Post-
Fukushima
accident

Lithuania

Peer review country report

Stress tests performed on European nuclear power plants

ENSREG
European Nuclear Safety Regulators Group
Stress Test Peer Review Board

1 GENERAL QUALITY OF NATIONAL REPORT AND NATIONAL ASSESSMENTS

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

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

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

It has to be considered that the Lithuanian NPP is already shutdown since a number of years and that as such the potential risk to the environment is much lower than during operations and therefore some aspects of the stress test are less relevant.

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

The national report is compliant with the topics defined by ENSREG. Generally the report is well written and focuses on the key issues.

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

The adequacy of the information provided in the report is in general consistent with the guidance provided by ENSREG. The part describing accident management measures at the loss of the core cooling function focuses mainly on the accident management procedures. Plant design features are only briefly described. However, it should be noted that the ENSREG guidance is relatively general in this regard.

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

There is no evidence in the report to indicate that the plant is not compliant with the current licensing/safety case. The licensing basis regarding severe accidents was clarified during the Topical Review meeting and is described in Chapters 4.1.1 and 4.1.2.

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

As both units are finally shut down the focus is on spent fuel transportation and storage. The assessments appear to be adequate in general. The report addresses the types of accidents that could eventually cause a severe accident and the time available for accident management measures. Because both units are in cold shutdown, the only scenarios endangering the fuel integrity are a long time (about one week) loss of core cooling at the partially defueled unit 2 reactor, a very long (several weeks) loss of cooling of spent fuel storage pools or some events causing a sudden loss of coolant inventory at unit 2 reactor or the spent fuel pools. Because the unit 2 reactor cooling circuit is not under pressure a sudden loss of cooling has a low probability.

1.5 Regulatory treatment applied to the actions and conclusions presented in national report

A review of Probabilistic Safety Analysis (PSA) studies has been carried out by an international group of specialists.

The operator of the Ignalina NPP has prepared a plan of safety improvement measures. The plan has been presented to the State Nuclear Power Safety Inspectorate (VATESI) for approval. During the presentation, VATESI indicated that two of the proposed improvement measures were endorsed, their implementation was inspected and that discussions with the utilities are still ongoing for other issues. Information is also provided that the regulator performs a programmatic on-site inspection programme with announced and non-announced inspections.

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

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

2.1.1 DBE

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

The two units at the Ignalina site are permanently shut down and under decommissioning process. Unit 1 reactor was defueled at the end of 2009 and about 7200 fuel assemblies are stored in spent fuel pools. The Unit 2 reactor is partly defueled with about 1300 fuel assemblies still in the reactor and about 7000 stored in spent fuel pools. There are 8 pools for temporary storage of spent fuel in water and 4 pools for handling operations at each unit, as well as an open air spent fuel interim storage facility of dry type for storage of 120 casks (6120 Fuel Assemblies (FAs)) for 50 years common for both units. A new dry spent fuel storage facility for storage of the remaining fuel is under construction.

2.1.1.2 Derivation of the DBE

The defined earthquake for the Ignalina site, which is located in the East European Platform with low seismic intensity, is based on historical records, data about the geological and tectonic structure, detailed soil characteristics as well as the assumption that the focus is located directly under the site.

2.1.1.3 Main requirements applied to this specific area

The design basis earthquake (DBE) for the Ignalina site is defined in the report as peak ground acceleration PGA=0,05g. In the presentation during the topical review this value has been corrected into PGA=0,075g for unit 1 and PGA=0,06g for unit 2.

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

Both deterministic and probabilistic approaches have been used. The PSA was carried out by an international group of specialists from three different countries.

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

The latest review from 2004-2011 was mentioned during the national report presentation. After permanent shutdown of both units Ignalina NPP provided VATESI a Safety Analysis Report (SAR) for review for the period of fuel removal from the reactor core and the spent fuel pools. External events were considered in this report.

During the country visit it was confirmed that there is a mandatory requirement to carry out a periodic safety review (PSR) every ten years.

2.1.1.6 Conclusions on adequacy of design basis

It is stated in the national report that the probabilistic characteristics of available seismic spectra correspond to the beyond design basis earthquake. This is based on results of calculations made for the Ignalina NPP main structure floor response spectra.
It is also stated that the design of casks used for transport/storage of spent nuclear fuel ensures the stability against tip over in case of a DBE.
The report provides information about the capacity of fuel casks with respect to shock loads, which is not directly relevant in this case.
The peer review team considers the DBE adequate for local geological conditions taking into account that both Units are permanently shutdown. However, it is below the International Atomic Energy Agency (IAEA) Safety Standards Guide SSG-9 recommendation for a minimum PGA of 0.1g. The existing and new spent fuel store facilities are designed to be capable of withstanding this recommended level of seismic event.

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

According to the national report all structures, systems and components needed for maintaining safe shutdown after an earthquake remain in operable condition.

2.1.2 Assessment of robustness of plants beyond the design basis

2.1.2.1 Approach used for safety margins assessment

In the national report no clear description of the approach to determine safety margins is given. During the presentation at the topical review meeting it was stated that a ‘review level earthquake’ (RLE) has been applied, based on a conservative evaluation of values of maximum amplitudes and with regard to the most unfavourable conditions (e.g. the epicentre directly under the site), corresponding to PGA=0,13g. It is judged unnecessary to pursue this for the shutdown reactors however it would be relevant for new facilities such as the dry fuel store.

2.1.2.2 Main results on safety margins and cliff edge effects

According to the report it cannot be excluded that in case of an earthquake with a higher magnitude than the RLE, (0.13g) that spent fuel damage happens as well as a loss of the integrity of the NPP leak-tight compartments that function as a containment. Regarding the spent fuel interim storage facilities using casks of all types, it is stated that the safety limits of fuel sub-criticality, fuel temperature and cask external radiation will not be exceeded in case of beyond design basis earthquake BDBE. The national report does not indicate whether the seismic margins are quantified or not, but considering that the units are not in operation, it is judged to be inappropriate to pursue this any further.

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

During the country visit it was explained that the Accident Management Centre (AMC), designed as a bombproof shelter, is located in the basement of the administrative building. This includes filtered ventilation, leak-proof doors, biological shielding etc. A seismic alarm and monitoring system (early warning) is available. Specific procedures are in place in case of alarms and early warning.

2.1.2.4 Possible measures to increase robustness

It is proposed to perform a BDBE analysis for the new spent fuel interim storage by postulating cracks/collapse of walls of cask storage hall and hot cell, turnover of casks during transportation, loss of cask sealing as well as cask blockage by debris. It is also proposed to perform a BDBE-analysis of cracks or collapse of the guarding concrete fence of the spent fuel storage.
It is further proposed to perform a BDBE analysis of the accident management centre structure to confirm their seismic capability as well as to examine the possibility to use signals of seismic alarm and monitoring systems to formulate emergency preparedness criteria. Details and timescales are currently under discussion with the utility.

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

Measures mentioned by the licensee are linked to emergency preparedness procedures.
The construction of a new spent fuel interim storage is in progress and the current schedule is for it to be finished by the end of 2013.

2.1.3 Peer review conclusions and recommendations specific to this area

The reactors are permanently shut down and spent fuel pools of both units will be empty by 2019 and all fuel will be stored in dry storage facilities. During the country visit it was demonstrated that the new dry fuel store is being designed to appropriate modern standards for external events and that these standards have been used to assess the capability of the existing spent fuel pools. It is recommended that the regulators should consider extending this approach to include a beyond design basis margins assessment for the new dry fuel store.
It is noted that the Lithuanian regulator will be continuing the PSR process for the dry storage facilities on the site.
Consequences of possible releases in case of a BDBE on radiation protection should be envisaged.

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

2.2.1 DBF

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

During the country visit it was explained that requirements for deterministic analysis according to local regulations and IAEA standards are used.

2.2.1.2 Derivation of DBF

The methodology to evaluate the design basis flood is based on the comparison of the highest theoretically possible level of Lake Drūkšiai (the level of hydroelectric power station "Druzhba Narodov" dam) and levels of Ignalina NPP buildings and structures. During the country visit it was demonstrated that a man-made dam on the perimeter of the lake controls the highest feasible level of Lake Drūkšiai, and that it is 0.7m below the cooling water pump house and 5.7m below the power station grade level. It was also demonstrated during the country visit that the geography of the site and locality prevents any significant flood from extreme precipitation.

2.2.1.3 Main requirements applied to this specific area

It was explained during the country visit that no requirements are applied to this specific area because even in the extreme case the water level cannot reach the NPP buildings and structures.

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

See 2.2.1.3

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

There is a mandatory requirement for PSRs to be completed every ten years during the decommissioning phase. The decommissioning phase is assumed to be started after defueling of the plant. A new license will be issued for that phase. Up to this phase no further safety analysis are planned. A PSR will be carried out for the dry spent fuel storage by 2014.

2.2.1.6 Conclusions on adequacy of design basis

Information provided during the country visit confirmed that the design basis is adequate.

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

On the basis of information in 2.2.1.2 it is concluded that the plant is compliant with this aspect of the design basis.

2.2.2 Assessment of robustness of plants beyond the design basis

2.2.2.1 Approach used for safety margins assessment

An investigation and assessment of the elevation differences between Ignalina NPP compared to adjacent water sources has been performed.

2.2.2.2 Main results on safety margins and cliff edge effects

During an uncontrollable, abnormal rise of the water level in Lake Drūkšiai, at the most negative flooding scenario, irrespective of the cause of its occurrence, the water level in Lake Drūkšiai cannot reach heights that could lead to the flooding of the Ignalina NPP buildings and facilities, thus no cliff edges are envisaged.

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

No improvements are identified.

2.2.2.4 Possible measures to increase robustness

The Ignalina NPP design ensures the adequate protection against external flooding. No additional measures are needed to increase the robustness of the plant against flooding. The sole measure carried out during the “Stress Tests” was the re-checking of levels of all three hydro-technical structures regulating the level of the Lake Drūkšiai.

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

No measures have been identified.

2.2.3 Peer review conclusions and recommendations specific to this area

Information provided during the country visit confirmed that the design basis flood (DBF) and safety margins are appropriate. There is no identified need to implement any measures to increase robustness. Even in the most negative scenario, the water level in Lake Drūkšiai cannot reach heights which could lead to flooding of the Ignalina NPP buildings and facilities and therefore no cliff edges exist.

During the country visit it was explained that a systematic assessment of potential for flooding arising from external precipitation has recently been completed in the context of the new dry fuel store. The data has been used to carry out a safety assessment of the existing spent fuel pools and the regulator has concluded that the case is adequate.

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

2.3.1 DB Extreme Weather

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

The original design was based on regulations current at the time that are consistent with conventional building standards. New regulations have been produced for the new dry fuel store that are based on modern standards.

2.3.1.2 Derivation of extreme weather loads

Weather conditions used as the original design basis of the Ignalina NPP were based on the area climate conditions. Extreme external temperature, wind speed and atmospheric precipitates, including their combinations, were considered in the plant design in accordance with construction regulations current at the time of design. For the new dry fuel store it was confirmed that the design is based on modern standards equivalent with IAEA guidance.

2.3.1.3 Main requirements applied to this specific area

The original design of the NPPs was based on regulations current at that time. Subsequently assessments of external events have been made as a result of an International Probabilistic Safety Assessment Review Team. (IPSART) mission 2000 to 2001. For the new dry fuel store the requirements are based on a statistical assessment of extreme events consistent with IAEA guidance.

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

For the original design the design basis conditions correspond to real weather conditions in the area of the site. Further assessments were carried out as a result of the IPSART mission. For the new dry fuel store modern standards have been adopted for external events.

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

Periodic safety reviews at a ten-year interval are mandatory. The last review was completed for the reactors in 2004.

2.3.1.6 Conclusions on adequacy of design basis

According to the report Ignalina NPP operation during 26 years and additional 3 years of post-operational shutdown state confirm the adequacy of the plant protection against extreme weather conditions. The original design basis was appropriate for its time and modern standards are being adopted for the new dry fuel store.

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

The regulator has stated that Ignalina NPP meets requirements for the design basis.

2.3.2 Assessment of robustness of plants beyond the design basis

2.3.2.1 Approach used for safety margins assessment

Extreme weather conditions with respect to the NPP are analyzed in the Technical Safety Justification for the operation of single unit 2. No information about margins is given.

2.3.2.2 Main results on safety margins and cliff edge effects

No margins and/or cliff edges are mentioned.

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

Not identified.

2.3.2.4 Possible measures to increase robustness

No measures are proposed.

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

No measures identified which could be envisaged to increase plant robustness against extreme weather conditions and would enhance plant safety.

2.3.3 Peer review conclusions and recommendations specific to this area

In the National report the weather conditions are briefly described. During the country visit it was confirmed that the design basis for original NPPs was in line with historic data. Some elements of this were reviewed as a result of the IPSART mission. For the new dry fuel store modern standards have been adopted. There is no information regarding beyond design basis capability in respect of extreme weather and it is recommended that regulators should consider this for future PSRs.

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

3.1 Description of present situation of plants in country

The two Channelized Large Power Reactor (RMBK) Units are permanently shutdown as explained above.

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

The Lithuanian nuclear regulator, the State Nuclear Power Inspectorate (VATESI), issued the stress test requirement to the licensee on 27th of May 2011. It should include the RMBK Unit 1and 2 and the Spent Fuel Interim Storage Facility (SFISF)andthe new SFISF. The results of the stress test were presented to the regulator in October 2011.

For both Units separate operation licenses are valid as nuclear fuel is in Unit's buildings. Licenses holder is State Enterprise Ignalina NPP. Ignalina NPP has the following valid licenses:

- License for operation of Unit 1;
- License for operation of Unit 2;
- License for operation of SFISF;

- License for operation of Cemented Waste Storage Facility, which is outside the scope of this stress test;
- Licenses for construction of various radioactive waste management nuclear facilities (outside the scope of this exercise),
- License for construction of New SFISF;
- License for design of Disposal Facility for Very Low Level Waste (outside scope of this stress test).

3.1.2 Main requirement applied to this specific area

Main requirements specific to Topic 2 are not identified in the national report. More specific information was presented during the country visit. For the spent fuel pool a safety temperature limit of 60 degrees Celsius is given. A limit of 150 degrees Celsius in the reactor core is given for graphite.
According to an existing contract between the grid owner and the power plant power supply has to be restored to the site within 30 minutes of interruption. Taking into account the number of power lines, the restoration of the grid in this timeframe is considered realistic by VATESI, even after an earthquake. However, with the given emergency power supplies this issue is not considered to be critical.

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

A PSA (full power and shutdown) has been performed for Ignalina Unit 2, based on a generic RBMK project. Experience gained at the different phases of PSA development were used for the development of the Unit 2 safety analysis reports, the beyond design basis accidents list, beyond design-basis accidents management procedures. The PSA model does not address the spent fuel pools.

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

There is a mandatory requirement for PSRs to be completed every ten years during the decommissioning phase. The decommissioning phase is assumed to be started after defueling of the plant. A new license will be issued for that phase. Up to this phase no further safety analysis are planned. A PSR will be carried out for the dry spent fuel storage by 2014.

3.1.5 Compliance of plants with current requirements

VATESI has concluded the following:
The time needed for restoration of power supply after total shutdown of the energy system is approximately 30 minutes. The existing Diesel Generators (DGs) are capable to provide backup power supply of remaining systems important to safety for at least 5 days and that existing batteries are capable to provide a diverse backup power supply of vitally important systems. Mobile diesel generators provide additional diversity of backup power supply.
Water feeding of the Unit 2 reactor and of spent fuel pools at both Units is carried out using sufficient redundancy of feed sources. The possibility to use the domestic potable water system should be noted. The domestic potable water system has independent pumps with own diesel generator. This system is protected against winter conditions. However, piping modifications are necessary to use this supply.
Unloading of 350 fuel assemblies from Unit 2 reactor eliminated the risk of criticality. The long-term shutdown state of the reactor significantly reduced the risk of fuel damage in the reactor and spent fuel pools in case of loss of cooling.
If the electrical power supply and ultimate heat sink (UHS) is lost, the coping time is very long (several days). Details are given in other sections of this report. Ignalina NPP staff will have enough time and necessary means to prevent cliff edge effects.

3.2 Assessment of robustness of plants

3.2.1 Approach used for safety margins assessment

The general approach adopted in assessing the safety margins with respect to the loss of electrical power and loss of heat sink aspects of the stress test requirements is to firstly describe the relevant systems available together with the associated level of redundancy and diversity of equipment. Secondly, the timescales by which various safety functions need to have been established by this equipment in order to prevent significant fuel damage are presented. Various scenarios were considered, even the loss of the batteries. Finally the level of autonomy with respect to fuel or coolant supplies is quantified. These aspects are considered in Section 3.2.2 below.

3.2.2 Main results on safety margins and cliff edge effects

- **Electric Power supply**
- **External Power Supplies**

Ignalina NPP site is supplied from the national grid with 6 power lines of 330kV and 2 power lines of 110kV via a 110/330 kV switchyard. There are 2 Hydro Power Stations nearby foreseen for backup/restoration of off-site power after LOOP. AC power supply may be provided from any power line. Connection between 330 kV switchyard and 110 kV switchyard is carried out via two coupling autotransformers. Power rating of each autotransformer is 200 MVA. Each Unit has two block transformers, 4 operation transformers and 4 start-up auxiliary transformers. At present the consumers are powered via start-up auxiliary transformers from the 110kV grid. Block transformers and operation transformers are in standby mode.

- **Internal power supplies**

Each Unit is equipped with 6 diesel generators of 5600 kW each. The diesel generators at Unit 1 are put out of operation and isolated, 3 of them are conserved. All six diesel generators at Unit 2 are available for operation. The radiation monitoring of Unit 1, which is common to both units, is now backed up by one of the DGs of Unit 2. The amount of fuel for full load operation is 72h, but in the shutdown situation with reduced load the time available as calculated to be 130 – 220h depending on the generator. The minimum operation time of Unit 2 all 6 diesel generators without refuelling is at least 5 days. Every DG is equipped with an independent tank of lubricant oil with a capacity of 6 m^3, which gives enough autonomy with a demand of 2.3 – 2.8 g/kWh.

Each Unit is equipped with 7 accumulating batteries, of which 6 batteries provide power supply for instrumentation, communication and radioactivity monitoring systems and the seventh battery mostly for emergency lighting. Six batteries at Unit 1 are put out of operation. Capacity of instrumentation batteries is enough for at least 12 hours and lighting battery for at least 9 hours without recharging. Communication facilities and computers of the Accident Management Centre can be powered by the independent stationary diesel generator, which is installed in the Organization of Emergency Preparedness (OEP) auxiliary room. During the country visit, information was provided on the instrumentation and components supplied by the batteries: valves and other executive mechanisms important to safety (e.g. control rod drives) are powered from batteries directly (DC power supply) or via converters (AC power supply).

There is the independent diesel generator (75kW) intended for the AMC only; it is placed in the special room of the AMC.

Two additional mobile DGs and special connecting points (including for the backup power for AMC) are foreseen. The capacity of one of the mobile diesel generators is 20 kW, the second is 60 kW. A contract has been signed between the plant and an oil company to ensure fuel supply for the DGs (01/2012) if needed.

Fuel pools: No backup power is necessary because of the natural circulation. Radiation monitoring and security systems are supplied by independent systems. A design change has been implemented to supply the temperature and level measurements with one the DGs of Unit 2 and by the mobile DGs.

If the offsite power supply and all DGs are lost, the critical temperature and water levels are reached by the following times:

- Unit 1 spent fuel pools water temperature (100˚C) after 16 days.

- Unit 2 spent fuel pools water temperature (100˚C) after 7 days and low level (top of fuel) after 40 days.
- Unit 2 transportation compartment: low level (top of fuel) after 15 days.

Loss of Off-site Power (LOOP)

At Loss of off-site power all six DGs start automatically and with an interruption of maximum 15 seconds supply the safety important systems that are necessary for the current state of the reactor. The utility reported in the review session that in the current situation for performance of necessary functions it is enough to have in operation 3 DGs .

The consumers of service water of Unit 1 are provided with service water by operating pumps of Unit 2. Unit 1 water and foam extinguishing systems are operated using Unit 2 pumps that are powered from DGs.

Loss of Off-site Power and loss of ordinary backup AC power source (station black out (SBO) for Ignalina NPP)

When additionally all DGs are lost the batteries supply the safety important systems without interruption. The discharge time of the batteries with the reactor at power was originally one hour, but due to the current decommissioning state it is calculated 9-12 hours depending on the battery function. VATESI concludes that there will be enough time available to restore off site power (30 min.).

Loss of off-site power and loss of the ordinary back-up AC power sources, and loss of permanently installed diverse back-up power sources

In this case it is assumed that also all batteries are lost. Then within one hour two additional mobile DGs will be connected and started manually. One provides power for instrumentation and radioactivity monitoring systems recharge points for the batteries of flashlights, temperature and level meters of spent fuel pools (SFPs) , and the other for communication system. Connecting points for those DGs are installed on walls of the Unit 2 building and the administrative building. Operations are described in instructions. The involved personnel are trained. The most recent testing of these DGs was carried out on 14 April 2011.

- **Ultimate Heat Sink (UHS)**

The main ultimate heat sink for the Unit 2 reactor and for SFP of both Units is Lake Drūkšiai. Heat abstraction to the lake is provided by the following supporting systems:

- Blow-down and Cooling System,
- Intermediate Circuit,
- Service Water Supply System,
- Pump-Cooling Plant of SFPs.

The alternative ultimate heat sink for the Unit 2 reactor and for SFPs of both Units is the environment (atmosphere).

An additional source for cooling is available by supplying artesian water to the main circulation circuit of NPP Unit 2 from the water intake area of the domestic potable water system. There is the possibility to power the domestic potable water pumps from their own DG; therefore this system is independent and considered to be reliable. This system is not seismically classified but it increases the robustness of the installations in other cases (LOOP). The system has 4 water tanks of 3000 m^3 each and 8 pumps with flow rate of 400-600 m^3/h each. The artesian water of the domestic potable water system may be used for the Unit 2 reactor coolant circuit and for the SFPs of both units (via a fire hydrant).

Heat removal from reactor Unit 2 is possible through several options using main and/or alternative heat sink:

- Non-boiling mode of coolant natural circulation: main + alternative
- Boiling mode of coolant natural circulation: alternative
- Forced circulation of the coolant: main + alternative
- Broken natural circulation of the coolant: alternative
- Coolant bubbling alternative

Each option in itself is available for an unlimited amount of time if a number of conditions are fulfilled.

For the case of SBO (LOOP and all DGs) analysis has shown that for the unit 2 reactor (1661 FAs) the critical temperature of the fuel cladding (700ºC) will be reached after 6 days. Taking into account, that the Unit 2 reactor is partly defueled with about 1300 fuel assemblies in the

reactor and more than 2 years passed since the reactor shutdown, critical temperature of the fuel cladding (700ºC) will be reached after significantly larger period of time
Heat is removed from the SFPs by using the operating pump-cooling plants. The alternative mode is diffusion of heat via evaporation of water and periodic makeup by means of water exchange in the SFP using the drain waters and contaminated Low Salted Water LSW collection.
The temperature of water in the SFP is maintained within the range of 20 to 50°C. Since the decay heat in Unit 1 SFP is low, the Unit 1 SFP pump-cooling plant is switched off. The Unit 2 SFP pump-cooling plant is constantly operating in a nominal mode (2 pumps, 2 heat exchangers) and ensures the operational values of the water temperature in the SFP.

- **Loss of primary UHS**

According to the report loss of primary UHS will not cause problem in the non-boiling mode of natural circulation (blow down and cooling system available) and in the mode of forced circulation. The cooling mode will be transferred to the boiling mode of natural circulation. In the second case, the cooling will be switched over to the coolant bubbling mode. In both cases the heat will be removed to the alternative UHS and the cooling of the reactor core is ensured during the unlimited time by means of steam removal.
The heat removal from the SFPs can be carried out by water exchange in the SFP. In the report it is stated that the heat removal can be carried out with the flow rate up to 100 m³/h during at least 48 hours.

- **Loss of primary and alternative UHS**

The complete black out of the plant covers this case.

- **Loss of primary UHS & SBO**

This case is covered by SBO. As already stated above critical temperature of fuel cladding is reached after 6 days. After 8,5 days all water above the fuel has been evaporated. The fuel pool of unit 1 starts boiling after 16 days and unit 2 after 7 days. According to the report it takes more than 40 days before fuel damage occurs.

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

Ignalina nuclear plant is in defueling state. For the fuel pools the available time to restore cooling before fuel damage would occur is in the range of several days. The decay heat will gradually go down with time and by continued unloading of the core of unit 2, although that will take still more than a year, the available time will further increase. Under the current circumstances the autonomy time of DGs and batteries is much higher than with reactors at power. A strong feature is that the 2 hydro plants that can provide electrical power when the off-site power is lost. If power is available several alternatives for cooling are available that will operate indefinitely. Without any power the only alternatives are the mobile DGs and the domestic potable water system (safety improvement).
Further safety improvements have been identified as described below.

3.2.4 Possible measures to increase robustness

All of the measures identified are understood to have either been implemented or are planned and are therefore considered in Section 3.2.5 below.

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

The measures decided and implemented are:

- Contract for supply of fuel for DGs
- DG and Mobile DG connection to the temperature and level indicators of the SFP
- Use of domestic potable water pumping system with own backup DG as diverse heat sink cooling the reactor and SFPs
- Modifications to supply Unit 1 systems by Unit 2 DGs
- Make the mobile DG connections for power supply backup of the I&C important to safety, radiation monitoring system, communication system, recharge points for the batteries of flashlights, temperature and level meters of SFPs

Recommendations from the WANO-SOER inspection have been implemented.

3.3 Peer review conclusions and recommendations specific to this area

With respect to electrical supplies there is an appropriate level of redundancy and diversity. In particular it is noted that the emergency diesels provide an independent, seismically qualified emergency power supply system, with all diesels physically separated. The diesel fuel supply for continuous operation is sufficient for at least 5 days for each unit. A system of batteries is also available for each safety DC-bus that provides 9-12h power. It is also noted that 2 mobile DGs are available and connected within one hour. Times could be extended by external supplies. The accident control centre is supplied with an independent DG.

The new installed connection to the domestic potable water system offers an additional water supply. In addition, this system can be powered by its own diesel driven pumps

A new spent fuel storage facility is under construction that will allow removal of fuel from the reactor core (unit 2) and from the SFPs. Some delays occur for his project. Even if the present circumstances do not present a significant threat (limited residual heat), it is recommended that regulators consider how to expedite this improvement.

If the decommissioning phase is delayed it is recommended that the regulator should consider the need for a further PSR for reactor unit 2 and the SFPs.

4 PLANT(S) ASSESSMENT RELATIVE TO SEVERE ACCIDENT MANAGEMENT

4.1 Description of present situation of plants in Country

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

The general authority regulations of the nuclear facilities are for nuclear and radiation safety, safety analysis, emergency preparedness and decommissioning are detailed in the following regulations:

- BSR-2.1.2-2010 "Main requirements for assurance of safety of NPPs with RBMK-1500 type reactors",
- BSR-2.1.1-2009 "Requirements for Ignalina NPP deterministic safety analysis",
- BSR-1.9.3-2011 "Requirements for radiation safety on nuclear facilities",
- P-2008-01 "Emergency preparedness for nuclear facility operating organization", and
- P-2009-02 "Requirements for decommissioning of nuclear facilities".

4.1.2 Main requirements applied to this specific area

The main requirements for severe accident management (SAM) are given in regulation BSR-2.1.2-2010. Specific requirements concerning severe accidents were planned by the authority but not implemented due to the shut down of the reactors.

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

A PSA (Full power and shutdown) has been performed for Ignalina unit 2. The decommissioning schedule foresees the last fuel to be loaded into dry casks in 2019. Currently there are no plans to develop a specific PSA for the SFPs. However, probabilistic methods were used in the course of the development of the SAR for the final shutdown stage and defueling of unit 2. Considering the remaining time under these operational conditions it is recommended that regulator should consider further safety studies to identify possible practical improvements, one approach could be to carry out a dedicated PSA for the SFPs.

4.1.4 Periodic safety reviews

Decommissioning is performed according to the decommissioning plan approved by VATESI. VATESI will modify the requirements if necessary.

4.1.5 Compliance of plants with current requirements

A comparison with WENRA reference levels has been conducted. It has demonstrated that all relevant levels have been implemented in the legislation.

4.2 Assessment of robustness of plants

4.2.1 Adequacy of present organizations, operational and design provisions

4.2.1.1 Organization and arrangements of the licensee to manage accidents

The Emergency Preparedness Plan and related Emergency Preparedness Operational Procedures have been updated and put into force taking into account the shutdown state of both units.
The OEP and Emergency Preparedness Headquarters have been established at the NPP. The OEP consists of about 20 experts from all NPP departments and service offices will be put in operation if a beyond design basis accident occurs. Accident management activities of the OEP are directed to:

- prevent accidents progressing into reactor core damage;
- ensure continuous cooling of the reactor core;
- if possible, ensure integrity of the accident localization system.

The national report indicates that SAM interventions are carried out by the Emergency Technical Service (ETS) consisting of three brigades:

- Brigade of Damage Repair at Nuclear Facilities consisting of 56 persons in 5 groups and 12 units,
- Brigade of Emergency Recovery Works consisting of 33 persons in 4 groups and 4 units,
- Brigade of I&C Equipment consisting of 12 persons in 2 groups and 2 units.

The information was provided during the country visit about additional three brigades:

- Brigade of Emergency Recovery Works on chemical equipment consisting of 19 persons in 2 groups and 3 units,
- Brigade of Emergency Recovery Works on turbo compressors, diesels, boiler-house equipment, pipe communications and transport facilities of 30 persons in 4 groups,
- Brigade of Emergency Recovery Works on electrical equipment consisting of 55 persons in 2 groups and 6 units.

The plant has a regular training programme for the OEP and ETS. The Heads of the OEP brigades and groups are responsible for development of the training programmes according to the Plan of Emergency Preparedness activities. The Heads of the units and groups are responsible for organization of training of the subordinated personnel, as well as for preparation and implementation of functional trainings.
After the Fukushima accident, a specific training programme: “Decrease of Water Level in Ignalina NPP Unit 2 MCC and SFP” has been developed. The purpose of this training is

- inspection of the knowledge and skills of the operational personnel to perform work, and
- inspection how the shift interacts with the personnel of the Ignalina NPP OEP in a beyond design-basis accident, which causes the decrease of coolant level in the main coolant circuit and SFP of unit 2, with impossibility of its restoration by regular makeup sources.

On three year intervals, Ignalina NPP organizes a complex training exercise. The latest such exercise was conducted in February 2011.
The regulator has also an emergency centre at Vilnius HQ with some parameters and information transmitted from site.
There are also provisions made on a national level, including the offsite emergency centre located at the fire and rescue department in Vilnius.

Considering the status of the Ignalina plant, the organization established to manage accidents is considered adequate.

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

The Ignalina NPP has symptom based Emergency Operation Procedures (EOP) and Severe Accident Management Guidelines (SAMGs) that cope with beyond design basis accidents. EOP were intended for the power plants when in operation and abolished after shut down. SAMGs are based on the Westinghouse methodology. The instructions consist of strategies to ensure coolant injection into the reactor (Unit 2) and into the spent fuel storage pools, isolation of leakages and isolation of relevant rooms. The instructions focus on fuel damage prevention (ensuring coolant injection prior to fuel damage), and to some extended fission product retention by the isolation of rooms. The SAMGs have been approved by VATESI in 2008, after the Ignalina NPP has fulfilled the recommendations of the IAEA RAMP mission, which took place in 2007. SAMGs were developed during plant operation and modified and adopted for the final shut-down of the last reactor in 2010. The SAMGs were reviewed and improved after Fukushima. However, no major deficiencies were identified. Technical specifications and other supporting documents have also been updated to reflect the current plant status.

4.2.1.3 Hardware provisions for severe accident management

The RBMK reactors have only a partial containment; leak tight compartments and the so-called Accident Localization Tower are for the functions of localisation and retention of steam and fission products. In the current decommissioning stage, most of the phenomena associated with severe accidents of operating nuclear power plants are physically impossible or have a very low probability:

- There is no criticality risk in the core of unit 2 because of the limited number of fuel assemblies present.
- Fuel damage under high pressure is impossible because unit 1 is defueled and unit 2 is in cold shutdown. There is no pressure in the fuel channels.
- In case of a total loss of heat removal, it would take more than a week for fuel in the unit 2 core to reach temperatures that could cause hydrogen production due to cladding oxidation. Some hydrogen is produced in unit 2 due to water radiolysis. The systems designed for hydrogen monitoring, concentration reduction and removal are still in operation at unit 2. To prevent a hydrogen accumulation, the drum separators and steam lines are ventilated through open air taps and the top part of the accident localization system blown out regularly.
- Basemat melt-through is very improbable due to the long delay to fuel melting, low decay heat and the diversity and number of water makeup possibilities.
- In the SFPssub-criticality is ensured by the distribution of fuel assemblies. No burn-up credit or neutron absorbing additives in the pool water are needed to ensure sub-criticality.
- In the Spent Fuel Interim Storage Facility sub-criticality is ensured by the distribution of fuel assemblies in the casks, and the distribution of casks.

The accident management focuses on restoration of coolant prior to any fuel damage. If restoration is unsuccessful, cooling water will be provided from an independent water source from a borehole – using borehole pumps powered by an independent DG. All the corresponding modifications and procedures and instructions are implemented. There are specific hardware provisions for severe accidents provided by the following modifications: “Supply of Domestic Potable Water to Fuel Channels through MCT Pipelines”, “Water Supply to SFP from Service Water Supply System”, “Water Supply to Room 125 of Unit A-2”, “Bld.101/2, 185 Consumers Supply at Full Auxiliaries Blackout”, “Supply of the Absorber to SFP”. There are corresponding procedures and instructions, including personnel regularly trained.

Two mobile DGs are available at Ignalina NPP. One of them will provide power supply for instrumentation and radioactivity monitoring systems, recharge points for the batteries of flashlights, temperature and level meters of SFPs; the other one for the communication system. Connecting points for those DGs are installed on walls of the unit 2 building and the administrative building. Time to bring them on site and put in operation is about one hour.

4.2.1.4 Accident management for events in the spent fuel pools

SAMGs described in 4.2.1.2 also cover accidents in SFPs.
Accessibility of the SFPs under SA conditions has been considered and Ignalina NPP has radiation protection provisions in case manual actions are required.

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

The licensee and the Lithuanian regulator have evaluated factors which may impede accident management. Of these, seismic events may cause some difficulties. Some facilities on site, which are not seismically qualified, could be destroyed during a design basis earthquake. In this case ruins and debris could make recovery conditions difficult. All roads between buildings would still be available, but access to some buildings or rooms in them might be difficult or impossible. Access recovery works will be carried out by personnel of two brigades, which have all needed equipment, tools and mechanisms such as pneumatic tools, saws, tractors, truck cranes, dump-trucks, mobile pumps etc. These brigades are: Brigade of Emergency Recovery Works and Brigade of Emergency Recovery Works on turbo compressors, diesels, boiler-house equipment, pipe communications and transport facilities.
Premises used by the crisis teams for the management of beyond design basis accidents are the OEP AMC and the Technical Support Centre. The AMC is located under the administrative building in rooms designed as bomb proof shelter.

4.2.2 Margins, cliff edge effects and areas for improvements

4.2.2.1 Strong points, good practices

The margins for fuel damage in case of total loss of heat removal have been evaluated for unit 2 and for the spent fuel storage pools.
The decay heat of the fuel assemblies still in the reactor core of unit 2 is low, 443 kW (July 1, 2011). Without any heat removal, the time required for the reactor core temperature to rise from the initial temperature 45°C up to boiling temperatures is ~50 hours. It has been further estimated that the time for the fuel cladding temperature to reach 700°C (failure criterion) is about 6 days.
In case of the most limiting unit 1 spent fuel storage pool compartment, a total loss of heat removal increases the SFP coolant temperature with a rate of 0.13°C/h. With this temperature gradient, the pool would reach boiling conditions after about 16 days. Without any coolant addition, the coolant level would reach the top of the fuel assemblies after about 40 days.
For the unit 2 spent fuel storage pool, the decay heat of the limiting compartment (compartment 336) has been estimated to be 147 kW. Without any heat removal, the time needed for the water temperature to rise in the compartment from the initial temperature (50°C) up to the boiling temperature is about 7 days. Without any coolant addition, the coolant level would reach the top of the fuel assemblies after about 15 days.
Heat is removed from the CONSTOR RBMK1500 and CASTOR RBMK casks passively from the external surface of the casks by natural air circulation.
Considering the low decay heat levels and the long delays for the unit 2 core and in the SFPs, the accident management strategies of the Ignalina NPP are judged to be adequate.

4.2.2.2 Weak points, deficiencies (areas for improvements)

The Lithuanian national report indicates that there is no additional PSA foreseen for the SFPs. Considering the remaining time under these operational conditions it is recommended that regulator should consider further safety studies to identify possible practical improvements, one approach could be to carry out a dedicated PSA for the SFPs.

The regulator should consider the benefits of qualifying the level and temperature instrumentation in the SFPs for accident conditions and having these signals available in all relevant locations.

4.2.3 Possible measures to increase robustness

4.2.3.1 Upgrading of the plants since the original design

The PSA has been utilised since 1994 to identify possible safety improvement modifications for the Ignalina nuclear power plant. The modifications have mainly been focused on safety design upgrades and accident prevention but not on severe accident mitigation.

4.2.3.2 Ongoing upgrading programmes in the area of accident management

Due to the decommissioning status of the plant, there are no upgrading programmes in the area of SAM foreseen.
An annual improvement programme has been developed by the operator and approved by VATESI. According to this program guidelines have been developed on the management of BDBA (RUZA). In addition the following modifications have been identified:

- Development of the Service Water Supply Circuit to Power Unit 1 SFP during Beyond-Design Basis Accidents
- Water Supply to SFP from the Service Water Supply System
- Water Supply to Room 125 of Unit A-2
- Supply of Domestic Potable Water to Fuel Channels through MCT Pipelines
- Bld.101/2, 185 Consumers supply at Full Auxiliaries Blackout,
- Design of power supply connection from Mobile DG to Electric Assemblies and Bld. 101/2 and 185 consumers

Appropriate improvements will be included in the next versions of the Safety Improvement Program of the Ignalina Nuclear Power Plant.

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

4.2.4.1 Upgrading programmes initiated/accelerated after Fukushima

The plants are under decommissioning. There are a few follow-up actions which the licensee and the Lithuanian safety authority have identified during the stress tests and which they consider necessary:

- Beyond design basis analyses for the new Spent Fuel Interim Storage
- BDBE analysis of cracks or collapse of guarding concrete fence of the Spent Fuel Storage, and cask blockage by debris
- Analysis of the possibility to use signals of Seismic Alarm and Monitoring System for formalization of Emergency Preparedness criterion and subsequent including of this criterion to the Instruction of Accident Classification at Ignalina NPP
- B DBE analysis of the OEP AMC structures and to propose and implement appropriate measures
- Contract for supply of fuel shall be negotiated to ensure refuelling of DGs during operation over a long period of time (implemented)
- To ensure power supply of temperature and level instrumentation of SFPs it is necessary to implement new design of backup power supply from mobile DGs and to include addenda to corresponding procedures (implemented).

Deadlines for remaining actions are defined in the Ignalina NPP safety improvement plan and will be implemented within the next 1-2 years.

4.2.4.2 Further studies envisaged

No further studies on severe accident mitigation are envisaged.

4.2.4.3 Decisions regarding future operation of plants

The plant is under decommissioning.

4.3 Peer review conclusions and recommendations specific to this area

The only nuclear installation in Republic of Lithuania corresponding to the scope of European Commission and ENSREG stress tests is the Ignalina NPP. The two RBMK-1500 type units at the site are under decommissioning. The reactor of unit 1 has been completely defueled. The reactor of unit 2 is in cold shutdown and partly defueled. The reduced number of fuel assemblies still in the unit 2 core guarantees its sub-criticality.

In case of a total loss of heat removal the time for fuel to reach cladding failure temperatures is about 6 days in unit 2. If the spent fuel storage pool heat removal capability is lost, and no coolant is added, the pool at unit 1 would reach boiling conditions after about 16 days. The corresponding time for unit 2 is 7 days. The critical low level of water in the unit 2 SFPs corresponding to the top of the fuel would be reached after 40 days and after 15 days for the fuel stored in transport baskets. The only conceivable type of accident, which could reduce the safety margins, would be a sudden loss of coolant in the coolant circuit of unit 2 or in the SFPs of unit 1 or 2. Because the cooling circuit of unit 2 is not under pressure, a sudden loss of cooling has a low probability.

Considering the remaining time under these operational conditions it is recommended that regulator should consider further safety studies to identify possible practical improvements, one approach could be to carry out a dedicated PSA for the SFPs.

The regulator should consider the benefits of qualifying the level and temperature instrumentation in the SFPs for accident conditions and having these signals available in all relevant locations.

Considering the low decay heat levels and long delays to reach fuel failure conditions in the core of unit 2 and in spent fuel storage pools of unit 1 and 2, the SAMstrategies of the Ignalina NPP are judged adequate.

List of Acronyms

AMC	Accident Management Centre
BDBE	Beyond Design Basis Earthquake
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DG	Diesel Generator
FA	Fuel Assembly
IAEA	International Atomic Energy Agency
IPSART	International Probabilistic Safety Assessment Review Team.
NPP	Nuclear Power Plant
OEP	Organization of Emergency Preparedness
PGA	Peak Ground Acceleration
PSA	Probabilistic Safety Analysis
PSR	Periodic Safety Review
RLE	Review Level Earthquake
RMBK	Russian acronym Channelized Large Power Reactor
SAM	Severe Accident Management
SAMG	Severe Accident Management Guidelines
SBO	Station Black Out
SFP	Spent Fuel Pool
SFISF	Spent Fuel Interim Storage Facility
UHS	Ultimate Heat Sink
VATESI	Lithuanian acronym for “State Nuclear Power Safety Inspectorate”