APPENDIX 2 Safety improvements

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Loviisa nuclear power plant

Replacement of high pressure emergency cooling system pumps

Fortum Power and Heat Oy replaces two pumps of the high pressure emergency cooling system with a new type of pump at both units of Loviisa nuclear power plant. The new type of pump is introduced because of the reduced availability of spare parts for the old pumps, and to improve system reliability. STUK in 2004 approved the utility's conceptual design plan for the pump replacements and their timetable.

The high pressure emergency cooling system operates in situations where normal make-up and boron control systems are not sufficient to take care of the make-up water supply. The system divides into two redundant sections independent of each other, with two parallel pumps in each (four pumps in all).

At the Loviisa 2 annual maintenance, two pumps were replaced in accordance with the approved timetable for replacements, one for each redundant system section, and the necessary piping modifications were made. Corresponding work at Loviisa 1 will be done in the 2008 annual maintenance outage.

STUK and the STUK-approved "Inspection Organisation Loviisa YVL" reviewed and authorised the plans for the modifications, conducted construction inspections and supervised the testing of the pumps.

Olkiluoto power plant

A high pressure turbine and steam reheaters were replaced at Olkiluoto 1

The power upratings completed at Olkiluoto in 1998 had increased the loading on the reheaters. Reheater tubes have been plugged to stop leaks, which has restricted their service life. For improved efficiency, the utility replaced one-stage steam reheating with two-stage steam reheating.With two-stage steam reheating, a new high pressure turbine extraction was required. In the Olkiluoto 1 annual maintenance outage, the utility installed new reheaters and high pressure turbine internals. High pressure turbine blading were improved, which increased the turbine output. The process changes necessary at the turbine plant due to the reheater and high pressure turbine replacements were made. The projects implemented at the turbine plant were equivalent to the renewals made in the Olkiluoto 2 annual maintenance of 2005.

The steam dryer was replaced at Olkiluoto 1

The moisture content of the reactor-to-turbine steam at Olkiluoto 1 and 2 increased after the power uprating in 1998. The moisture content was approx. 0.1% before the power uprating. After it, the annual average moisture content has been 0.27–0.33% at Olkiluoto 1 and 0.31–0.34% at Olkiluoto 2.

The steam from the reactor at Olkiluoto 1 and 2 is channelled direct to the turbine plant. Thus, along with the moisture, radioactive substances dissolved in water are transported to the turbine plant, causing elevated radiation levels there. The dose rates measured at the turbine plant have been 2-10 fold compared with those measured before the power uprating. An increase in the steam moisture content increases the occupational doses of those working with or around systems having to do with steam. The moisture content of steam has not been established to have increased erosion-corrosion in the turbine systems.

In order to reduce the moisture content of steam, Teollisuuden Voima Oy decided to replace the steam dryers. The steam dryer of Olkiluoto 2 was replaced in the 2005 outage and that of Olkiluoto 1 in the 2006 annual maintenance outage. The new design of their dryer panels aimed at reducing steam moisture below 0,1 %.

Due to problems with impurities during the delivery of the Olkiluoto 2 steam dryer, special attention was paid to the protection of the steam dryer during manufacturing and in transit. In addition to manufacturing inspections, Teollisuuden Voima Oy carried out, prior to delivery, a thorough endoscopic inspection of the steam dryer at the manufacturing facility.

Based on 12 months of operating experience, the steam moisture content at Olkiluoto 2 had clearly reduced: it was below 0.01%. However, due to mechanical problems caused by manufacturing non-conformities, the dryer had to be removed in the 2006 annual maintenance and replaced with the old dryer. A steam moisture content of 0.31% was measured at full power after the 2006 annual maintenance outage. The Olkiluoto 1 dryer is not expected to have manufacturing-induced problems similar to Olkiluoto 2. A steam moisture content of 0.0049% at full power was measured at Olkiluoto 1 after the annual maintenance.

Turbine plant automation system renewal at Olkiluoto 1

In the annual maintenance outage, the process automation system of the Olkiluoto 1 turbine plant was upgraded. One reason was the reduced availability of spare parts for the old system. In addition, the modifications made in the turbine plant process required some additional modifications to the automation system. Along with the new system, component maintenance is facilitated. Other system renewal objectives are to increase reliability and to reduce susceptibility to malfuctions. The new system was pre-installed at Olkiluoto 1 and 2 in the 2004 annual maintenance. A similar modification was implemented at Olkiluoto 2 in 2005 already and minor additional modifications were made in the 2006 annual maintenance.

The new automation system is implemented by programmable technology. This allows an increased number of process status measurements. As regards turbine automation, it facilitates for turbine operators more versatile 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 systems control desk and a turbine systems control and monitoring desk, and the control room was fitted with a large 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 turbine plant automation system renewal made it possible, for the first time at a Finnish nuclear power plant, to control some processes from the control room via the screen based operating work station system. The processes thus controlled are of minor safety importance.

The automation interface was introduced at the Olkiluoto 1 and 2 training simulator in September 2004, which made possible the training of operating personnel in its use.

Modernisation of Olkiluoto 1's medium voltage switchgears

In the 2006 annual maintenance outage at Olkiluoto 1, the 6.6 kV medium voltage switchgears of the internal power supply system, which distribute most of the internal electrical power required by the unit, were modernised. This was done mainly because of the ageing of the original switchgears, the reduced availability of spare parts and to bring the switchgears up to modern requirements. During this REMES project, a total of over 60 medium voltage switchgear cubicles were modernised. The project included several significant modifications and replacements as regards i.a. the control, relay protection and auxiliary voltage systems as well as cabling and structural work.

The modernisation improved the availability, protection, control and resistance to malfunctions of the switchgears. The same modifications were made at Olkiluoto 2 in 2005.

APPENDIX 3 Significant operational events

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Loviisa nuclear power plant

Inoperability of the condenser activity measurement and a simultaneous calibration of a steam generator blow-down system activity measurement at Loviisa 2

On Friday, 2 June 2006, the sampling flow of the continuous radioactivity measurement of the turbine condenser was found inadequate. A work order was made to repair it and the diaphragms of the sampling pump in question were replaced the same day. After the repair work, a test run established that the measurement function still did not work and it was decided to continue repairs on the pump the next Monday. The tasks of the two condenser activity measurements include, among others, detection of potential small primary–to–secondary circuit leaks in the steam generators.

The night shift manager on Monday gave permission to repair the pump and the work supervisor in the morning acknowledged the work as done. The Technical Specifications require that the blow-down monitors of the steam generators must be available during repairs.

The morning shift manager gave permission for the calibration, done every 24 weeks, of the blow-down system activity measurement monitor of the steam generators. In about an hour from this he noticed that one condenser activity measurement was still out of order. The steam generators blow-down activity measurement monitor had been calibrated by then and was being returned to service.

The plant was in non-conformity with the Technical Specifications for about two hours due to the simultaneous unavailability of components caused by the condenser activity measurement malfunction and the calibration of the steam generator blow-down activity measurement. Other activity measurements for monitoring radioactivity in the secondary circuit were in operation. During this period of component unavailability, no exceptional releases to the environment occurred.

In a special report on the event, Fortum clarified its causes and proposed corrective action to prevent recurrence.

Switchgear buses sustained damage at Loviisa 2

At Loviisa 2, on 13 September 2006 cracks were detected in the 6 kV switchgear buses during a periodic inspection conducted every four years. They were located in screw couplings between branch and power busbars. The branch busbars of the switchgear feed electrical power to i.a. 6 kV motors and distribution transformers. The cracks in question could have caused switchgear damage.

After the discovery, the branch busbars of all of the plant unit's 6 kV diesel backed and normal switchgears were inspected. Of the checked busbars, approx. 20% had cracks in them. After the inspections, all the damaged busbars were replaced.

The structure of Loviisa 1's corresponding 6 kV switchgear busbars is dissimilar to that of the Loviisa 2 busbars. This is why, according to the utility, a similar failure is not possible at Loviisa 1.

The utility will submit to STUK a special report on the event.

Spreading of contamination at Loviisa 2

At Loviisa 2, on 22 September 2006, personal surface contamination monitors alarmed unusually often during the checking of worker protective clothing and contaminated clothing had to be replaced with clean ones. Shoe covers in particular were contaminated, from which it was concluded that controlled area pathways are contaminated to some extent.

An investigation by the utility determined that, on Thursday evening of 21 September 2006, extractor hoses used in the cleaning of the reactor pool had been transported from the Loviisa 2 reactor building via a material lock to the decontamination centre on the first floor. The Thursday evening shift decontaminated the outer surfaces of the hoses and took them to the corridor without any plastic covers. During the morning shift of 22 September 2006 the hoses were taken from the hauling gallery to a corridor in the controlled area on the fifth floor to wait for a transfer to the storage area. During the transfer, radioactive dirt had fallen from inside the extractor hoses onto the floor. After this was found out, the contaminated floors of the controlled area were cleaned.

Onsite contamination was detected also in the plant yard, in the immediate vicinity of the hauling gallery door, where dirt had apparently spread on the wheels of transport vehicles used for goods transfers. The yard area near the hauling gallery door was decontaminated. The total activity of the dirt that had spread on the plant yard was very low. Some Loviisa 1 areas were decontaminated, too.

The event did not endanger occupational radiation safety since the contamination was detected and decontamination was efficiently carried out. Radioactive substances did not spread offsite. The utility has drawn up a special report on the event, proposing changes to procedures and instructions.

Since the routines of action for the controlled area were clearly deficient the event is classified as INES Level 1.

Emergency accumulator discharge test was not done

Loviisa 2 has four emergency accumulators for cooling the reactor core in case of a LOCA caused by a potential pipe break.

To ensure the appropriate operation of the accumulators and the associated valves, the Technical Specifications require that the accumulators be submitted to a discharge test to the reactor pressure vessel once every two years. In addition, the emergency coolant system test procedure always requires a discharge test after servicing or when the emergency accumulators have been internally inspected.

One emergency accumulator was internally inspected during the Loviisa 2 annual maintenance outage. No discharge test was done since a loose part (measuring device head Ø1.5 cm, length 3 cm) was suspected to have dropped into the pressure accumulator during internal inspection. No loose part was found during searching though. The utility commissioned an analysis to VTT Technical Research Centre of Finland for determining the lost component's consistency. The inspection and the accomplishment of VTT's analysis took so long that the deadline for the discharge test passed. A test would have included the risk of unknown material getting into the reactor. VTT's analysis, submitted later, indicated that the loose part does not endanger reactor operation.

The utility did not give STUK an official explanation of why the accumulator test was not done. STUK discontinued the handling of the start-up licence and asked the utility for a clarification of the availability of the emergency coolant system and of the effects of a potential loose part on the system and the reactor.

In its clarification to STUK the utility stated that the test was not done because the accumulator in question was tested the previous year, with acceptable results. Prior to its closing, the accumulator underwent careful internal examination. According to the utility, there was no reason to suspect that the reactor would contain items that could prevent the performance of the accumulator's designed safety function in case of need. Three other accumulators were tested during this annual maintenance, with acceptable results. The utility proposed that the emergency accumulator testing not having been done has no safety significance and is thus acceptable.

Based on the above clarification, STUK established that the utility's actions give confidence of the safety function's availability. However, the handling of the matter was found inadequate. STUK's resident inspector was informed on 25 September 2006, by which time the event was over, that the discharge test of the emergency accumulator had not been done and that there may be a loose part in the accumulator. The utility's decision not to do the test had been made on 19 September 2006 i.e. before the results of the loose part analysis were known. The information was not included in the Loviisa 2 start-up application either.

STUK required in its Loviisa 2 start-up licence decision that the utility must submit a special report on the matter.

Voltage transformers were damaged at Loviisa 2

At Loviisa 2, on 27 September 2006, two busbar voltage transformers of one of the two main transformers exploded, causing a minor local fire. Nobody was injured and the plant unit's safety was no endangered. The annual maintenance planned timetable suffered some delays due to the event.

During the first energisation of the Loviisa 2 main transformer after annual maintenance work, the control room received an earth fault alarm and in about 15 minutes a protection function opened a transformer switch, triggering an advance warning of an automatic fire alarm. The fire brigade on arrival observed smoke and flames. After the component had been earthed, the fire brigade quickly extinguished the oil fire.

The event was caused by the explosion of two voltage transformers coupled to the busbars of the main generator. The explosion ignited their oils and insulation materials. The voltage transformers are located outside the building below the generator busbars in casings that also sustained damage. The casings housed not only the voltage transformers but also condensers and overvoltage protectors, some of which sustained damage in the explosion. The damage was investigated after the event and the site of the fire was cleaned of oil and soot, whereafter damaged components, casings and couplings were replaced. The repairs took about a week.

The utility will submit to STUK a clarification about the event's causes and corrective actions. The event is preliminary attributed to human error in the restoration of couplings after testing.

High capacity pressuriser discharge lines were not tested

The pressurisers of both Loviisa plant units have two high capacity depressurisation lines for severe accidents, with two successive valves in each. During severe accidents, discharge through the depressurisation lines reduce pressure in the reactor loop to avoid its failure at high pressure. The capacity of the lines is dimensioned such that the opening of one line is enough to sufficiently reduce pressure.

The Technical Specifications (TTKE) of the Loviisa plant units require that the depressurisation lines are tested every two years. Before the 2005 annual maintenance, Loviisa plant decided to extend the testing interval to four years. The testing procedure and the follow-up procedure for testing during annual maintenance were revised accordingly but not the TTKE.

The new 4-year testing interval was introduced in the 2005 annual maintenance. One line was tested at Loviisa 1 in 2005 and one at Loviisa 2 in the 2006 annual maintenance. The TTKE require that both lines should have been tested at Loviisa 1 in 2005 and at Loviisa 2 in 2006. At both plant units, condition monitoring measurements have been conducted for the valves in the discharge lines at the 2006 annual maintenance outage i.e. the operation of the valves has been verified. Only the capacity measurement of the lines and the verification of the availability of severe accident control from the auxiliary control room had thus been left out from the testing.

Due to the event, Loviisa power plant has checked that no corresponding discrepancies exist between the follow-up procedure for testing during annual maintenance and the TTKE. Prior to the forthcoming annual maintenances, the uniformity of instructions, testing procedures and the TTKE as regards the testing in question will be ascertained. An application to change the testing interval of depressurisation lines will be submitted to STUK. The utility annually assesses testing procedures and the needs for change identified during testing. After this event, the assessment meetings will also address the acceptability, from the TTKE point of view, of testing modifications proposed. In case the testing intervals given in testing procedures are changed, the power plant's safety engineer will review the procedures.

Olkiluoto nuclear power plant

Operator maximum working hours were exceeded at Olkiluoto 1

As of the beginning of 2006, the operators of the Olkiluoto plant units began working in 12 h shifts. With the new shift system, the operators normally work two successive night shifts only. The Technical Specifications (TTKE) limit maximum working hours at 16 hours max. in 24 hours, at 24 hours max. in 48 hours and at 72 hours max. in 7 days.

An Olkiluoto 1 operator was on sick leave from the night shift on 21 February 2006 and the day shift operator stayed on for four hours more, until the arrival of the day shift substitute. Since he had done the preceding day shift, his working hours exceeded the maximum allowable working hours by four hours. The same happened in the next night shift. The substitute had worked a 9 hour day shift and his working time thus exceeded by one hour the working time limit of the TTKE.

Both operators had had a normal night's rest the previous night and sufficiently long rest periods prior to their next shift. As a single event, this has no safety significance.

Shift managers cannot follow extended working hours very well. The TTKE's working time limits also do not agree well with the 12 h shift system.

The utility has introduced in the control rooms of the Olkiluoto plant units follow-up lists to ensure that the necessary deviations from the shift system comply with the TTKE limits. In addition, the updated maximum working hours to accomodate for corresponding unexpected events close to change of shift are 16 hours max. in 24 hours, 28 hours max. in 48 hours and 76 hours max. in seven days.

The event was classified Level 0 on the INES Scale.

Design pressure was exceeded in an auxiliary feedwater system relief valve test at Olkiluoto 2

The allowable pressure was exceeded in a periodic test of an auxiliary feed water system relief valve at Olkiluoto 2 on 8 February. Sections of piping and some valves were subject to a pressure exceeding their design pressure.

A certain section of piping is closed by valves for the test and the pressure required in the tested relief valve is obtained by means of the system piston pump. The relief valve opened at correct pressure and correctly but, with an increased flow through the relief valve, pressure increased and exceeded the allowable limit. The test had to be aborted. The three other auxiliary feed water system branches were operable during the event.

The tested relief valve was replaced and its investigation was started immediately. The valve's opening pressure had been adjusted by testing equipment earlier and it was still found to open faultlessly. During servicing, the valve's spindle was replaced with a new one, in which dimensional variances were observed. Final investigation established that, due to the dimensional variances, the safety valve is not capable of opening sufficiently at large flows and, consequently, pressure within the piping increases.

Because design pressure was exceeded, the utility conducted a strength analysis for the components and section of piping that had been subjected to high pressure. The overpressure had not damaged the piping and its components, and the system is operational.

Turbine trip at Olkiluoto 2

On 14 February 2006 a trubine trip occurred at Olkiluoto 2 from the failure of a card for control electronics of the turbine control system. The plant's automatic protection and control functions restricted the reactor power as planned and no other significant failures occurred during the event.

The card failure caused a turbine trip, a partial reactor scram and the main circulation pumps running on minimum revs. The reactor power decreased to approx. 30% and the turbine plant remained on bypass operation. The fault in the original card for electronics, installed in 1979, has not been identified yet. The turbine control system is not diversified in this respect and thus is not capable of handling a single failure. The system has not experienced failures or ageing before. It is due for upgrading in 2010.

The reactor water level quickly exceeded normal level after the turbine trip. The reactor operator switched the feedwater pumps on to manual drive and reduced the feedwater flow to prevent a water level increase and a subsequent reactor scram. He returned the pumps to automatic operation after the reactor water level had decreased slightly below normal level. A level transmitter interpreted the lower level as a large-scale need for feedwater. The quick increase in flow quickly decreased the pumps' suction pressure close to trip limit. The pressure decrease was so brief, however, that it did not lead to the tripping of the pumps' protection function and their stopping. A level increase is normal in such a situation and the operator would not have needed to intervene in the operation of the automated functions. Feedwater automation adjusts water level but, due to the slowness of the adjustment, level changes are fairly large.

The event showed that the procedures for automatic level control need to be developed. The system's operation will be addressed more closely in operator training. In addition, due to the event, development needs were identified in the turbine control system and in feedwater control during transients. The utility has set up a feedwater control improvement work group.

The utility submitted a detailed clarification about the event to STUK. It had no safety significance but it revealed development needs in both plant engineering and operator action in transients.

Control rod problems at Olkiluoto 1

The control rods of Olkiluoto 1 and 2 have two safety functions: the scram function and the screw shutdown function. In a scram, the control rods enter the reactor by means of water driven by nitrogen pressure. The screw shutdown function serves as scram backup and inserts the control rod drive nuts by means of electric motors in about four minutes, thus inserting any rods that may have failed to go in during a scram.

During cold shutdown testing prior to post annual maintenance start-up at Olkiluoto 1, three control rod drive mechanisms tripped from torque protection while they were inserting control rod drive nuts after a successful scram. The drive mechanisms were made manoeuvrable but later, when placing the reactor in hot shutdown state for scram testing, one control rod drive mechanism tripped from torque protection. It was made manoeuvrable again and the scram tests were conducted successfully.

The cause of the torque protection trips is being investigated. One cause may be impurities in the nitrogen tanks of the scram system, which during cold scram testing entered the control rod drive mechanisms and the space between the drive nut and screw. The problems only pertained to the control rod screw shutdown function; no non-conformances were detected in the movability of the control rods or the scram function.

In order to assure the functioning of the control rods after a partial scram test pertaining to plant modifications following seven days of operation, a control rod test was conducted in which each rod underwent a scram and a screw-operation test. During a scram, the drive mechanism of one control rod got stuck again and its motor and torque switch were replaced and inspected. In a repeated screw-operation test, no non-conformances were detected. For added confidence, the functioning of all control rods is tested during the operating cycle with additional manoeuvring tests every two months.

The utility will submit a clarification to STUK, assessing the causes of the control rod manoeuvring problems and the necessary actions.

The time limit for the periodic inspection of batteries was exceeded at the Olkiluoto spent fuel storage

The condition of batteries assuring the electrical power supplies of the Olkiluoto spent fuel repository (KPA respository) is monitored i.a. by regular inspection of the status of individual battery cells. Periodic measurement of the cells, carried out every six weeks, was not done as required. The measurement is a TTKE requirement to ensure at specific intervals that the batteries fulfil the given criteria. The periodic test is contained in the preventive maintenance programmes of the KPA repository but was not done because persons in charge changed, problems occurred in the flow of information and awaraness of the validity of the TTKE requirements was lacking. The non-conformance from the TTKE requirement was detected on 3 July 2006 i.e. when the deadline was two days overdue.

The batteries are designed to assure auxiliary power supplies of the KPA repository to i.a. switchgears, safety lighting, and I&C systems. The exceeding of the deadline for the condition monitoring measurement had no bearing on the performance of the batteries in case of need. The event did not endanger the safety of the KPA repository.

Periodic testing of a radiation dose rate monitor of the off-gas stack was not done at Olkiluoto 1

The off-gas stacks of the Olkiluoto plant units are equipped with several radiation dose rate monitors some of which are designed for use primarily during normal operation. Their measuring range could be exceeded during exceptional circumstances, however, and the off-gas stack is therefore equipped with monitors capable of measuring high radiation dose rates to ensure the activity measurement of off-gases.

The testing of these dose rate monitors is specified in the Technical Specifications. Testing includes i.a. calibration of the entire measuring range, inspection of calibration data, calibration of the measuring equipment in the measurement signal box and daily inspection.

Towards the end of 2006 the utility found out that one high radiation dose rate monitor had not undergone the required 2-yearly calibration in the measurement signal cubicle. The same test had been left undone in 2004 as well. This was found to be due to the combining of two different maintenance tasks in the same work permit. The work phases had not been separated out and thus the acknowledgement of one task was erroneously interpreted to mean that the other had been done as well.

The event is of minor safety significance. The radiation monitor left untested could have been replaced by other radiation measurements, if necessary.

A special report by the utility states that the task of calibrating the entire measuring range of the monitor in question and the task of calibrating the measuring equipment in the measurement signal box will be divided into separate tasks. During 2007 the utility will review meeting practices and procedures relating to the maintenance process to avoid recurrence. The test was done on 23 November 2006.

Dryout margin went below its smallest allowable value during an Olkiluoto 1 power reduction

The critical power ratio (CPR), which represents the adequacy of fuel cooling water flow with respect to reactor power (i.e. the margin to dryout), went below its smallest allowable value at Olkiluoto 1 for ca. 20 minutes on 13 October. The event took place when reactor power was being reduced for periodic testing by decreasing the main circulation flow. The plant's Technical Specifications allow two hours to repair the situation. During the planning of the power reduction, the allowable repair times were erroneously interpreted to mean that the minimum CPR limit could be briefly deliberately crossed during a reactor power reduction.

The event has no direct bearing on safety since fuel cooling would only have been endangered if, simultaneously with the limit violation, a significant plant transient would have occurred, resulting in degradation of fuel cooling in relation to reactor power. In the determination of dryout limits, a pressure regulator malfunction has been analysed as the limiting event whose anticipated frequency of occurrence is of a magnitude of once in a hundred/thousand years.

The utility will draw up a special report on the event.

APPENDIX 4 Significant events at nuclear power plants abroad

Tapani Virolainen

A disturbance in the electrical power systems of Forsmark 1

On 25 July, during the changing of couplings on the 400 kV external power transmission grid connection at the Forsmark 1 nuclear power plant unit, Sweden, a disturbance occurred, which, in consequence of several consecutive failures, resulted in a partial loss of power in the unit's internal electrical power systems important to safety. The plant unit's safety systems operated as designed and shut down the reactor. No radioactive releases occurred. The event was classified Level 2 on The International Nuclear Event Scale (INES).

The Swedish nuclear safety authority (SKI) required from the utility detailed reports on, among others, event progress as well as the necessary immediate and long-term improvements to prevent recurrence. SKI reviewed the reports submitted and, based on them, assessed the unit's restart readiness. SKI approved the proposed modifications and on 28 September gave a restart permission in which an additional effort to improve safety culture at the unit is expected from the management.

Forsmark 1 was in power operation when a live disconnector in the 400 kV switchyard opened during the making of post-maintenance couplings, and a two-stage arc short circuit resulted. Due to the short circuit, the 400 kV line voltage decreased and caused the plant unit to disconnect from the power transmission grid and switch to house load operation. Due to undervoltage, the voltage regulation systems of the main generators increased voltage and caused two internal pieces of Uninterruptible Power Supply (UPS) equipment to trip. Further into the disturbance both turbine generators tripped and the unit's diesel-backed 500 V busbars became de-energised due to relay protection malfunctions and caused all four emergency diesel generators to start as designed. Two of them began feeding electrical power to diesel-backed consumers as designed. Two stopped after start because supply voltage to their control system had been lost due to the tripping of the UPS equipment.

The simultaneous stopping of two emergency diesel generators and UPS equipment important to safety brought about a partial loss of the information displayed in the main control room. Operators restored electrical power supply from the 70 kV power transmission grid to all subsystems in about 22 minutes from event start, whereafter plant unit control and cooling continued as usual.

Forsmark 1 is equipped with onsite batteries, UPS equipment and emergency diesel generators to provide against the loss of offsite power transmission grids and power supply from the main generators. The plant unit has four emergency diesel generators, one in each redundant electrical subsystem.

The event brought about in Sweden numerous immediate and long-term investigation assignments and improvements, among others in relay protections, supply voltage back-ups, instructions for action as well as maintenance and control room activities.

The licensee (Forsmark Kraftgrupp AB) informed SKI about the event. SKI immediately set about to investigate it, informing STUK, among others, about it. The possibility of a similar event was assessed at Forsmark 1's sister plants Olkiluoto 1 and 2. Even though Forsmark and Olkiluoto originally shared the same plant concept, their electrical power systems originally had, and were later modified to have, differences that would have either prevented a similar event or mitigated its consequences. A UPS equipment malfunction for example would not have prevented the starting of emergency diesel generators at Olkiluoto.

Immediate corrective actions were thus not considered necessary at Olkiluoto. Teollisuuden Voima Oy and STUK follow further investigation of the Forsmark 1 event. At the same time, they assess the need to carry out at Olkiluoto the corrective actions implemented at Forsmark.

Fortum Power & Heat Oy has evaluated the likelihood of a similar event at the Loviisa plant units. The electrical systems of the Loviisa plant units are dissimilar to those of Forsmark 1 to such extent that no immediate corrective action has been necessary. In the Olkiluoto 3 plant project, the event is taken into consideration by design modifications to be made in the detailed design of electrical power systems.

APPENDIX 5 Licences in accordance with the Nuclear Energy Act in 2006

- C214/270, 7 Feb 2006 Teollisuuden Voima Oy
  Import from Spain, and possession, of mock-up assemblies made of zirconium. One full-length and one short assembly with a total max. of 130 kg of zirconium. Valid for import until 31 December 2006 and for possession until 31 December 2018.
- C214/271, 7 Feb 2006 Teollisuuden Voima Oy
  Import from Sweden, and possession, of mock-up assemblies made of zirconium. Two short assemblies with a total max. of 22 kg of zirconium. Valid for import until 31 December 2006 and for possession until 31 December 2018.
- A214/75, 13 March 2006 Fortum Power and Heat Oy
  Import of neutron flux sensors from Canada. Number of in-core sensors is 21. Valid until 31 December 2006
- C214/272, 27 March 2006 Teollisuuden Voima Oy
  Import of control rods from the USA. Eight control rods, weighing approx. 130 kg each. Valid until 31 December 2006.
- C214/273, 27 March 2006 Teollisuuden Voima Oy
  Import of replacement control rods from Sweden. Number of control rods is 12, weighing approx. 130 kg each. Valid until 31 December 2006.
- C214/274, 28 March 2006 Teollisuuden Voima Oy
  Import of zirconium rods from Spain. Two rods with a total max. of 1 200 kg of zirconium. Valid until 30 June 2006.
- A214/79, 28 April 2006 Fortum Power and Heat Oy
  Import from Spain of nuclear fuel containing Kazakhstan origin uranium, and its transport within the Finnish territory. Number of assemblies is 12, with a total of approx. 1 500 kg of low enriched uramium. Validity expired on 7 June 2006 on which date this licence was replaced by licence A214/82, 7.6.2006.
- A214/82, 7 June 2006 Fortum Power and Heat Oy
  Import from Spain, and a related transport, of nuclear fuel containing Kazakhstan origin uranium. Number of assemblies is 12, with a total of approx. 1 500 kg of low enriched uramium. Valid until 31 December 2007.
- A214/80, 8 June 2006 Fortum Power and Heat Oy
  Import of neutron flux sensors from Germany. Number of ionisation chambers is 15. Valid until 31 December 2010.
- C214/275, 4 July 2006 Teollisuuden Voima Oy
  Export to Sweden of rods made of zirconium. Four rods, totalling 8 kg. Valid until 31 December 2006.
- C214/276, 4 July 2006 Teollisuuden Voima Oy
  Export to Spain of rods made of zirconium. Two rods, with a total max. of 1.2 kg of zirconium. Valid until 31 December 2006.
- F214/16, 22 September 2006 VTT
  Export to the USA, and import back to Finland, of control rod drive mechanisms. Two sets of drive mechanisms. Valid until 31 December 2010.
- C821/82, 23 October 2006 Teollisuuden Voima Oy
  Transfer of an approx. 9 m3 batch of waste oil cleared from regulatory control from Olkiluoto nuclear power plant to Ekokem Oy for use as saw chain oil. Valid until 31 December 2007.
- C214/278, 12 October 2006 Teollisuuden Voima Oy
  Import from Sweden of rods made of zirconium. Three rods with a total max. of 6 kg of zirconium. Valid until 30 June 2007.
- A214/89, 1 December 2006 Fortum Power and Heat Oy
  Export to Germany of information pertaining to Loviisa's I&C upgrading. Valid until 31 December 2008.
- A214/92, 12 December 2006 Fortum Power and Heat Oy
  Export to Germany of components relating to control rod control and position indication. Valid until 31 December 2007.

APPENDIX 6 STUK's periodic inspection programme

Basic programme	Inspection in 2006	
	Loviisa nuclear power plant	Olkiluoto nuclear power plant
A. Safety management		
B. Main functions		
B.1. Assessment and improvement of safety		
B.2. Operation	x	
B.3. Plant maintenance and ageing management	x	
C. Inspections by functional unit and field of competence		
C.1. Plant safety functions	x	
C.2. Electrical and I&C systems		x
C.3. Mechanical engineering*	x	x
C.4. Structures and buildings	x	x
C.5. PSA and safety management	x	x
C.6. Document and information management	x	x
C.7. Chemistry	x	x
C.8. Nuclear waste*	x	x
C.9. Radiation protection	x	x
C.10. Fire protection	x	x
C.11. Emergency preparedness	x	x
C.12. Physical protection	x	x
C.13. Training / Human resources and training	x	x
C.14. Quality assurance		x
C.15. LARA**	x	
C.16 Fatigue management (Human resources)		x

* Inspection comprises several subinspections, ** Loviisa I&C upgrading

APPENDIX 7 STUK's periodic inspection programme during construction

	Inspections in 2006
Main functions	
Project quality management (two inspections in 2006)	x
Project management, resources and safety issues	x
Project management and realisation, document management	x
Work processes	
Training of operational personnel (two inspections in 2006)	x
Quality assurance • Plant commissioning • Component installation control	x
Utilisation of PSA	x
Inspection procedures (two inspections in 2006)	x
Inspection of:	
• Process planning and layout design	x
• Air conditioning systems	x
To be inspected in connection with the periodic inspection programme	
Emergency preparedness	x
Physical protection	
Fire protection	x
Nuclear waste	

APPENDIX 8 STUK-financed technical support projects completed in 2006

Nuclear power plants

Technical support for regulatory decision-making

OL3 – Reactor Building, Inspection of construction plan documents of the prestressed containment ; Consulting company Pontek Oy

OL3 – Reactor building, Inspection of construction plan documents of the prestressed containment; VTT Building and Transport

OL3 – Inspection of the non-linear 3D structural analysis model of the containment; VTT

OL3 – Inspection of the structural design; Inspection of of construction plan documents of the circular water structures (UQA); Consulting company Pontek Oy

FINFLO-program; development for analyzing of two-phase flows; Finflo Oy

OL3 – Inspection of the structural design; Inspection of of construction plan documents of the reactor auxiliary building (UKA); Consulting company Pontek Oy

OL3 Reactor fuel analyses: OL3 fuel transient behaviour analyses. OL3 fuel rod performance analyses in steady-state conditions. VTT Processes

OL3 – Inspection of the structural design; Inspection of construction plan documents of the internal structures from level -2.30 to level 7.80, Reactor building (UJA), Consulting company Pontek Oy

OL3 – Reactor building, Inspection of the structural analysis report of the prestressed containment; CEB 11508 RP 214-217; VTT

OL3 – Inspection of the structural design; internal structures of Reactor Building (UJA), inspection of the construction plan documents of the Reactor Pit, Consulting company Pontek Oy

OL3 – Inspection of construction plan documents of the radioactive waste processing building (UKS), Consulting company Pontek Oy

Evaluation of automation systems of nuclear power plants; OL3 and refurbishment of Lo1&2; tasks started in 2005; VTT

Heat flux from melt spreading floor to coolant in Olkiluoto 3 severe reactor accident; VTT

Impact of meteorological phenomena on nuclear power plant safety. Participation in a seminar on meteorological phenomena and other environmental conditions; Finnish Institute of Marine Research.

OL3 – Concrete's constituent materials; Activity coefficient of the blast furnace slag in different exposure classes; VTT

Management of safety requirements in subcontracting during the Olkiluoto 3 nuclear power plant construction phase; Pia Oedewald, expert in Safety Culture; VTT

Management of safety requirements in subcontracting during the Olkiluoto 3 nuclear power plant construction phase; Aila Valkila, expert in Quality Management; private consultant

Management of safety requirements in subcontracting during the Olkiluoto 3 nuclear power plant construction phase; Pertti Pitkänen, expert in Concrete Structures; VTT

OL3 – Coatings; Inspection of coating plans and inspection and supervision of coatings and surface finishings; Consulting company H. Raatikainen

OL3 – Structural capacity of the airplane crash (APC) shield and vibration caused by airplane crash; Participation in the meeting 6.7.2006; VTT

OL3 – Pool liners of the Containment, inspection of construction plan documents of the pool liners (30FAB01, 30FAB11, 30FAB12) ; Consulting company Pontek Oy

OL3 – Pool Liners of the containment, inspection of construction plan documents of the pool liners (30FAB01, 30FAB11, 30FAB12) ; Consulting company Pontek Oy

OL3 – Water chemistry of the primary coolant; Water chemistry specifications; VTT

Heat transfer analysis of the EPR core catcher test facility Volley (Master's thesis). Lappeenranta University of Technology

FIN5 – Analyses of containment behaviour during accident situations ; update of APROS-containment model.

OL3 – Coatings; Inspection of coating plans and coating works, inspection of concrete and steel surface's coating combinations, Fortum Power and Heat Oy, Turbines

FIN5 – TRAB-3D/SMABRE-model; Developing of an EPR plant model and reactor transient analyses; VTT Processes

Nuclear waste management

Technical support for regulatory decision-making

Loviisa LILW repository safety case review; VTT

Posiva – Review of the geological studies and models concerning the site investigations at Olkiluoto. Review of Posiva's QA-guides concerning EDZ, ground water flow predictions and injections, and QA guidance during Onkalo construction. Olkiluoto Review Group (Sven A. Tiren, Auli Niemi, Martin Mazurek, Ove Stephansson)

Posiva - Review of the disposal canister design; Hannu Hänninen

Posiva; Review of the rock engineering plans and construction of Onkalo URCF; Ortogeo Oy

Scoping calculation of coupled modeling of far-field radionuclide migration; University of St. Petersburg

Alternative transparent tools for uncertainty analysis in safety assessment; Comissáo Nacional de Energia Nuclear

Nuclear non-proliferation

Technical support for development of regulatory control

Satellite imagery of Olkiluoto nuclear site: purchace of images, basic processing, change detection and visualisation

ENVIMON project (shared costs) – Development of earth observation techniques; VTT