STUK Report on preparedness to external events at Finnish nuclear power plants

May 16, 2011

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1. Report request from the Ministry of Employment and the Economy

A strong tsunami wave created by an underwater earthquake that happened on March 11, 2011 in the sea area East of Japan, caused a severe reactor accident at the Fukushima Dai-ichi nuclear power plant, situated on the Japanese coast line.

On the account of the accident the Ministry of Employment and the Economy (MEE) asked the Radiation and Nuclear Safety Authority (STUK) to report by May 15, 2011 on the preparedness of Finnish nuclear power plants to floods and other extreme natural phenomena and their effect to the functioning of the power stations, and how the power stations have secured the availability of electricity in different kinds of situations ensuing from accidents and disturbances.

The MEE asked the report to pay special attention on how nuclear power stations' internal and external electricity feeding during accidents and disturbances has been organised, and how the continuous feeding off electricity has been arranged to ensure sound security functions also when the normal power back-up systems are no longer available.

The report also asked to pay attention to national and international operating experiences on faults detected in power plants' electric systems, and to the significance of such detected faults.

The MEE asked to describe how the nuclear power plants currently in use, the plants currently being built and the nuclear power plant units that have been granted decisions-in-principle have prepared to the afore-mentioned situations.

In order to collect the materials for the report requested by the MEE, STUK sent detailed report requests on the matter to Teollisuuden voima PLC (TVO), Fortum PLC (Fortum) and Fennovoima Ltd. (FV) on March 21, 2011. These licensees delivered their responses to STUK on April 15, 2011.

Based on information gathered from license holders, independent reports related to the topic and STUK's own estimates, STUK has assessed the licensees' reports and drafted this report as response to the MEE request.

2. Special characteristics of the Fukushima nuclear power plant accident

The exceptionally strong earthquake and tsunami that caused the Fukushima nuclear power station accident on March 11, 2011, were external threats characteristic to that geographical area. Similar threats are not relevant to Finland or our near areas. The main characteristics of the accident are described in Appendix 1.

The immediate cause of the accident was a tsunami, for which the power plant planners had not prepared for. About one year earlier the Fukushima power station had carried out an analysis based on experiences of the Chile earthquake (February 27, 2011) and tsunami caused by the earthquake. The analysis proved that a tsunami wave up to 5,7 meters of height would not have caused harm to the power plant. Marks left on the outer surface of the power station show that the tsunami wave was more than 14 meters high.

The earthquakes that led to the Fukushima accident have no effect on estimations of earthquake risks in Finland or in our neighbouring areas. The way earthquakes are taken into account in the planning and construction of nuclear power stations in Finland is still based on information about the structure and characteristics of the Finnish bedrock and seismic history.

The Radiation and Nuclear Safety Authority considers that there is no reason to change their opinion on the adequateness of methods used to assess the earthquake acceleration in the Finnish bedrock, nor is there any reason to change opinion on the acceleration values determined by using these methods. The Fukushima accident also had no direct impact on estimating flood risks at the Finnish nuclear power station locations.

However, when compared to previous serious reactor accidents, e.g. the following features in the Fukushima accident give ground for approaching the security of Finnish nuclear power stations, too, from a new angle:

- the original cause of the accident was an event that was known to be a potential threat, but for which the security margins did not provide adequate preparedness;
- the event (flood) causing the accident simultaneously destroyed nearly all the systems required for managing the accident (electricity and cooling systems);
- the acute phase of the accident developed slowly and the situation persisted for a long time (at the time of writing this report the accident situation is still ongoing, but the cooling of the reactors and fuel pools is under control);
- the damage that the natural disaster caused to the area's infrastructure made carrying out of counter measures at the nuclear power plant more difficult;
- in addition to reactors, also the over-heating of spent nuclear waste in the storages of the reactor buildings and related emissions caused a threat;
- after nuclear fuel was damaged radiation levels made it more difficult to manage the accident at the power plant;
- several reactors and spent fuel storage pools at the same site were affected by the accident.

3. Finnish nuclear power plants and their special characteristics

Fortum has two reactors equipped with a Russian type VVER-440 pressurized water reactor in Hästholmen, Loviisa (Loviisa 1 and 2). The units were commissioned in 1977 and 1980.

Teollisuuden voima has two operating reactors in Olkiluoto, which are equipped with boiling water reactors delivered by the Swedish Asea-Atom. The reactors were commissioned in 1978 and 1980 (Olkiluoto 1 and 2). In addition, the EPR type Olkiluoto 3 unit is currently being built, delivered by a consortium formed by the French Areva NP and the German Siemens GmbH. Olkiluoto 3 was granted a construction license in 2005. Another reactor unit (Olkiluoto 4), which got a government decision-in-principle in 2010, and for which a construction license must be placed in mid-2015 at latest, is being planned in Olkiluoto. The supplier of the Olkiluoto 4 unit has not yet been chosen. The application for decision-in-principle presented two unit alternatives equipped with boiling water reactors and three pressurized water reactor alternatives.

A new nuclear power company, Fennovoima Ltd., was also granted a decision-in-principle in 2010 to build one new nuclear power plant unit on a new site, either at Simo or Pyhäjoki. The application for construction license for this unit, too, must be placed by mid-2015. The reactor type and supplier have not been chosen yet. Fennovoima presented one pressurised water reactor and two boiling water reactor types as alternatives.

There are some differences in the currently operating nuclear power reactors in Loviisa and Olkiluoto that may have an effect on preparedness to external threats. In the Loviisa pressurised water type reactor there is a separate primary circuit (reactor circuit) and a secondary circuit (turbine circuit). The steam directed to the turbine is produced with steam generators at the interface of the primary and secondary circuits. The water in the highly pressurised primary circuit does not boil. Water in the secondary side of the steam generator with lower pressure, evaporates. The pressurised water reactor can be cooled by feeding water into the secondary circuit and by letting it boil in the steam generators. As there are no radioactive substances in the secondary circuits, the steam that is generated may be blown to open air. This way the reactor can be cooled as long as water is available to be pumped into steam generators, there is propulsion for pumps and the primary circuit is dense. Since there is a relatively large water inventory in the secondary side of the steam generators, an interruption in pumping, caused by e.g. a complete loss of alternating current (both external electric connections and loss of reserve power diesel generators), does not immediately weaken the cooling of reactors. The amount of water in steam generators in the Loviisa VVER-440 type reactor is significantly larger than in other pressurised water reactor types used in the world. This is why the reactor can handle a 5-8 hour interruption in water pumping without the reactor heart getting too hot. The time the reactor can take lengthens significantly if the reactor can be shut down before the pumping is lost. This time lengthens proportionate to the time that pumping goes on after the reactor has been shut down. The Loviisa power station also has installed a system that feeds water into the steam generators (additional emergency feedwater system). The system uses pumps that are directly powered by diesel engines, and does not depend on availability of electric power and sea water cooling.

Olkiluoto units 1 and 2 are equipped with boiling water reactors. They create vapour by boiling water in the reactor. The boiling water reactor does not have a separate secondary circuit nor does it have steam generators. Water inventory in boiling water reactors is relatively smaller than in pressurised water reactors' secondary circuits. Thus the core of a boiling water reactor gets hot faster than the core of a pressurised water reactor, when pumping of water is interrupted.

Preparations have been made at all Finnish nuclear power stations for a severe reactor accident so that significant emissions to the environment will not be caused. The containments are equipped with independent systems that ensure that the they will not be damaged even after the core of the reactor has melt down. These systems can prevent e.g. hydrogen explosions and excess pressure in the containment, which in Fukushima led to radioactive emissions. The systems will be available even if the power station's emergency diesel generations would be lost. The hydrogen explosion in

Loviisa power stations is prevented by the use of passive catalyser plates, on the surface of which hydrogen reacts with oxygen in a controlled manner as hydrogen is released. Keeping the containment filled with nitrogen always when the reactor is in use prevents hydrogen fires and explosions in Olkiluoto.

The excess pressurising of the shield building is prevented at Loviisa power station by spraying the steel containment building with water from the outside. This way the vapour created by the residual heat cools off on the surface of the shield building. Electric pumps are needed for this. They get their electricity from diesel generators, independent from other systems. These diesel generators also produce electricity for all other equipment needed for managing a severe accident. Securing these diesel generators separately from other electric sources is necessary in order to manage even severe accidents without causing radioactive emissions. In the Olkiluoto reactors currently in use the vapour-gas mix generated by residual heat can be filtered and blown out, and the evaporating water can be replaced by new water from outside the power station. With the exception of Finland and Sweden no back fitting have been made to currently functioning nuclear power stations in order to prevent severe emissions occurring when the reactor is damaged.

4. Assessing the safety of Finnish nuclear power plants

The Nuclear Energy Act defines a three-stage licensing procedure for nuclear power stations and other significant nuclear facilities: a decision-in-principle, construction license and operating license. The operating license is granted for a restricted period of time, usually for 10-20 years. About once in ten years a periodic safety assessment is carried out for reactors in use, either as part of the operating license procedure or as a separate intermediate assessment. The last time STUK carried out a security assessment for Olkiluoto 1 and 2 was when the operating license was renewed in 1997 and in 2008 when STUK made a separate intermediate assessment. The last time that safety assessment was made in Loviisa 1 and 2 was in 2007, when the operating license was renewed.

In 2009 STUK made preliminary safety assessments for new reactor units proposed in Fortum, TVO and Fennovoima decision-in-principle applications. The assessment dealt also with the Loviisa Hästholmen and Eurajoki Olkiluoto sites, as well as the adequateness of the alternative sites in Fennovoima's application, Karsikko in Simo and Hanhikivi in Pyhäjoki. In the site-specific assessments all potential weather conditions and the maximum sea levels, taken into account the climate change effect, ice conditions, seismic conditions and other external threats, including oil transport accidents, were taken into account in each locality.

There have been no relevant changes to the site-specific information after the decision-in-principle handling. Fennovoima has provided STUK with specified plan values of its potential station locations. These values are to be used in the call for tenders for the power plant. E.g. the maximum acceleration of the bedrock, which describes the biggest possible earthquake, was slightly increased. The assessment of the planning values presented by Fennovoima is currently ongoing. In addition to STUK, independent experts take part in the assessment.

Appendix 2 describes the potential external threats in Finnish nuclear power plant sites and the assessment of threats.

5. Main findings of the report made following the Fukushima accident

Although the natural phenomena that caused the Fukushima accident are not considered possible in Finland, it has been considered justifiable to reconsider the following questions after the accident:

- what kinds of external events and event combinations that threaten the security of a power station may occur in the Finnish station localities and how forceful could these events be?
- how have we prepared for these events?
- what would happen if the estimated intensity of a natural phenomena, used as basis for planning, exceeded?
- how is a station’s electricity feeding secured and are there situations where both the normal sources of electricity and the reserve power sources would be simultaneously threatened?
- what alternative methods are there for cooling the reactor, the containment and the spent fuel storage pools, and are they sufficiently inter-independent?

STUK has assessed the afore-mentioned questions based on its own expertise and the reports requested from the power companies. When it comes to questions related to external threats, STUK has also discussed with external experts, e.g. in the framework of the national nuclear safety research programme. STUK bases its conclusions on a detailed report it has drafted. However, the particulars of the report need yet to be sharpened by analysis and expert evaluations. STUK aims at delivering the final assessment to the MEE by end of June. The report is not a public document as it contains information that could be used to plan deliberate damage to the power stations.

Based on its reports STUK states the following most important conclusions:

1. The reports carried out after the Fukushima accident, reveal no new threats or shortcomings that would require immediate safety improvements.
2. On account of the Fukushima accident it is justifiable to continue drafting more detailed reports on preparedness to certain abnormal natural phenomena and, if needed, carry out safety improvements. It is especially useful to look at situations that simultaneously endanger the functioning of several parallel safety systems and or/ the levels of the defence in depth safety principle (e.g. preventing core melting and managing a melt-down accident). Reports and plans on safety improvements can be carried out of in “stress tests”, carried out of the request of the Council of the European Union, and within the set “stress test” timetable during this calendar year.
3. The experience gathered in the Fukushima accident and the findings of the reports will be taken into account also in the current, on-going development of the nuclear safety

regulations and in the emphasis of the national nuclear safety research programme SAFIR2014 projects. So far no significant need for changes in emphasis has come up.

4. Continuously improving safety has been carried out efficiently during the operating life of the plants . The license holders have long-span programmes to manage the ageing of the power plants, secure the planned life time, modernise the stations and improve the safety.

6. Questions that need more attention and investigation

Questions that especially need additional clarifications are:

- The effect of high sea level to the Loviisa power station. The flood level that endangers safety is +3.0 m. It is highly unlikely that this level would ever exceed, and it may even not be physically possible. However, a flood would affect several security systems and would cause a difficully manageable situation. Preparing flood protections so that no significantly higher (than +3.0 m) sea level rise would endanger the functioning of flood systems could be, based on preliminary estimates, quite easily arranged, and should be considered. The proportionate share of the sea level flood risk in the total risks of the station has increased, as security improvements have diminished other risks.

- Assessing the earthquake resistance of some structures and systems with stronger earth quakes than those currently used as design basis. At least fuel storage pools and fire extinguishing systems are examined.

- The potential effect on the plants' safety systems of colder and hotter weather than the current design basis.

- Ensuring the availability of a battery backed direct current for longer time periods than nowadays in all power stations. Suitable alternatives would be increasing the battery capacity in certain places and arrangements that make it possible to recharge batteries better than nowadays and by various means.

- Increasing the amount of fuel needed for emergency power generators in the storage tanks located ot the site.

- Securing the functioning of equipment in individual safety systems by scrutinising the operating power, contol and cooling needed for each device in the long term. The starting point in designing systems and equipment has been that the secured electricity and cooling systems will function at least at their designed minimum capacity, in situations where those systems and equipment are needed. Also situations in which electricity supply and the final heat sink as well as their back-ups have been damaged due to external events in a larger scale than taken into account in the design basis.

- Securing Olkiluoto 1 and 2 reactors' cooling in case of total loss of the station's direct current systems.

- Improving the availability of demineralized process water and raw water in long-term accident situations.
- Securing heat transfer to the final heat sink (sea, atmosphere) also in very exceptional external threat situations.
- The need for transferable electric generators, pumps and other equipment, or the possibility to store similar equipment in the station area or to bring similar equipment to the station from the outside, and measures to ensure their rapid deployment.
- Ensuring water feed to spent fuel storage pools.

The power companies have presented, in the reports requested by STUK, some potential targets for safety improvements and preliminary technical solutions for carrying them out. STUK will make separately decisions on utility specific additional reports and the planned improvements.

7. EU “stress tests” on nuclear power plants

Common safety assessments, the so called “stress tests” are being planned in the European Union’s region. National officials would have the responsibility to carry out stress tests, but the tests would include an international peer review by other nuclear safety regulators. The time table and the extent of stress tests will be agreed in the near future. According to the preliminary plan stress tests are to be carried out during 2011. The afore-mentioned power company –specific additional reports are to be carried out simultaneously with the EU stress tests. STUK estimates the results of the EU stress tests and the afore-mentioned additional reports as one totality, based on which it will decide on measures needed for ensuring the continued safety at the Finnish nuclear power plants.

APPENDIXES

Appendix 1 Fukushima Dai-ichi nuclear power plant accident

Appendix 2 Nuclear safety principles and external threats