 5 Olkiluoto NPP unit 4 and Hanhikivi NPP unit 1 in planning phase

Environmental Impact Assessment of new nuclear power plants and candidate sites

In 2007, initiatives for building additional nuclear power plant units in Finland were announced. Environmental Impact Assessment (EIA) was carried out according to EIA legislation for the possible Olkiluoto 4 and Loviisa 3 units in 2007–2009. The Competent Authority for EIA procedure for NPP's in Finland is the Ministry of Employment and the Economy.

A new nuclear power company, Fennovoima Oy, was founded in 2007. The company started a preliminary site survey process, mainly on the coast of the Gulf of Bothnia (the northern gulf of the Baltic Sea) and on the eastern Gulf of Finland (the eastern gulf of the Baltic Sea), the northernmost candidate site being 20–30 km from the borderline of Sweden. Fennovoima prepared an EIA programme and subsequently an EIA report for three (originally four) alternative new candidate sites in 2007–2009.

The EIA process did not reveal any major nuclear or radiation safety issues as regards the proposed new NPP sites or new units on the existing sites. EIA is a legal process to cope comprehensively with the environmental issues depending on the specific site (e.g. sea environment and eutrophication, special natural species and phenomena, biodiversity, Natura natural reserve assessment, fisheries, salmon migration, combined heat and power production) and to increase the opportunity for citizens and other stakeholders to receive informa-

Figure 24. Hanhikivi site in Pyhäjoki selected for Fennovoima new NPP (FH-1). Source: Fennovoima.

tion, become involved in the planning and express their satetments and opinions on the project.

Comments were requested from altogether nine countries near the Baltic See by the Finnish Environmental Ministry on the basis of so called Espoo convention. Several comments from e.g. Estonia, Sweden and Germany were given and considered by the Finnish authorities. Additionally, the Austrian Government as a party of the Espoo convention sent their statement on each EIA and requested for consultation in Finland. Thus, subsequent meetings were arranged in 2008–2009 at the Finnish Ministry of the Environment where a Finnish delegation of experts from the utility concerned, STUK and the Ministry of Employment and the Economy gave detailed explanations to the questions provided.

Separate applications for the Decision-in-Principle for new NPP units were submitted to the Government in 2008 and 2009 by TVO, Fortum and Fennovoima. The relevant site-related factors potentially affecting the safety of a the planned new NPP units and the related nuclear facilities during their projected lifetime were evaluated for the existing Loviisa and Olkiluoto sites and for the alternative new sites at Pyhäjoki, Simo and Ruotsinpyhtää proposed by Fennovoima. In late 2009, Fennovoima removed the Ruotsinpyhtää site from its application for the Decision-in-Principle. The evaluations were reviewed by STUK and other expert organisations in their respective fields. In addition to the Finnish regulations, IAEA Safety Requirements and Safety Guides and WENRA requirements were considered in the review.

Specific issues regarding the new sites are the size of precautionary action zone (5–6 km radius in Finland), the limitation of maximum population within it which may be affected in a severe accident situation and the possibility to evacuate the population. According to the Finnish regulations, an early evacuation before an expected release shall be possible within a time of four hours from the evacuation decision. The population in 2010 in the vicinity of the Finnish candidate sites is internationally compared relatively small (maximum of 3000 inhabitants up to 6 km from the site at Simo).

According to STUK's preliminary safety assessments, no site related factors were found at any of the sites which would prevent building the proposed new NPP units and the related other nuclear facilities according to the safety requirements. More detailed evaluation of the site related factors will be conducted and site characterisation is accepted in connection with the Construction Licence process.

Fennovoima completed site selection process in October 2011 by selecting Hanhikivi site in Pyhäjoki. The company stated that the main technical arguments for site selection were bedrock intackness, lower seismicity, shorter cooling water tunnels and population density.

Decisions-in-Principle and safety assessments of new nuclear power plant units

Three new nuclear power plant units have been under consideration in Finland (see more details of the licensing process under Articles 7 and 17). TVO submitted application for a Decision-in-Principle (DiP) to the Ministry of Employment and the Economy in 2008, Fennovoima and Fortum in 2009. In addition, two DiP applications by Posiva Oy have been handled for the expansion of the planned capacity of spent fuel repository for Olkiluoto 4 and Loviisa 3 units. The applications for NPP units were accompanied by documents of a total of seven alternative plant designs.

In the Decision-in-Principle (DiP) the Government judges whether the proposed use of nuclear energy is in line with the overall good of society. STUK gave the Ministry of Employment and the Economy preliminary safety assessments of all Decision-in-Principle applications in 2009. STUK's preliminary safety assessments consisted of an assessment of the safety of the plant alternatives and the sites as well as of an assessment of the organisations, expertise and the quality management of the applicant. The assessments also covered the physical protection and emergency preparedness arrangements, nuclear fuel and nuclear waste management, nuclear liability and non-proliferation. STUK stated in its preliminary safety assessment whether any factors have arisen indicating a lack of sufficient prerequisites for constructing a nuclear facility as prescribed in the Nuclear Energy Act. Safety assessment was based on the Government Decrees issued under the Nuclear Energy Act. Furthermore, STUK took a stand on the possibility of fulfilling other requirements laid down in legislation and YVL Guides as regards the issues to be reviewed by STUK. The aim of the preliminary safety assessment was to find any “show stoppers” in sites, organisations or plant design alternatives. Seven different plant design alternatives were assessed during the preliminary safety assessment period: ABWR (Toshiba-Westinghouse), AES-2006 (Atomstroyexport), APWR (Mitsubishi Heavy Industry), APR-1400 (Korean Hydro and Nuclear Power), ESBWR (GE Hitachi), EPR (AREVA) and KERENA (AREVA).

Most of the plant alternatives reviewed in the STUK’s preliminary safety assessments did not meet Finnish safety requirements as such. The nature and the extent of the required modifications vary between the plant alternatives. Some plant alternatives would only require fairly minor modifications; some would require more extensive structural modifications. The required technical solutions are still open for some alternatives.

All DiP applications were handled simultaneously and in May 2010 the Government granted two Decisions-in-Principle, one to Teollisuuden Voima Oyj (TVO) and another to Fennovoima Oy. TVO’s DiP was granted according to the application to build Olkiluoto unit 4 (OL4), single reactor with maximum output of 4600 MWh. In the Fennovoima’s case Government granted DiP only for a single reactor with maximum reactor power of 4900 MWth, although Fennovoima applied to build one or two reactors with maximum reactor power of 4300–6800 MWth.

The Government also granted a Decision-in-Principle for Olkiluoto unit 4 spent fuel final disposal, applied by the spent fuel management company Posiva Oy. For Fennovoima’s spent fuel disposal, the Government gave two options. By mid 2016, Fennovoima shall present an co-operation agreement of spent fuel final disposal with TVO and Fortum (the owners of Posiva) or start its own EIA process for the spent fuel final disposal. Regardless of the option chosen a separate DiP will later be required for disposing of the spent fuel from Fennovoima’s planned reactor unit. For this DiP process also the corresponding EIA report needs to be updated or prepared for a possible new site.

At the same time the Government rejected Fortum’s DiP application to construct a new reactor to Loviisa site (Loviisa unit 3), as well as the DiP application for expanding the capacity of the spent fuel disposal facility to include also the spent fuel from the Loviisa unit 3 was rejected.

According to the Nuclear Energy Act, the granted DiP’s were sent without delay to the Parliament for confirmation. The Parliament may reverse the Decision-in-Principle as such or may decide that it remains in force as such. After the hearings in the all main permanent committees, the Parliament ratified both granted NPP applications on the 1st of July 2010. The both Decisions-in-Principle for new reactors state that the construction licence shall be applied within five years from the Parliaments confirmation. This sets the schedule for Fennovoima and TVO to conclude their preparations for the construction licence applications to the Government by mid 2015.

Preparations for the construction licence phase

According to the Nuclear Energy Act, the applicant may ask advice or sent plans for STUK’s review before the applications are filed to the Government. With this mandate, the utilities and STUK have had meetings to be prepared for the construction licence safety assessment process. STUK has organised seminars with licence applicants on construction licence application requirements in relation to the plant design processes and shared the lessons learned from the Olkiluoto unit 3 construction project as well as had seminars on requirement management. Process system and plant engineering (layout) design maturity in PSAR phase is dominating factor for successful construction licence application review. Also both applicants have sent nuclear safety related bid requirements to STUK for information. These are the first steps for STUK to prepare regulatory project for construction licence review phase.

The main challenge for the upcoming construction licence application review is to conclude the renewal process of the legislation and the regulatory guides – new YVL guides. Another challenge for STUK is to recruit the needed competent regulatory staff if two new NPP projects will commence simultaneously.

ANNEX 6 Implementation of the IAEA Action Plan on Nuclear Safety

The transparency and international co-operation are one of the corner stones in the Finnish nuclear safety policy. Finland has signed the international conventions and treaties aiming on safe and peaceful use of nuclear energy. After the TEPCO Fukushima Dai-ichi accident, Finland signed among 130 other countries in the General Conference in September 2011 the IAEA Action Plan. The twelve main actions included in the IAEA Action Plan and the related Finnish measures are discussed in this Annex.

Safety assessments in the light of the accident at TEPCO's Fukushima Daiichi NPP

Undertake assessment of the safety vulnerabilities of nuclear power plants in the light of lessons learned to date from the accident

Following the accident at the TEPCO Fukushima Dai-ichi nuclear power plant on the 11th of March in 2011, safety assessments in Finland were initiated after STUK received a letter from the Ministry of Employment and the Economy (MEE) on 15 March 2011. The Ministry asked STUK to carry out a study on how the Finnish NPPs have prepared against loss of electric power supply and extreme natural phenomena in order to ensure nuclear safety. STUK asked the licensees to carry out assessments and submitted the study report to MEE on 16 May 2011. Although immediate actions were not considered necessary, STUK required the licensees to carry out additional assessments and present action plans for safety improvements. Assessments were conducted and reported by the Finnish licensees to STUK on 15 December 2011. STUK has reviewed the results of national assessments, and made licensee specific decisions on 19 July 2012 on the suggested safety improvements and additional analyses.

Finland also participated in the EU Stress Tests and submitted the national report to European Commission at the end of 2011. An EU level peer review on the report was completed by April 2012. The recommendations of the EU peer review have been taken into account in the regulatory decisions and will be considered in the development of national regulations. In addition, Finland participated in the second Extraordinary Meeting of the Convention of Nuclear Safety (CNS) in August 2012 and prepared a report introducing national actions in Finland initiated as a result of the TEPCO Fukushima Dai-ichi accident. STUK has prepared a National Action Plan in the framework of EU stress tests addressing the measures initiated on a national level and at the nuclear power plants as a result of the TEPCO Fukushima Dai-ichi accident. The National Action Plan takes into account the national safety assessments and related regulatory decisions as well as the recommendations from the EU stress tests and Extraordinary CNS. All STUK's related decisions, the national report to European Commission, the report to the Extraordinary CNS, and the National Action Plan have been published on STUK's website.

Based on the results of assessments conducted in Finland to date, it is concluded that no such hazards or deficiencies have been found that would require immediate actions at the Finnish NPPs. Areas where safety can be further enhanced have been identified and there are plans on how to address these areas. The experiences from the TEPCO Fukushima Dai-ichi accident are also taken into consideration in the ongoing renewal of the legislation and Finnish Regulatory Guides (YVL Guides).

IAEA peer reviews

Strengthen IAEA peer reviews in order to maximize the benefits to Member States

Finland regularly hosts international peer reviews and also offers its experts for the review in other countries. Finland also supports activities to improve peer review services and has already participated in the development of IAEA's peer review services (e.g. IRRS and the OSART missions for construction).

The latest peer reviews in Finland are the following:

- IAEA OSART safety review at Loviisa NPP in March 2007, with a follow-up review in July 2008
- WANO peer review at Loviisa NPP in March 2010, with a follow-up in April 2012
- WANO peer reviews at Olkiluoto NPP in 2006, with a follow-up in August 2009, and in 2012
- IAEA's International Physical Protection Advisory Service (IPPAS) mission in Finland in 2009, with a follow-up mission in April 2012
- A Peer Review of STUK's waste management related activities in 2009 (all EU member states were invited and representatives from 11 countries participated in the peer review)
- In 2011 STUK hosted a peer review of the emergency preparedness with the OECD NEA countries
- STUK participated in the work carried out by the working group of European authorities (European Pilot Study on Demonstrating the Safety of Geological Disposal), which resulted in a recommendation for safety case content for final disposal at different stages of final disposal. The recommendations were published in 2011.
- Finland had IRRT mission in 2001 and the follow-up mission in 2003. IRRS mission was carried out to the regulatory body in October 2012 and the follow-up mission is planned in 2015. An action plan has been prepared.
- IAEA has agreed to carry out a pre-OSART (Operational Safety Review Team) mission to Olkiluoto NPP unit 3 in 2013 depending on the project schedule with regard to fuel loading.

Finland continues the hosting and participation in the international peer reviews and will report the findings of these peer reviews as well as progress of the action plans in the CNS report.

Emergency preparedness and response

Strengthen emergency preparedness and response

The Finnish concept of off-site nuclear emergency response has been developed since 1976, when the first public authorities' off-site emergency plan was prepared. The development has been a continuous process since then. The requirements for off-site plans and activities in a radiation emergency are provided for in the Decree of the Ministry of the Interior issued in 2011. Off-site emergency plans are prepared by regional rescue authorities. Legislation and plans define clearly the roles and responsibilities of stakeholders having a role in an emergency. Emergency exercises are conducted annually between the licensee and STUK. Every third year all authorities are training together at each site.

As a result of the studies made after the TEPCO Fukushima Dai-ichi accident, no major changes are identified in the area of emergency preparedness so far. However, there is a need to ensure accessibility to the site in case of extreme weather conditions, a sufficient amount of radiation protection equipment and radiation monitoring capabilities for rescue services and communication capabilities. In addition, there is a need to ensure that the resources of rescue authorities can be reasonably coordinated between radiological and other emergencies, should they happen simultaneously. The coordination of activities and sharing of resources between different regional rescue authorities also needs to be enhanced. Discussions between rescue authorities, STUK and the licensees are ongoing. Futhermore, STUK conducted in 2011 a self-assement of its own response during the TEPCO Fukushima Dai-ichi accident. As a general result, no major deficiences were identified. However, findings and experiences resulted in some minor modifications of STUK's emergency plan, procedures and arrangements.

A close local co-operation between the regional rescue services, regional police departments, NPP licensees and STUK has taken place since several years. Permanent coordination groups have been established for both Loviisa and Olkiluoto NPP's in order to ensure coordinated and consistent emergency plans, to improve and develop emergency planning and arrangements and to share lessons from the exercises, regulations and other information. Also extensive training is arranged by these groups. In addition, a National Nuclear Power Plant Emergency Preparedness Forum is needed in order to have co-operation and communication between permanent groups and establishment of the National Forum has been agreed. The Ministry of the Interior and the Ministry of Social Affairs and Health, the regional rescue service authorities, STUK and the NPP licensees will be participating in the Forum. The forum will handle at least issues related to:

- long term accidents of several NPP units
- recovery phase actions
- emergency measures outside the planning zones
- scope of the emergency exercises,
- radiation monitoring capability during prolonged emergency situations
- communication capability during prolonged emergency situations
- availability of the emergency centres with respect to power supply, filtration of the intake air and the distance from the NPPs
- public information, information between the authorities
- clearance of the roads, alternative transport ways and means
- decontamination resources and facilities
- supply of contractor staff during the emergencies
- warning the population.

In addition, a transportable, insulated and heated container for personnel protective equipment and radiation measuring instrument is to be purchased to quickly provide a certain amount of equipment in such a case when the normal storages in the NPP are unavailable e.g. due to the external hazards or fallout. The container can be transported by a truck and it can be connected to the electricity grid or to the movable power engine. The container is estimated to be in use on 2014.

Further improvement of arrangements for the coordination of information to the public and media during emergencies is needed to ensure that the messages issued by different authorities are consistent. Guidelines for co-operation among authorities have been written in a guidebook published in November 2012. To help the implementation of guidelines seminars and workshops will be organised from the beginning of 2013.

Finland participates actively in the international co-operation also in the field of emergency preparedness, such as IAEA, OECD/NEA and EU/EC (WENRA and HERCA). These working groups discuss i.a. mutual assistance and communication, co-operation and co-ordination of actions during nuclear of radiological emergencies. STUK has also hosted in 2009 a peer review organised by OECD/NEA on guides concerning protective measures in early and intermediate phases of a nuclear or radiological emergency.

National regulatory bodies

Strengthen the effectiveness of national regulatory bodies

According to the Finnish Nuclear Energy Act, the overall authority in the field of nuclear energy is the Ministry of Employment and the Economy. It prepares for example licensing decisions for the Government. According to the Radiation Act, the overall authority in the field of the use of radiation and other radiation practices is the Ministry of Social affairs and Health. According to Section 6 of the Radiation Act and Section 55 of the Nuclear Energy Act, STUK is responsible for the regulatory control of the safety of the use of radiation and nuclear energy. The rights and responsibilities of STUK are provided in the Radiation and Nuclear Energy Acts.

The regulatory control of the safe use of radiation and nuclear energy is independently carried out by STUK. No Ministry can take for its decision-making a matter that has been defined by law to be on the responsibility of STUK. STUK has no responsibilities or duties which would be in conflict with regulatory control.

STUK carried out a self-assessment concerning i.a. the effectiveness of the regulatory body for the latest IRRS mission conducted in Finland in October 2012. STUK identified many topics to be further improved during the self-assessment and some additional recommendations and suggestions were also given during the mission. The IRRS mission team found that STUK is a competent and highly credible regulator and is open and transparent. It also concluded that STUK is very active in promoting experience sharing both nationally and internationally. Areas for further improvement to enhance overall performance of the regulatory system, included for example the following:

- although STUK operates in practice as an independent regulatory body, the government should strengthen the legislative framework by establishing the regulator as a body separate in law from other arms of government

- the government should seek to modify the Nuclear Energy Act so that the law clearly and unambiguously stipulates STUK's legal authorities in the authorization process for safety. In particular, the changes should ensure that STUK has the legal authority to both specify any licence conditions necessary for safety and specify all regulations necessary for safety
- Finnish legislative framework should be further developed to cover authorization for the decommissioning of nuclear facilities and the final closure of nuclear waste repositories
- STUK can further enhance the effectiveness of its inspection activities by enhancing the focus of inspection on the most safety-significant areas and developing a formal qualification programme for inspectors.

Based on the recommendations and suggestions an Action Plan has been prepared by STUK. The follow-up mission is planned to be conducted in 2015.

Operating organizations

Strengthen the effectiveness of operating organizations with respect to nuclear safety

The responsibility for the safety rests with the licensee as prescribed in the Finnish Radiation and Nuclear Energy Acts. Accordingly, it is the licensee's obligation to assure safe use of radiation and nuclear energy. Furthermore, it shall be the licensee's obligation to assure such physical protection and emergency planning and other arrangements, necessary to ensure limitation of nuclear damage, which do not rest with the authorities.

It is the responsibility of the regulatory body to verify that the licensees fulfill the regulations. This verification is carried out through continuous oversight, safety review and assessment as well as inspection programmes established by STUK. In its activities, STUK emphasises the licensee's commitment to the strong safety culture. The obvious elements of licensee's actions to meet these responsibilities are strict adherence of regulations, prompt, timely and open actions towards the regulator in unusual situations, active role in developing the safety based on improvements of technology and science as well as effective exploitation of experience feedback.

The Finnish NPP licensees have regularly hosted international peer reviews (OSART, WANO). Several peer reviews have been carried out at the both Finnish NPPs during the last ten years (see above the section concerning peer reviews). The licensees have annually sent several peers to foreing peer reviews.

According to the Finnish regulatory guides, the licensees shall carry out a periodic safety review (PSR) at least every ten years. The Finnish PSR process and scope are in line with the IAEA guidance (NS-G-2.10). PSR is seen as a very important tool for promoting the continuous safety improvement approach. The last periodic safety reviews were finalised in Loviisa in 2007 and in Olkiluoto in 2009. STUK regularly updates the regulatory requirements based on the operational experience feedback, research and technical development. The procedure to apply new or revised regulatory guides to existing nuclear facilities is such that after having heard those concerned, STUK makes a separate decision on how a new or revised YVL Guide applies to operating nuclear power plants, or to those under construction.

IAEA safety standards

Review and strengthen IAEA Safety Standards and improve their implementation

The most important references considered in rulemaking at STUK are the IAEA safety standards, especially the Requirements-documents, and WENRA (Western European Nuclear Regulators' Association) Safety Reference Levels and Safety Objectives for new reactors. Finnish policy is to participate actively in the international discussion on developing safety standards and adopt or adapt the new safety requirements into national regulations. The newly developed regulations are highly in line with the most recent development of the IAEA safety requirements. Lessons learned from the Forsmark event in 2006 and the TEPCO Fukushima Dai-ichi accident in 2011 are incorporated into the updated governement decrees and the new set of YVL guides to be published in 2013.

International legal framework

Improve the effectiveness of the international legal framework

Finland signed on 20 September 1994 the Convention on Nuclear Safety which was adopted on 17 June 1994 in the Vienna Diplomatic Conference. The Convention was ratified on 5

January 1996, and it came into force in Finland on 24 October 1996. Finland has implemented the obligations of the Convention and also the objectives of the Convention are complied with. Finland has regularly reported and participated in the review meetings. Finland observes the principles of the Convention, when applicable, also in other uses of nuclear energy than nuclear power plants, e.g. in the use of a research reactor. Finland has participated in the working group on effectiveness and transparency of the Convention on Nuclear Safety and is supporting the initiatives to improve the CNS process.

The financial provisions to cover the possible damages to third parties caused by a nuclear accident have been arranged in Finland according to the Paris and Brussels Conventions. Related to the revision of the Paris and Brussels Conventions in 2004, Finland has decided to enact unlimited licensee's liability by law (the Finnish Nuclear Liability Act). This means, that insurance coverage will be required for a minimum amount of EUR 700 million and the liability of Finnish operators shall be unlimited in cases where nuclear damage has occurred in Finland and the third tier of the Brussels Supplementary Convention (providing cover up to EUR 1500 million) has been exhausted. The revised law will also have some other modifications, such as extending the claiming period up to 30 years for victims of nuclear accidents. The law amendment (2005) has not taken effect yet. It will enter into force at a later date as determined by government decree. The entering into force of the amending act will take place as the 2004 Protocols amending the Paris and Brussels Conventions will enter into force.

As the ratification of the 2004 Protocols has been delayed, Finland made a temporary amendment in the Finnish Nuclear Liability Act in 2012, implementing the provision on unlimited liability and requirement of insurance coverage for a minimum amount of EUR 700 million. The temporary law came into force in January 2012 and will be repealed when the 2005 law amendment takes effect. In Finland, the finishing off the international ratification process of the convention amendments without any undue delay is considered to be extremely important.

Finland is a Member State of the European Union. In 2011 some amendments were done in the Nuclear Energy Act due to the Nuclear Safety Directive (Council Directive 2009/71/Euratom). In 2013, the Nuclear Energy Act and the Radiation Act are under an amendment process to implement the Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste.

Member states planning to embark on a nuclear power programme

Facilitate the development of the infrastructure necessary for Member States embarking on a nuclear power programme

Providing support to embarking countries is considered important in Finland. Finland is a member of the IAEA Regulatory Co-operation Forum and has participated on the Integrated Nuclear Infrastructure Reviews (INIR) missions organized by the IAEA. In addition, Finland participates in EU/EC INIS activities by providing experts and training to embarking countries as well as tutoring to experts from embarking countries. Finland has also organised and continues to organise training courses on the experience on regulatory oversight on new construction and project management, regulatory framework in Finland, and experts from embarking countries have participated. Experts from Finland have also lectured in individual IAEA training courses focused on embarking countries.

Capacity building

Strengthen and maintain capacity building

The competence of the licensees as well as the vendor and main subcontractors is one of the key review areas in the licensing processes for the use of radiation and nuclear energy and during the lifetime of the facilities. STUK is currently updating the legislation and regulatory guides and is going to set goals and requirements on the resources needed to be available for the licensee during normal operation as well as during emergencies.

The management of STUK highlights the need for competent workforce. STUK has adopted a competence management system and nuclear safety and regulatory competencies are also emphasised in STUK's strategy. Implementation of the strategy is reflected into the annual training programmes, on the job training and new recruitments.

The national nuclear safety and waste management research programmes have an important role in the competence building of all essential organisations involved in nuclear energy. These research programmes have two roles: for the first ensuring the availability of experts and for the second ensuring the on-line transfer of the research results to the organisations participating to the steering of the programmes and fostering the expertise. STUK has an important role in the steering of these programmes.

There is a basic professional training course on nuclear safety organised together with the Finnish organisations in the field. The first 6-week course commenced in September 2003 and the 11th basic professional training course will commence in autumn 2013. At the moment, about 500 newcomers and junior experts, of whom about 80 have been from STUK, have participated in these courses. The content and structure of the course has been enhanced according to the feedback received from the participants.

Due to planned expansion of the use of nuclear energy in Finland, a comprehensive study has been conducted in Finland to explore the need of experts and education of experts in Finland to meet the needs from the organizations in the field. The study was completed in March 2012.

(http://www.tem.fi/files/33402/Report_of_the_Committee_for_Nuclear_Energy_Competence_in_Finland.pdf)

Protection of people and the environment from ionizing radiation

Ensure the on-going protection of people and the environment from ionizing radiation following a nuclear emergency

During nuclear or radiological incidents and emergencies STUK is responsible for safety assessment of radiation situation and recommendations and advice for protective measures as defined in the Rescue Act. STUK provides recommendations of protective measures to authorities on local, provincial and governmental level. Furthermore, STUK provides advice to private sector for trade and commerce.

STUK has prepared so called VAL Guides, which contain the intervention strategy in Finland. VAL Guides contain protective measures and intervention levels in early and intermediate phases of a nuclear or radiological emergency, for various types of emergencies (such as fallout from nuclear detonation, severe accident in a NPP, malicious acts, contamination due to radioactive substances etc.). VAL Guides contain reference levels of exposure during the first year and factors, other than radiation, affecting choice of protective measures and protective measures to be considered during nuclear or radio-logical emergencies and transition to recovery. VAL Guides contain criteria when protective measures are needed and when those can be lifted or modified. Criteria are given for each countermeasure as a projected dose and as an operational intervention level. They also include triggers such as plant condition, or emergency action levels such as duration of a protective measure. VAL Guides include principles for reducing exposure of various parts of society (e.g. actions concerning population, exercising own profession in a contaminated area, decontamination, handling of waste containing radioactive substances etc). VAL Guides are to be put into force by the Ministry of the Interior.

In Finland, there is an automatic external dose rate monitoring network consisting of about 250 stations throughout the country. Results are available in real time (every 10th minute). In addition, a network has 22 stations with spectrometers situated around the Finnish NPPs and in Helsinki. Nuclear power plants have trained monitoring teams capable of making dose rate and air concentration measurements. STUK has trained monitoring teams for dose rate monitoring, mobile spectrometers and a laboratory vehicle which has state of the art monitoring equipment for gamma (HPGe), alpha and air sampler. Results can be obtained in 30 second interval.

There is also a network of environment and foodstuffs laboratories which have the capability to measure gamma radioactivity levels in the food and environmental samples. STUK coordinates operation and provides technical support if needed. In addition, STUK has delivered regional hospitals monitoring equipment for monitoring iodine in thyroid. This measuring capability is meant for screening the public for contamination of iodine.

In addition to actual emergency rescue planning, roles and responsibilities of authorities for longer-term actions following a nuclear accident have been defined. Longer-term actions include e.g. decontamination of environment, management of waste containing radioactive substances, radiation monitoring and surveys, health control of the population, measures concerning agricultural and other production and measures to ensure uncontaminated food and feeding stuffs.

Communication and information dissemination

Enhance transparency and effectiveness of communication and improve dissemination of information

The Decree on STUK defines STUK's tasks. One of the tasks is to inform about radiation and nuclear safety matters and participate on training activities in the area. STUK utilises many means to communicate with public and interested stakeholders, such as meetings, seminars, and training courses. All these are tailored and targeted to differen stakeholders and stakeholder groups.

STUK puts special interest in internet to inform public and interested stakeholders about nuclear and radiation safety in general, risks related to radiation and use of nuclear energy, safety requirements, roles and responsibilities of STUK, STUK's organization, current activities and operating experience, significant regulatory decisions taken, events and publications and safety research. STUK web pages can be found (www.stuk.fi) in Finnish, Swedish and in English. STUK has also made itself available in social media (facebook and twitter).

What comes to radiation emergencies and hazards, according to the Rescue Act and the Decree of the Ministry of the Interior concerning informing public during nuclear or radiological emergencies, the authority in charge is responsible for informing public on protective measures and other activities to be carried out. Authorities at governmental, provincial, and municipal level provide information on their own activities and give instructions regarding their own sphere of responsibility. In case of a nuclear power plant accident there are many organisations providing information. Thus special attention needs to be paid to coordination of timing and content.

Further improvement of arrangements for the coordination of information to the public and media during emergencies is needed to ensure that the messages issued by different authorities are consistent. Guidelines for co-operation among authorities have been written in a guidebook published by the Ministry of Interior in November 2012. To help the implementation of guidelines seminars and workshops are organised from the beginning of 2013. Even more general principles and guidance of coordination or public communication during emergencies are given in the guidance by prime ministers office. This guideance will be updated during 2013.

In an accident situation the principal information route of warnings to the public is FM radio, TV and internet. The first outdoor warning to the public close the NPP is given by general warning signal via sirens or loudspeakers. By arrangement with broadcasting companies, urgent RDS-notifications can be transmitted promptly over the FM-radio and TV. There is a new specific law for warning messages via radio and TV. Law is entering into force on 1st June 2013.

Finland has several bilateral agreements for exchange of information on nuclear facilities and on notification of a nuclear and radiation emergency, e.g. with Sweden, Norway, Russia, Ukraine, Denmark and Germany. In addition, STUK has done bilateral arrangements with several foreign regulatory bodies, which cover generally exchange of information on safety regulations, operational experiences, waste management etc. Such an arrangement have been made with NRC (USA), ASN (France), FANR (United Arab Emirates), NSSC and KINS (Republic of Korea), TAEK (Turkey), ENSI (Switzerland), SUJB (Czech Republic), Rostechnadzor (Russian Federation), and CNSC (Canada).

Research and development

Effectively utilize research and development

The Nuclear Energy Act was amended in 2003 to ensure funding for a long term nuclear safety and nuclear waste management research in Finland. Money is collected annually from the licence holders to a special fund. Regarding nuclear safety research the amount of money is proportional to the actual thermal power of the licensed power plants or the thermal power presented in the Decision-in-Principle. For the nuclear waste research, the annual funding payments are proportional to the current fund holdings for the future waste management activities.

The research projects are selected so that they support and develop the competences in nuclear safety and to create preparedness for the regulator to be able to respond on emerging and urgent safety issues. These national safety research programmes are called SAFIR and KYT. The key topics of the recent nuclear safety research programme (SAFIR2014) are organisation and human factors, automation and control room, fuel and reactor physics, thermal hydraulics, severe accidents, structural safety of reactor circuit, construction safety, probabilistic safety analysis and development of research infrastructure. The amount of money collected from the licensees in year 2012 was about 5.6 million € for nuclear safety research. The research projects have also additional funding from other sources. The total volume of the programme in 2012 was 10 million €. The results of the research programme are public. More information on the planning, steering and the research reports of the SAFIR and KYT programmes are available on the puclic websites (http://safir2014.vtt.fi/ and http://kyt2014.vtt.fi/).

In 2011, research needs originating from the TEPCO Fukushima Dai-ichi accident were studied, and an appendix addressing the topics for further research (e.g. spent fuel pool accidents) was added to the research programme. The ongoing SAFIR2014 research programme already included research projects on extreme weather phenomena, extreme seawater level variations and seismic issues. As a result of the TEPCO Fukushima Dai-ichi accident, a reassessment was made how the accident should be taken into account, and the research projects were somewhat redirected. The research programme was supplemented with research topics related to natural hazards and multiple failure events, the adequacy and scope of nuclear power plant design basis, mitigating the impact of accidents (e.g. high concentration of boron in the reactor circuit, hydrogen formation and transport, range of fission products released in core melt), and the overall life cycle of nuclear fuel including spent fuel pools. Some additional resources have also been allocated to the research of external events.

The objective of KYT2014 (Finnish Research programme on Nuclear Waste Management) is to ensure the sufficient and comprehensive availability of the nuclear technological expertise and other capabilities required by the authorities when comparing different nuclear waste management ways and implementation methods. KYT2014 is divided into three main categories:

- new and alternative technologies in nuclear waste management
- safety research in nuclear waste management
- social science studies related to nuclear waste management

and the main emphasis is on safety related research. The programme is conducted during 2011–2014 and the total funding is 2.8 M€, of which State Nuclear Waste Management Fund (VYR) covers 1.7 M€.

In Finland, the Technical Research Centre of Finland (VTT) is the largest research organisation in the field of nuclear energy. At VTT, about 200 experts are working in the field of nuclear energy, half of them full-time. The total volume of the nuclear energy research in the year 2012 was about 75 million € (estimate of the Ministry of Employment and the Economy). This figure includes research related to use of nuclear energy made in all the stakerholder organisations. Two thirds of the research is focused on the final disposal of spent fuel. The largest individual organizations are VTT, GTK (Geological Survey of Finland), LUT (Lappeenranta University of Technology) and Aalto University (former Helsinki University of Technology, HUT).

Finland also participates in international research activities, such as OECD/NEA/CSNI working groups, consortium which builds a research reactor in France, scandinavian NKS research programme, EU programmes, and bilateral co-operation with several countries. The Finnish tecnical support organisations are active parties of TSO organisations co-operation such as ETSON in Europe and IAEA TSO Forum.