Post-
Fukushima
accident

Rumania

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 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 extent information specific to each country and installation. Draft country review reports were initiated during the topical reviews based on discussions with the country involved in the three topics and on the generic discussions within each of the three topical reviews. Issues identified for each country during the topical reviews, due to only limited time available for each country, have required follow-up discussions in more detail, both between the topical reviews and the country reviews, and during the country reviews.

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

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

Although the Romanian report complies entirely with the ENSREG stress tests specifications, it does not adequately address in depth margins to cliff edge effects for Earthquakes and extreme external events.

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

The Romanian report is judged to be adequate and at an appropriate level of detail except for earthquakes and extreme external events where it does not adequately address weak points and cliff-edge effects and the measures for the prevention of cliff-edge effects.

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

The report indicates that the plants are compliant with their current licensing/safety case. Severe accident (SA) analysis is still not part of the licensing basis for NPPs currently operating in Romania and CNCAN has recently formalized (December 2010) regulatory requirement on this issue. This topic is nevertheless part of the periodic safety review (PSR) process.

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

Although most assessments are generally considered to be adequate but the following few issues still remain: the margins for seismic events and flooding have been assessed with limited identification of cliff edge effects and weak points; margins for extreme weather are not quantified in the report; specific issues such as diversified shutdown systems, behaviour under beyond design earthquake, plant management during an extreme event in shutdown or on-going refuelling state may need further analysis.

1.5 Regulatory treatment applied to the actions and conclusions presented in national report (review by experts groups, notification to utilities, additional requirements or follow-up actions by Regulators, openness,…)

Romania is making a significant effort to implement all modern IAEA requirements and WENRA Reference Levels in its regulations and in practice. It is taking Romania a slightly longer time than originally agreed in WENRA (2010) to introduce into regulatory requirements all the reference levels (including those relevant for severe accidents management). This is now planned to be before the end of 2012.

CNCAN is monitoring the licensee's progress in the implementation of the planned improvements and will continue to perform safety reviews and inspections with a focus on the implementation of the lessons learned from the Fukushima accident, to ensure that all applicable opportunities for improvement are identified and addressed. It is noted that a number of measures have already been implemented and that there is a timeframe for the implementation of the others. The improvements identified by the licensee are endorsed by the CNCAN, however, apart from the requirement to also implement the measures for the new units 3 and 4, no further requirements are identified by CNCAN.

Within the frame of Earthquake, flooding and extreme weather conditions, there is evidence that a regulatory treatment has been applied in view of identifying possible improvements and areas for further analysis with the operator.

Within the frame of loss of electrical power and heat sink it is noted that the claim that the CDF complies with the IAEA value for existing reactors does not seem to be correct, at least for Unit 2, which started commercial operation less than 10 years ago. A comparison with the IAEA value for new reactors (a factor ten lower) may be more appropriate. It should be noted that the PSA for Cernavoda Units will be updated taking into account; new best estimate analyses; hardware and procedural modifications implemented or planned as a result of the stress test ; and probably considering credits for restoration of equipment.

Within the frame of the Severe Accidents, regulatory reviews performed to date focused on verification of the completeness and quality of the stress test report and supporting analyses. Inspections have been performed by CNCAN to verify the quality of the process implemented by the licensee in the development of plant specific SAMGs, training records on the implementation of the SAMGs, the availability of up-to-date EOPs at the points of use, procedures for connecting the mobile DGs and the related test reports, the procedures for injecting fire water into plant cooling systems, etc. Proposed plant modifications have been submitted to CNCAN for review and approval. In May 2011 CNCAN approved a modification that allows a supplementary means of water injection into the calandria vessel for moderator water make-up, aimed at preventing core damage and/or to delay progression of a severe accident. The installation of filtered containment venting systems has also been approved by CNCAN. Further modifications are scheduled for 2012-2013. CNCAN will continue safety reviews and inspections related to these modifications.

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 Law no. 111/1996 on the safe deployment, regulation, licensing and control of nuclear activities, republished on the 27th of June 2006, provides the legislative framework governing the safety of nuclear installations and the new regulations, "Nuclear Safety Requirements on Siting of Nuclear Power Plants" and "Nuclear Safety Requirements on Design and Construction of Nuclear Power Plants" which also include WENRA requirements. A revision of the nuclear safety regulation, applicable for new units, establishing general design criteria for nuclear power plants has been finalised in 2010. The revision of this regulation was aimed at endorsing more of the NS-R-1 requirements, in addition to those which served as basis for the reference levels of WENRA. The regulatory requirements on siting have also been revised. The new regulation on siting has entered into force at the end of 2010. One of the elements introduced by this new regulation is the establishment of new numerical nuclear safety targets / quantitative nuclear safety objectives. There is however no specific numerical target in the regulation relative to earthquake. The regulation prescribes instead global safety goals in terms of doses versus probabilities for the public.

2.1.1.2 Derivation of DBE

The seismic analyses considered the NPP site area on a radius of up to 300 km. The calculation of the initial DBE was based on a deterministic assessment of the maximum estimated earthquake with conservatism (seismotectonic method - Deterministic Seismic Hazard Assessment – DSHA). PSHA (Probabilistic Seismic Hazard Analysis) was performed later and showed that the exceedance probability associated to the DBE was 10^{-3}/year. This value is considered by the team not to be consistent with current European practices (10^{-4}/year), but at the time when the DBE was defined (licensing), only DSHA was available.

2.1.1.3 Main requirements applied to this specific area

The DBE for Cernavoda units corresponds to a PGA of 0.20 g (calculated using DSHA) and has an exceedence probability of 10^{-3}.

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

The report mentions that the determination of the site seismicity was made employing the seismic-tectonic method and the probabilistic method. In 2004 a probabilistic seismic hazard analysis (PSHA) was carried out for the Cernavoda NPP. The report mentions: 1) for the maximum historical recorded event, with a magnitude M = 7.5 the corresponding PGA at the NPP rock surface is 0.11g. 2) For the maximum estimated event with a magnitude M = 7.80, the PGA at the NPP rock surface is 0.18g. For the design basis earthquake (DBE) a PGA value of 0.2g has been chosen, which corresponds to the afore mentioned exceedence probability of 10^{-3} as calculated more recently
An update of the seismological catalogue was done in September 2011 to cover the earthquakes recorded in the period 2004 to 2011. According to CNCAN, it has been confirmed that the seismicity directly around the site is low, with no active faults. The seismic activity recorded recently (2004 – 2011) around the site by the seismic stations of the National Institute for Earth Physics and the local seismic network designed to monitor the seismic activity in the vicinity of the NPP site has confirmed the already known seismic activities typical for the seismogenic areas, such as the Vrancea, Sabla-Dulovo and North Dobrogea areas.

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

Besides the activities carried out to ensure compliance with the current licensing basis, CNE Cernavoda is currently conducting its first 10-year Periodic Safety Review (PSR). This first PSR is currently being finalized as the requirement for it was introduced in 2006. The PSR includes the review of external hazards

The seismic hazard has been re-evaluated recently, before the stress test as part of the seismic hazard study performed for U1 and U2.

2.1.1.6 *Conclusions on adequacy of design basis*

The Design Basis has been explained and is considered to be consistent with the minimum levels in international standards but not with current practices in Europe. Margins have however been demonstrated beyond the Design Basis (see next chapters).

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

According to the report, the licensees have confirmed that the plant is compliant with CNCAN request following the Fukushima accident. There are routine inspections and seismic walk downs in the plant. Focused inspections of seismic design features have been performed occasionally by CNCAN. The information on the seismic qualification level of the different safety relevant SSCs is not presented in the report, but a presentation of the seismic safe shutdown path was given by the counterparts during the country visit.

2.1.2 Assessment of robustness of plants beyond the design basis

2.1.2.1 *Approach used for safety margins assessment*

Seismic margin analyses have been based on the methodology and on the reports elaborated as part of the PSHA performed in the period 2004 - 2005 for both Cernavoda NPP Units. The fragility analyses performed as part of these studies that have been successfully verified by an IAEA IPSART mission in 2005. A review level earthquake (RLE) was established, based on site seismicity and plant specific design features. The selected RLE has a return period of less than 10000 years, with a Ground Motion Response Spectrum (GMRS) with a PGA of 0.33g. A more recent study with reduced uncertainties, not yet validated by CNCAN, has provided a PGA value of 0.29 g corresponding to an exceedance frequency of 1E-4/yr. Based on a review of the DBE qualified systems required for performing the safety functions, a Safe Shutdown Equipment List (SSEL) for a seismic-induced station blackout has been compiled. Further a screening level of 0.4 PGA expressed in HCLPF capacity was established, to include additional margin above 0.33 g, especially for the safe shut down path. The robustness of the SSCs in the success path, as well as their protection against adverse effects of seismic interactions, including seismic initiated internal flood, has been verified through walk-downs. The report states that the seismic margin assessment shows that in comparison with the original design basis earthquake of 0.2g, which has a frequency of 10-3 events/year, all SSCs which are part of the safe shutdown path after an earthquake would continue to perform their safety function up to 0.4g, which has a frequency of 5E-5 events/year.

This value of 5E-5 should be used in the analysis of compliance with quantitative safety objectives in the new design regulations, with a verification of whether cliff edge effects are possible in more extreme conditions.

2.1.2.2 *Main results on safety margins and cliff edge effects*

Three such potential effects have been identified and analyses have been performed for the stability of the long vertical column support of the steam generator, the skirt support with openings of the vertical HPECC water tank, and the hanger rods of the dousing platform. The report also claims that no cliff-edge effect would occur for PGA up to 0.4g (additional margins exist beyond this value), without more details. The report does not strictly comply with the stress test specifications for the evaluation of cliff edge effects and weak points, which should be identified for each of the fundamental safety

functions along with the corresponding earthquake severity, and indication of possible provisions to prevent cliff-edge effects and to increase the robustness of the plant.
The report provides the assessment of safety functions availability only up to 0.4g

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

There is a substantial work recently being performed to update the seismic safety of the plant.

2.1.2.4 Possible measures to increase robustness

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

The seismic walk-downs and subsequent seismic robustness analyses were done. The seismic margin assessment has not revealed a need for any safety significant design change. However, several recommendations resulted from these inspections, which have been considered by the licensee as parts of the regular plant seismic housekeeping program were proposed.

2.1.3 Peer review conclusions and recommendations specific to this area

The calculation of the initial DBE was based on a deterministic assessment of the maximum estimated earthquake with conservatism. PSHA was performed later and showed that the exceedance probability associated to the DBE was 10^{-3}/year. The Design Basis is considered to be consistent with the minimum levels in international standards but not with current practices in Europe. At the time when the DBE was defined (licensing), only DSHA was available. Margins have however been demonstrated beyond the Design Basis, using a review level earthquake (RLE) with a PGA of 0,33 g and upgrading this by a screening level of 0.4 g for safety relevant SSCs on the safe shut down path.
The absence of a seismic level comparable to the SL-1 of IAEA leading to plant shutdown and inspection is regarded a critical issue at the background that the probability of large earthquakes occurring during the lifetime of the plant is extremely high (recurrence intervals for the Vrancea seismic zone: 50y for Mw>7.4). It is suggested to the regulator to consider implementing adequate regulations. Currently the actions taken by the licensee following an earthquake are based on decision-making criteria that include the estimated damage to the plant (walkdowns using a specific procedure) rather than on pre-defined ground motion design response spectra.
There is only little information about margins to cliff edges, weak points and no evidences that further improvements in the seismic upgrading have been considered. Further work is proposed in this area and it is recommended that the CNCAN obtains good quality programmes from the licensees and ensures that the work is appropriately followed up.
The ongoing PSR includes the review of all external hazards. The seismic hazard has been revaluated recently, before the stress tests as part of the seismic hazard study performed both units.

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,…)

The design basis flood (DBF) for Cernavoda NPP corresponds to a return period of 10000 years. The national report does not mention the national regulations for the frequencies, intensities and duration for the maximum rainfall. During the topical peer review, it was clarified that these are established in a national standard (STAS 9470-73)

2.2.1.2 *Derivation of DBF*

The sources of flooding have been identified as Danube River, Heavy Rains (both directly inside the site perimeter and on the catchment area) and combination of these. The initial DBF value has been confirmed by recent studies. Flooding induced by tsunami in the Black Sea is rejected for appropriate reasons.
Based on the original study for river flooding, the maximum water level for the return period of 1 in 10000 years, chosen as the design basis flood (DBF) for Cernavoda NPP, is of +14.13 mBSL. The Cernavoda site platform has an elevation of +16.00 mBSL.
Heavy rainfall on the catchment area (accumulation in the higher Cismeley valley) would lead to a maximum water height of +17.50 mBSL. A protection dike has been build to protect the plant site against this event. CNCAN mentioned based on a topographical model that in case of rupture of this dike, the water would not reach any safety-related building.

2.2.1.3 *Main requirements applied to this specific area*

See 2.2.1.1.

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

For the Danube River flooding scenario, the recent studies mentioned in the report reviewed and derived extreme water flow and level for different probabilities of occurrence making use of statistical data recorded during 1940 – 2003 time interval and empirical functions. In addition to the original design studies, two studies were performed by national institutes GeoEcoMar (2005) and INHGA (2008) in order to review and derive extreme water flow and level with 1%, 0.1% and 0.01% probability of occurrence making use of statistical data recorded during 1940 – 2003 time interval and empirical functions. The original DBF calculation has been therefore reconfirmed by more recent data and studies, the latest one having been performed in September 2011, using the modern tool of Digital Topographic Model (DTM) to create the external flooding hazard map for Cernavoda NPP site and adjacent area. The methodology used to derive estimated frequency (return period) of flow values considers a regression function applied to the set of recorded flow data and logarithmic distribution for the return period. Uncertainty evaluation with 95% confidence for the maximum flow and corresponding water level was considered in the results.
For the rainfall scenario, the effect of rainfall inside the Cernavoda NPP site perimeter was calculated according to the national regulations for the frequencies, intensities and duration for the maximum rainfall. The extreme meteorological characteristics were based on a statistical analysis performed, using data from neighbouring meteorological stations.

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

As already mentioned the PSR includes the review of external hazards, including external flooding.

. A systematic review of the original analyses done for Cernavoda NPP at the siting stage has been performed in the framework of the stress tests.

2.2.1.6 *Conclusions on adequacy of design basis*

The approach to defining flood requirements is consistent with international standard.

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

The report claims that there are no deviations from the licensing basis revealed by the existing inspection programs related to design and operating provisions for external flooding. The report highlights elements contributing to ensure the compliance of Cernavoda NPP with current requirements for design basis in Romania (such as assessment of the impact of plant modifications, maintenance, testing, seismic housekeeping, seismic monitoring program, inspections, surveillance program, PLIM).

There is a specific monthly inspection of the Cismelei Valley channel and of the dike. Topographical measurements are performed twice per year, to identify potential horizontal and vertical movements of the structures and buildings. Internal inspection of the site drainage system is periodically performed as part of Plant Preventive Maintenance Program.
The main provisions to protect the plant against flooding consist in: 1/ a site elevation higher than the DBF, 2/ a drainage system and 3/ a dike to protect the site against flooding caused by heavy rain on the catchment area.
Not all safety related SSCs are located above +16.00 mBSL but, according to CNCAN they are protected up to +16.24 mBSL by design (by elevating the openings and avoiding water ingress from sump). Among the safety related SSCs located in the basement of buildings are: the Secondary Control Room, and equipment from the ECCS, ESC, SFB, D2O supply, BMW, SDGs fuel transfer pump (unit 1 only), RSW, CCW, BCW, (only in U1 design) and RCW systems. There is no routinely inspection of the flood protection design features by the regulator.

2.2.2 Assessment of robustness of plants beyond the design basis

2.2.2.1 Approach used for safety margins assessment

The margin before flooding of buildings is mentioned, however without details about which building will be first flooded (and which associated safety relevant SSC will be first flooded). The report mentions that the plant can withstand an external flood until +16.24 mBSL without compromising any of the safety functions, but does not provide further information about the range of flooding severity before loss of each of the safety functions or severe damage to fuel.

2.2.2.2 Main results on safety margins and cliff edge effects

As for weak points and cliff-edge effects, there have been assessed by determining where water ingress could occur in external flooding events regardless of the source. For water to be able to enter buildings at ground level, the flood level has to be higher than 16.24 mBSL. The reports claims that there is no credible scenario for this to occur based on the assessments performed for this stress test.
The cliff edge effects, weak points and possible provisions were not identified in the report. The report says only that the plant can withstand a flooding up to +16.24 mBSL, without detail about the maximum flooding severity applicable for each fundamental safety function (as requested in the stress test specifications). There is a margin of approximately +2.5m for the river flooding scenario and of approximately +0.5m for the heavy rain coincident with the design basis flood (from Danube) scenario.
The protection against maximum flooding water level resulted from rainfall is not fully reliant on the site drainage system, as confirmed by deterministic analysis results performed using the Digital Topographic Model of the site. Even for rainfall rate 10 times greater than the design rainfall, the maximum average water height of 20 cm is accumulated mainly on pathways and is lower than 30 cm, representing buildings minimum elevation above site platform.

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

There is a substantial work recently being performed to update part of the analyses related to flooding.

2.2.2.4 Possible measures to increase robustness

It is suggested to consider improving the volumetric protection of the buildings containing safety related equipment located in rooms below plant platform level (such as the EPS, SCA, Service building, building containing the SDGs fuel transfer pumps in Unit1).

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

The report claims that no further measures are envisaged in this area.

2.2.3 Peer review conclusions and recommendations specific to this area

The Design Basis has been explained and is considered to be broadly consistent with international standards. There is evidence provided that the plant is compliant with the design basis requirements. A first PSR is currently being performed. A beyond design basis capability is mentioned and quantified. There is no further information about margins to cliff edges, weak points and no evidence that potential specific improvements have been considered. There is a substantial work recently being performed to update part of the analyses related to flooding. A number of safety significant equipment is located underground and improvements of the provisions to protect them against flooding (other that the elevation of the plant platform) should be considered (volumetric protection). It is suggested to the regulator to consider routine inspections of the flood protection design features.

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

2.3.1 DB Extreme Weather

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

The report does not mention the design bases for extreme weather. As part of the "stress test" assessment, a screening and bounding analysis for Cernavoda NPP response under severe weather conditions has been performed. The report claims that in order to derive a comprehensive list of severe weather events to be considered for Cernavoda Units 1 and 2, a review of CNSC regulatory documents and guides, IAEA guides, ANSI/ANS standards, and US NRC documents and IPEEE experience has been performed.

2.3.1.2 Derivation of extreme weather loads

Initial screening of severe weather events were performed by the screening criteria, established in accordance with International standards.

2.3.1.3 Main requirements applied to this specific area

After the application of screening criteria, the following events have been retained for further analysis: forest fires, external flooding, Extreme winds and tornadoes.

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

There is no detailed information provided in the report as regards regulatory requirements. There are no specific regulatory requirements for severe weather loads. External fires are dealt with by fire-fighters procedures and provisions. For extreme winds, a return period of 1000 years is considered, using data from neighbouring meteorological stations. Corrective actions to be taken in case of very high wind are mentioned in plant procedures. For tornadoes, the reports mentions that there is a lack of information to establish a credible estimate of an annual frequency of tornadoes per unit area in order to derive a Cernavoda specific frequency for a tornado direct hit on the plant.

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

Cernavoda is currently conducting its first Periodic Safety Review (PSR) for unit 1. As Unit 2 started operation in 2007 this issue will be dealt in 2017. The severe weather design basis is included in the PSR process. The licensee has a meteorological condition monitoring program and a program for abnormal conditions analysis and reporting to CNCAN.

2.3.1.6 Conclusions on adequacy of design basis

The approach followed is relying on Canadian standards which are basically consistent with the international standards level.

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

No information presented.

2.3.2 Assessment of robustness of plants beyond the design basis

2.3.2.1 Approach used for safety margins assessment

There is no detailed safety margin assessment. For external fire, the report indicates that there are preventive and protective actions in place, without describing the consequences in case it fails. For tornadoes, the report explains the probable scenario and judges that core damage scenario will not occur. For extreme wind speeds, the report states that there are margins, but there is no evaluation of the maximum wind speed before jeopardising the different safety functions.

2.3.2.2 Main results on safety margins and cliff edge effects

No information presented.

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

No information presented.

2.3.2.4 Possible measures to increase robustness

Not enough information in the report to assess this area.

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

The specific procedure which is in place for extreme weather conditions (covers also the actions to be taken in case of high winds), has been revised to include more proactive actions.

2.3.3 Peer review conclusions and recommendations specific to this area

There is limited information about extreme weather conditions. The approach followed seems to be consistent with Canadian standards. Re-evaluation of the design bases is included into the PSR process. There is no information about the plant capability beyond the design basis, no identification of cliff-edge effects and weak points.

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

3.1 Description of present situation of plants in country

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

Romanian Law no 111/1996, republished in 2006, addresses the safe deployment, regulation, licensing and control of nuclear activities and provides the legislative framework governing the safety of nuclear installations in Romania. The law empowers the CNCAN to issue mandatory regulations on nuclear safety, to issue licenses for nuclear installations and activities, to perform assessments and inspections to verify compliance with nuclear safety requirements, and to take necessary enforcement actions.
All the regulations issued by CNCAN are stated to be developed in observance of relevant international standards and good practice. The priorities for the development and revision of national nuclear safety regulations have taken into account the harmonization process in the WENRA countries.

CNCAN's participation in the harmonization process has meant that the use of IAEA Safety Standards within Romania has become more systematic.
The detailed regulatory requirements, as well as the assessment and inspection criteria used by CNCAN in the licensing process are derived from a number of sources including:

- Romanian regulations;
- Limits and Conditions specified in the different licences;
- IAEA Safety Standards and Guides and WENRA Reference Levels;
- ICRP recommendations;
- Regulatory documents developed by CNSC and US NRC;
- Applicable Standards and Codes (CSA, ANSI, ASME, IEEE, etc.).

3.1.2 Main requirement applied to this specific area

It is noted that most of the WENRA Reactor Safety Reference Levels (RLs) have been incorporated into the Romanian regulatory framework through the following regulations:

- Requirements on Fire Protection in Nuclear Power Plants (2006) – incorporating RLs in Issue S;
- Requirements on Periodic Safety Review for nuclear power plants (2006) – incorporating RLs in Issue P;
- Requirements on Probabilistic Safety Assessment for nuclear power plants (2006) – incorporating RLs in Issue O;
- Nuclear Safety Requirements on the Design of Nuclear Power Plants (2010) – incorporating most RLs in Issues E, F, G & N.

It is also noted that it is intended that a regulation will be published in 2012 on the commissioning and operation of NPPs which will incorporate the remaining reference levels, including the provisions for the management of severe accidents.
Whilst the specific requirements relating to loss of offsite power and loss of heat sink were not identified in the national report, CNCAN reported them during the country visit..

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

As indicated by the adoption of WENRA Reactor Safety Reference Levels (RLs) there are requirements for deterministic analysis, PSA and operational experience feedback. This is also clear from the national stress test report and the topical review meeting.
A level 1 PSA has been performed for Cernavoda 1 & 2. It is noted that the licensee has also initiated a Level 2 PSA.
It is noted that CNCAN intend monitoring the licensee's progress in the implementation of the planned improvements and will continue to perform safety reviews and inspections with a focus on the implementation of the lessons learned from the Fukushima accident, to ensure that all applicable opportunities for improvement are identified and addressed.

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

As noted above, a regulation addressing periodic safety reviews, based upon WENRA reference levels and IAEA NS-G-2.10 was issued in 2006 (Requirements on Periodic Safety Review for Nuclear Power Plants). Periodic safety reviews are conducted at least every 10 years
The first PSR for Cernavoda 1 is in progress and it is expected that the resulting reports will be submitted to CNCAN in 2012. Noting that Cernavoda 2 first went critical in 2007 it is expected that the first PSR will be completed by 2017.

3.1.5 Compliance of plants with current requirements

With respect to the adequacy of protection against loss of electrical power CNCAN have concluded that the current robustness and maintenance of the plant is compliant with its design basis against loss

of electrical power. Also, taking into account the operating procedures and accident management measures, the plant units have a high level of defence against the loss of power and its consequences. SBO, due to the redundancy of EPS and SDG, was not considered in the Design Basis.
CNCAN also notes that diverse heat sinks are available to ensure heat removal via the SGs to the atmosphere and that adequate systems are installed to feed the SGs, which do not require service water. A back-up to the alternate UHS can be also provided by additional operator actions. CNCAN conclude that the complete loss of the UHS can be coped with for Cernavoda NPP without leading to fuel failure.

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 then presented. Finally the level of autonomy with respect to fuel or coolant supplies is quantified.

- **Loss of Off-site Power and loss of the ordinary back-up AC power sources**

Cernavoda 1 & 2 power supplies and distribution is based upon 4 classes of power:

- Class IV: Normal electrical power supply to equipment and auxiliaries which can tolerate long term interruptions without affecting nuclear safety.
- Class III: Electrical power supplies to the safety related systems, backed up by stand-by diesel generators with 100% redundancy. Class III power supplies provide the charging source for the Class I batteries and back-up supply to Class II loads.
- Class II: Alternative current uninterruptible electrical power supply (UPS, 380 VAC & 220 VAC) for essential auxiliaries, control, protection and safety equipment. UPS is provided by batteries through inverters or by Class III if the inverters are unavailable.
- Class I: Direct current uninterruptible power supply (380 VDC, 220 VDC, 48 VDC) for essential auxiliaries, control, protection and safety equipment. Batteries provide uninterruptible power for 8 hours.

In addition to the above, for each of the Cernavoda NPP the Emergency Power Supply (EPS) system provides an independent, seismically qualified system designed to 100% redundancy and separation requirements. The EPS supplies Class II, and I seismically qualified equipment. The EPS DGs have sufficient fuel storage for at least 5 days operation for each unit. The entire building, support systems including diesel fuel storage and fuel transfer, batteries, structures and equipment of the EPS are seismically qualified against a DBE. It also can withstand an impact from a light aircraft
Following the events at Fukushima it is also noted that 2 mobile DGs have been procured to provide power if the EPS is not available. The mobile DGs have autonomy for 6 hours operation at full load without external support.
In summary, apart from the off-site power, the robustness of Cernavoda 1 & 2 electrical power supply is provided by four levels of defence in depth:

- the Class III electrical power supplied by the first set of standby diesel generators with 100% redundancy built-in;
- the Class I / II electrical power supplied from batteries which can provide power supply for 8 hours;
- the emergency electrical power supply provided by the second set of diesel generators (seismically qualified) known as emergency power supply (EPS) (designed with 100% redundancy and separation requirements);
- the mobile diesel generators.

A positive feature of the EPS's is the lubricating oil make up system.

Loss of off-site power (LOOP) is a design basis event. Depending upon the detail of the scenario there are a number of possible outcomes including islanded operation.
LOOP is represented by a total loss of Class IV power, following which the turbine and the reactor are automatically shutdown and the stand-by Class III DGs will start automatically to energise the Class II buses within about 10 seconds. The Auxiliary Feedwater (AFW) pump would be loaded within 110 seconds to supply feedwater to the SGs to ensure the primary coolant heat sink. The water inventory available from the secondary side tanks exceeds 4 days.
With the exception of the Class I/II batteries, the other electrical power sources ensure at least 5 days of continuous power supply without any external support. Based upon this it has been concluded that additional design or operational changes are not required in respect of LOOP.
Loss of off-site power and loss of ordinary AC back-up is represented by the loss of all Class IV and Class III power supplies and is a design basis event. In this scenario the operator will initiate SG depressurisation in order to bring into service low pressure water supply systems to the SGs (Boiler Make-up Water (BMW) or Emergency Water Supply (EWS)). The operator will open the Main Steam Safety Valves (MSSVs) and when the SG pressure has reduced below a certain level the water from the dousing tank will be fed by gravity into the SGs. Should the operator not depressurise the SGs then depressurisation is automatically initiated.
The dousing tank contains sufficient water for at least 23 hours supply, this can be extended to about 7 days by manually adjusting the BMW isolating valves. As long as water is provided to the SGs the thermosyphoning process will ensure decay heat removal and fuel damage is not expected.
For this scenario the EPS DG should have been started within 30 minutes which will enable longer term cooling to be established.

- **Station Blackout (SBO)**

SBO has been taken to be loss of offsite power, loss of ordinary back-up AC power and loss of permanently installed diverse back-up AC power sources. This is considered a beyond design basis event and assumes loss of external grid, stand-by DGs and the EPS DGs. It is assumed that the batteries remain available. For the first 30 minutes the scenario is essentially as described above although it then assumed that the EPS is not available.
As indicated above the dousing tank contains sufficient water for at least 23 hours, and up to about 7 days. During this time, the operators will attempt to restore EPS in order to start the Emergency Water Supply (EWS) pumps and ensure a long term heat sink. If the EPS cannot be recovered, the operator would use mobile DGs and once operational the EWS pumps can be used to supply water to the SGs. The mobile DGs have autonomy for 6 hours and the fuel oil from the EPS fuel tanks can ensure operation for 5 days. If the EWS system was unavailable the fire water trucks would be used to provide water directly to the SGs through the EWS pipework. There are three fire water trucks on site (one per unit and one for fire fighting) with a total capacity of 21 m^3. Since the electrical submersible pumps are not available, the mobile diesel engine driven pump could be used to provide water from the suction bay to the fire water trucks (directly or through the fire water system). If none of these features are available, the fire water trucks can be supplied with water from the domestic water system. The deep underground wells pumps can provide (running together) 90m^3/h. This water flow is equivalent to the flow required for decay power heat removal (from both units), at about 6 hours after the event.
It is noted that, at about one day after the event, a flow rate of 18 m^3/h is needed to feed the SGs. Currently the location of the fire trucks has yet to be qualified against extreme external events. In the case of a seismically induced SBO with the batteries unavailable and when the steam lines do not break at a weak link fuel damage would occur after about 4 hours as a consequence of not being able to depressurise the SGs. Whilst noting that for this highly unlikely scenario the mobile DGs should be available in 2.5 to 3 hours, it is also noted that it is proposed to provide different modes of opening the MSSVs to ensure SG depressurisation and also to increase the seismic robustness of the batteries.
The Emergency Control Room is manned continuously so that during SBO it can be made operational quickly, noting that the MCR would be battery powered under SBO.
During the country visit discussions revealed that if SBO were to occur at certain points during the refuelling process, two spent fuel bundles would not be adequately cooled. It was reported that the

fuel damage would occur in about 1.4 hours and the fuel melt in about 1.9 hours. It was also stated by the utility that the fission products would be retained either within the pressure boundaries of the refuelling machine (which is covered by DBA) or in the worst case in the spent fuel discharge room which is part of the containment extenstion.

- **Loss of Ultimate Heat Sink (UHS)**

The primary ultimate heat sink (UHS) uses the shutdown cooling system (SDCS) to remove decay heat by forced circulation through the Primary Heat Transport (PHT) system. The SDCS transfers heat to the Recirculating Cooling Water (RCW) system which in turn transfers heat to the Raw Service Water (RSW) system and hence to
the Danube River.

The alternate heat sink is only used if the primary UHS is unavailable. Natural circulation in the primary loop is used to transfer decay heat to the SG and this energy is then either transferred to the secondary side or released to the atmosphere through the Atmospheric Steam Discharge Valves (ASDVs) or MSSVs (Main Steam Safety Valves). Two different paths can be used to provide cooling water to the SGs secondary side.
The first of these provides demineralised water from the "feedwater train". Demineralised water is provided to the feedwater train by the Water Treatment Plant (WTP) The WTP can produce demineralised water continuously as long as off-site power is available and the WTP is supplied with freshwater from the CCW or BCW systems if any of these systems is available. The second initially uses the BMW (dousing tank inventory) followed by the EWS system.
Loss of the primary UHS is taken to be total loss of RCW and hence loss of the SDC system. Loss of RCW will also mean that cooling will be lost to both the MFW and AFW pumps. The back-up cooling for the MFW pump is provided by the Fire Water system. For the AFW pump back-up cooling can be provided under gravity from the Condensate Storage Tank.
If the WTP becomes unavailable the minimum stored demineralised water in the "feedwater train" is sufficient to provide feedwater to the SGs for at least 4 days (3 days if one of the emergency water tanks has been isolated for maintenance).
If the "feedwater train" is unavailable an alternative source of demineralised water is provided by the dousing tank through the BMW system. Water from the dousing tank will flow under gravity once the BMW pneumatic isolating valves are open and the SGs are depressurised to atmospheric pressure. The dousing tank inventory will provide adequate decay heat removal for at least 23 hours if the flow through the BMW valves cannot be manually controlled or for 7 days if this flow is controlled.
Once the demineralised water inventory is depleted the SG secondary side will be provided directly from the suction bay (Danube River) by 2x100% Emergency Water Supply (EWS) pumps (for each unit). The EWS pumps are powered by the EPS DGs. The intake for the EWS pumps from the suction bay is separated from the intake of the RSW pumps.
Loss of the primary ultimate heat sink and the alternate heat sink is beyond the design basis. Since the feedwater and EWS systems are assumed lost the operator will use the dousing tank inventory as described above. This will provide an adequate heat sink for at least 23 hours and up to 7 days if the SG level can be controlled with the BMW valves.
If the EWS has been lost due to failure of the power supply the operator is instructed to use the mobile DGs to provide a power supply. The mobile DGs can be installed within 2.5 to 3 hours.
The fire water trucks would ultimately be used for SG make-up via the EWS lines if none of the other heat transfer routes is available. The fire water trucks can be supplied from directly from the suction bay, from the fire water tanks or from the domestic water system. The last resort is the deep well system, which takes water from 700m deep wells.

- **Loss of UHS and SBO**

Noting that SBO effectively results in loss of the primary UHS combination of loss of UHS and SBO is essentially as described for SBO.

3.2.2 Main results on safety margins and cliff edge effects

SBO bounds most scenarios and as indicated above the dousing tank contains sufficient water for at least 23 hours, and potentially up to about 7 days. During this time, the operators will attempt to restore EPS in order to start the Emergency Water Supply (EWS) pumps and ensure a long term heat sink. If the EPS cannot be recovered, the operator would use mobile DGs and once operational the EWS pumps can be used to supply water to the SGs. The mobile DGs have autonomy for 6 hours and the fuel oil from the EPS fuel tanks can ensure operation for 5 days. If the EWS system was unavailable the fire water trucks would be used to provide water directly to the SGs through the EWS pipework

An exception to the above is the case of a seismically induced SBO with the batteries unavailable and where the steam lines do not break at a weak link. Under these conditions fuel damage would occur after about 4 hours as a consequence of not being able to depressurise the SGs. This scenario is avoided by the operator action to manually open the Main Steam Safety Valves using hydraulic levers, in less than 2 hours. In addition, in 2.5 to 3 hours from event initiation, the mobile DGs are available to provide electrical power. Also, the licensee has work in progress to increase the seismic robustness of the batteries.

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

With respect to the adequacy of protection against loss of electrical power CNCAN have concluded that the current robustness and maintenance of the plant is compliant with its design basis against loss of electrical power. Also, taking into account the operating procedures and accident management measures, the plant units have a high level of defence against the loss of power and its consequences.

CNCAN also note that diverse heat sinks are available to ensure heat removal via the SGs to the atmosphere and that adequate systems are installed to feed the SGs, which do not require service water. A back-up to the alternate UHS can be also provided by additional operator actions. CNCAN conclude that the complete loss of the UHS can be coped with in Cernavoda NPP without leading to fuel failure.

Notwithstanding this, a number of safety improvements for beyond design events 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 following measures have either been implemented or are planned:

- To increase protection against a SBO event response, two 880 kW, 0.4 kV mobile DGs (one for each of Unit 1 and Unit 2) have been procured and tested by powering the 380 VAC EPS buses and the EWS pumps. The capacity of each mobile DGs is almost equivalent to that provided by the design non-mobile EPS DGs. In order to replace the above mentioned DGs, the plant has already procured 2 new DGs 2x1MW (to cover entirely the EPS loads), which are more versatile as they can supply also 6KV loads supplementary to 0.4 KV loads.
- In order to further decrease the time to connect the mobile DGs, the plant has initiated a modification to install special connection panels to the loads which may be supplied from these DGs.
- Improve the seismic robustness of the existing Class I and II batteries.
- Provide an additional facility to open the MSSVs after a SBO.
- A mobile diesel engine driven pump has been procured and tested, for fire water tanks make-up or fire water truck supply. Also, 2 electrical mobile submersible pumps are already available on site.
- two new mobile diesel generators have been procured and tested, for electrical power supply to the two pumps that can provide water in the domestic water system from the deep wells which are available on site.

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- following the topical peer review and the country visit it was reported that the option of charging the batteries or the installation of a supplementary uninterruptible power supply for the SCA is being considered by the licensee as a potential improvement.

3.3 Peer review conclusions and recommendations specific to this area

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

With respect to electrical supplies there is a good level of redundancy and diversity. In particular it is noted that the EPS system provides an independent, seismically qualified emergency power supply system with 100% redundancy and separation and that the fuel oil supply for continuous operation is sufficient for at least 5 days for each unit. It is also noted that 2 mobile DGs are available which have autonomy of fuel supplies at full load of 6 hours and that this could be extended to 5 days using on site fuel supplies.

The primary and alternative heat sinks also appear to provide a good level of redundancy and diversity. In particular it is noted that if the “feedwater train” is unavailable an alternative source of demineralised water is provided by the dousing tank through the BMW system. Water from the dousing tank will flow under gravity once the BMW pneumatic isolating valves are opened and the SGs are depressurised to atmospheric pressure. The dousing tank inventory (2000 m3) is reported to provide adequate decay heat removal for at least 23 hours if the flow through the BMW valves cannot be manually controlled, or for up to 7 days if this flow is controlled. This provides a significant period of time for the operator to restore alternative sources of feedwater and is a very positive feature of the design.

If none of the other heat transfer routes are available the fire water trucks would ultimately be used for SG make-up via the EWS lines. The fire water trucks can be supplied directly from the suction bay using the electrical submersible pumps, using the motor diesel driven pump or from the fire water tanks or from the domestic water system and the deep wells.

Notwithstanding the above points a number of safety improvements for beyond design events have been identified as described in Section 3.2.5 above. Some of these have already been implemented ; two mobile DG’s have been procured; a mobile hand pump for fuel oil transfer from SDGs/EPS fuel oil tanks to the MDGs has been provided; temporary local connections have been set up for the fire water trucks to provide water directly to the EWS lines.

With respect to the coping times for LOOP, SBO and loss of the UHS it is noted that in general analyses have been performed by the plant designer (AECL / CANDU Energy). An exception to this is fuel oil consumption which has been estimated by the licensee through the use of engineering judgement. It is reported that CNCAN has performed a review of the licensee’s assessment. The regulatory review was aimed at verifying the assumptions of the analysis and the process employed by the licensee to ensure the quality of the analysis.

During the topical review meeting it was reported that the operator performs routine inspections and walkdowns of LOOP, SBO and UHS design features. This includes tests, surveillances and preventative maintenance, in accordance with the licensee's procedures for the SDGs, EPS, batteries, mobile diesel generators, distributions systems and UHS design features. CNCAN’s resident inspectors also perform routine inspections of the electrical systems and UHS design features. It is also noted that additional inspections have been identified for equipment required by the new SBO Emergency Operating Procedure - APOP G03 "Station Blackout".

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, ,…)

For existing NPPs: A number of the WENRA Reactor Safety Reference Levels (RLs) have been incorporated into the Romanian regulatory framework. A further regulation (to be issued by the end of 2012 on commissioning and operation of NPPs) will incorporate the remaining RLs, including provisions for the management of SA). The nuclear safety regulation establishing general design criteria for NPPs was revised in 2010 and incorporated IAEA NS-R-1 requirements (additional to those used for WENRA RLs).
For future NPPs: In 2010, new regulatory texts were issued by CNCAN that include the establishment of numerical nuclear safety targets/quantitative nuclear safety objectives; requirement for consideration of SA analysis in the establishment of design bases, demonstration of compliance with quantitative nuclear safety objectives. It includes accident analysis requirements and requirements on how deterministic and probabilistic safety analyses should be used in the design of NPP. This topic for future reactor is not examined in detail during the peer review process. This regulation is applicable also to existing NPPs starting with the next cycle of PSRs.

4.1.2 Main requirements applied to this specific area

Development of SAMG is on-going (this includes the period before the stress test review). SAMG for power states of reactor are implemented and development of SAMG for shutdown states is under consideration. However, there are currently no regulatory requirements on severe accident management (SAM) although analysis of severe accidents is required.

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

A L1 PSA has been performed for both Cernavoda NPP Units but this did not include external events (with the exception of seismic events) and the spent fuel bays (SFBs). The L1 PSA results for all operating stages, including external (seismic) and internal events show a core damage frequency (CDF) of 3.3 x 10-5 events/year for Unit 1 and 3 x 10-5 events/year for Unit 2. Finally, SNN is developing a L2 PSA for Cernavoda which will include SFB accidents.
SA regulatory basis for future plants have been defined in 2010.

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

SAMGs have very recently been developed and introduced at Cernavoda NPP. Their review is not covered in its currently ongoing PSR for unit 1. However, the review of the severe accident management will be included in the unit 2 PSR process/reports.

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

Even though there are currently no national regulatory requirements related to SA management, the compliance with WENRA RL for severe accident management is sought but maybe not yet fully achieved. For example, the RL F4.2 ‘The leak-tightness of the containment shall not degrade significantly for a reasonable time after a severe accident’ may require additional work..
SAM will be included in regulatory requirements by the end of 2012.

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

An emergency response program and provisions for responding to emergencies, including SA, are in place. All provisions of the emergency program and associated documentation have been approved by the regulatory body and undergo regular emergency exercises.
The regulator performed inspections on SA management as part of its stress test reviews and inspections. These included participation, as observers, in some of the licensee's exercises which included the testing of SAMGs.
Measures have been identified (and will be implemented) that aim to improve the reliability of the: (i) communication system and, (ii) on-site emergency control centre. An alternative off-site emergency control centre is being developed.
A review of the national off-site organisation is in progress and will take into account the lessons of the Fukushima accident.

Main arrangements are summarized as follows:

- Dedicated equipment are available for personnel and public alert (sirens, etc.,),
- Diversified communication and notification equipment are available during an emergency (phones, faxes, satellite phones, E-LAN and special communications service phones and radio systems),
- An On-Site Emergency Plan is in place to respond to any emergency, ranging from the lowest incident class to highest “General Emergency”,
- Local, county and national authorities are responsible for Off-site Emergency Plan (details of the organisation available in the national report),
- A seismically qualified Secondary Control Area (SCA) provides an alternative operating facility should the main control room (MCR) become uninhabitable. The SCA allows operators to control and command all the plant safety systems.
- The Command Unit and the Technical Support Group carry on their activities during an emergency in the On-site Emergency Control Centre, located ~ 800 meters from the plant.

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

Abnormal plant operating procedures (APOPs) or emergency operating procedures (EOPs) provide for response to design basis accidents (DBA) and design extension conditions.
During the Country visit the utility has presented the new EOP for SBO. The verification of completeness of existing EOPs for all types of accident (multiple failures….) has been discussed as a possible area of improvement.
Cernavoda NPP has implemented a set of SA Management Guidelines (SAMGs) to cope with situations in which accident conditions progress to severe core damage. The objectives of the SAMGs are to: terminate core damage progression; prolong containment capability; minimize on- and off-site releases. The SAMGs, based on generic CANDU Owners Group (COG) guides, were customised for Cernavoda NPP.
SA entry conditions are included in APOPs to guide on transition from APOP to SAMG. All plant personnel involved in the emergency response organisation are trained for SAMG use, and drills are being incorporated into emergency response training program.
The current SAMGs are only applicable to the at-power state of reactor. Romania considers the at-power SAMGs would still provide valuable guidance to respond to an accident that originated from a shutdown condition, because severe accident phenomena are largely independent of the initial state of the plant. However, the development of SAMGs specifically for shutdown states is under consideration.

4.2.1.3 Hardware provisions for severe accident management

The dual failure concept (failure of any system required for the normal operation and a simultaneous failure of a safety system) contributes to the robustness of the design. For example, the analysis of CANDU 6 reactors must show that:

- Coolability of the core geometry is maintained, even if the ECCS are impaired,
- radioactive releases are adequately prevented, even if the containment system were to be impaired.

The two diverse shutdown systems are excluded from the dual failure sequences.

The CANDU-6 reactor design has both preventative and mitigating features to ensure a robust design against severe accidents. It has inherent and engineered provisions to prevent core damage, terminate progression of core damage, retain the core within the calandria vessel, localize core debris within the calandria vault, maintain containment integrity, and minimize off site releases.

Other existing equipment/provisions available for SA management are summarised as follows:

- Additional sources of water for the reactor and SFB cooling (fire truck, mobile pumps taking water from fore-bay, fire water tanks, de-mineralized water tank or deep underground wells),
- Two mobile DGs stored in a secure location on-site for SBO conditions and connectable within 3 hours.
- Sufficient diesel fuel storage for 4.5 to 18 days DG operation,
- Containment venting via three existing routes that include two filtered vent paths (water scrubbed through the SFB or SG), and non-filtered vent paths through existing containment penetrations. Each of these options is described in the SAMGs.
- Spray system for containment to control pressure and reduce release
- Hydrogen management by inertization on unit 1 and igniters on unit 2 with containment features allowing natural convection and mixing of containment atmosphere,

The following equipment will be added as a consequence of the stress-test review:

- PARs on unit 1 and 2 for hydrogen management,
- Dedicated emergency containment filtered venting system for each unit,
- Additional instrumentation for SA management e.g. hydrogen concentration monitoring in different areas of the reactor building

SAMG development has also identified a design modification for water make-up to the calandria vessel and the calandria vault (completed for unit 2 calandria vessel).

The utility has also proposed to improve the reliability of existing instrumentation by qualification to SA conditions and extension of the measurement domain.

During the country visit the utility expressed its intent to perform the qualification of the SA instrumentation (especially cables and connectors) to withstand harsh conditions for 30 days.

4.2.1.4 Accident management for events in the spent fuel pools

EOPs based on WANO recommendations, developed following Fukushima, address extended loss of Spent Fuel Bay (SFB) cooling capability. The main goal of the procedures is to prevent damage to fuel bundles and hydrogen generation due to fuel overheating.

Without cooling, it is estimated to take 60 h until SFB water boils, nine days until radiation levels in the SFB start to increase significantly (to 1.7 mSv/h), and 15 days until the first row of fuel bundles become uncovered.

The EOPs guide the operator on how to establish another means of water supply in the SFB (using fire trucks or mobile pumps via hose connections). Without SFB leakage, sufficient time is available to ensure that fuel will remain adequately cooled and no personnel radiation doses exceeding regulatory limits occur.

The following provisions have been defined for loss of cooling and other harsh conditions:

- Natural ventilation for vapours and steam evacuation by opening SFLA doors or through a hatch in the roof and ventilation opening in the wall,
- H2 monitoring by portable H2 detectors connected to turbine line,
- Use of a new, seismically qualified, fire water pipe to allow water make-up without entering in the SFB area. Connections are provided outside the SFB building,

– Reinforced water height level instrumentation in the SFB and the reception bay.

The report concludes that no adverse consequence is expected as a result of the loss of SFB cooling and no damage to the SF is expected to occur. It also suggests that there is no possibility of re-criticality in the CANDU SFB whether in air or in light water. Hydrogen generation is not possible as long as the spent fuel remains submerged. The location on the ground of the SFB also contributes to its robustness.

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

Human and equipment resources appointed for emergency response activities have been assessed on the assumption that both Cernavoda NPP Units would be affected by an accident.
Cernavoda NPP will establish a new seismically qualified location for the on-site emergency control centre and the fire fighters. This location will include important intervention equipment (mobile DGs, mobile diesel engine pumps, fire-fighter engines, radiological emergency vehicles, heavy equipment to unblock roads, etc) and will be protected against all external hazards...
Cernavoda NPP has agreed a protocol with a number of state bodies (e.g. the Constanta County Inspectorate for Emergency Situations, Police County Inspectorate, etc.,) to ensure the transportation of Cernavoda personnel, fuel supplies, etc. to the site should access become hindered due to extreme meteorological conditions, natural disasters or other traffic restrictions. In addition, Cernavoda has protocols in place with medical centres and hospitals in the region, for the provision of medical services (first aid, initial treatment and decontamination, treatment of overexposed personnel).
Impairment of work performance due to high local dose rates, radioactive contamination and destruction of some facilities on site, as well as unavailability of power supply, have been taken into account in the emergency response measures.
The habitability of the MCR and SCA was assessed for various types of accidents (such at limited core damage with containment isolation failure or SA with no containment failure) and it is concluded,, that all (five) shift crews can perform their work either from the MCR or from the SCA without exceeding an integrated dose of 100 mSv in the seven days following an accident.. However, the case of a total core melt accident associated to a containment failure (or voluntary venting) has not been assessed.

4.2.2 Margins, cliff edge effects and areas for improvements

The national report states that potential cliff-edge effects identified based on the analysis of unmitigated accident scenarios and the time available before their occurrence have been addressed in the SAMGs, which include measures for the prevention of cliff-edge effects.

4.2.2.1 Strong points, good practices

The following strong point/good practices on the issue of severe accident management have been identified:
– The possibility to use diverse methods to open the MSSVs if the normal power supply are lost,
– The robustness of the CANDU design to SA progression (slow accident progression due to the quantity of water available in the vessel and calandria vault, the impossibility of in-pressure core melt, induced SGTR and maybe steam explosion), which maximises the chances to stabilize a degraded situation and limit the possibility of large early release (except for hydrogen combustion),
– The large spreading area in case of MCCI which contributes to the possibility of corium cooling in the late phase of an accident,

4.2.2.2 Weak points, deficiencies (areas for improvements)

The following areas for improvement have been identified:
- Verification of the completeness of event-based and symptom-based EOPs for all accident situations should be undertaken
– Further study is required for shutdown states. Including: SAMGs development, identification of possible weakness in case of external event especially for situations with limited core water

inventory or refuelling phase, PSA development, Possibility of deformation and leakage at the connection between reactor building and SFB building in case of beyond design earthquake.
- MCR habitability analysis to be continued (e.g. implementation of a close ventilation circuit with oxygen supply)
- Currently, no mandatory regulatory requirements for SAM

4.2.3 Possible measures to increase robustness

4.2.3.1 Upgrading of the plants since the original design

Unit 1 of Cernavoda NPP was commissioned in the period 1993-1996. The design installed and commissioned in Romania has incorporated most of the significant safety related design changes already made by other organisations operating CANDU-6 up to late 80's. Additional design changes have been incorporated during commissioning and operational phases. These originated from operating experience from other CANDU-6 stations and probabilistic safety evaluations performed to verify the adequacy of the design.
Unit 2 was commissioned in the period 2005-2007. Cernavoda Unit 1 (July 1997) was used as the reference design for Unit 2. In addition, the Unit 2 design incorporated safety significant design modifications implemented at other CANDU 6 plants. Some of the safety improvements safety improvements for Unit 2 include: provision for manual initiation of Shutdown System number one (SDS#1) from the SCA; emergency Core Cooling System initiation on low sustained pressure in the heat transport system and automatic initiation of low pressure ECC; provision for an alternate power supply for the LACs for mixing the Reactor Building atmosphere during a severe accident; provision of hydrogen igniters to prevent hydrogen accumulation in the Reactor Building in case of severe accidents.
Cernavoda NPP has a feed-back program to assess and implement the design modifications and improvements from Unit 2 to Unit 1, in order to maintain an equivalent level of nuclear safety with Unit 2.

4.2.3.2 Ongoing upgrading programmes in the area of accident management

The on-going upgrading programme (before the Fukushima accident) concerns the implementation of SAMGs with associated hardware modification.

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

SAMG development was already ongoing before the Fukushima accident and the development has been completed or accelerated in the following points:
- The Emergency Plan and Procedures, Conventions, Protocols and Contracts in place have been reassessed and revised to better accommodate emergency response to SA coincident with natural disasters.
- Cernavoda NPP will establish a new seismically qualified building to host the on-site Emergency Control Centre fire fighter’s facility and main intervention equipment.
- Cernavoda NPP will increase the reliability of the communication systems and the robustness of the on-site emergency control centre. The set-up of an Alternative Off-site Emergency Control Centre is in progress.
- A review of the national (off-site) emergency response strategy is currently being performed, with the aim of incorporating lessons learned from the Fukushima accident.
- Two new APOPs, for responding to SBO and Abnormal SFB Cooling Conditions, have been issued as part of the response to lessons learned from the Fukushima Daiichi accident.
- Hardware modifications to support SAMGs and increase robustness in case of extreme event: passive autocatalytic recombiners, filtered containment venting system, SFB provisions to cope

with harsh conditions, new reinforced (for earthquake and flooding) emergency control centre, additional mobile equipment, additional instrumentation for SAMG
- Qualification to SA conditions for equipment (e.g. 30 days resistance for cables and connectors)
- Implementation of a hydrogen monitoring system (proposed by the utility and considered by the Romania safety authority to be reliable).

4.2.4.2 Further studies envisaged

All identified modifications are planned to be implemented before 2013. No further studies are described in the national report.

4.2.4.3 Decisions regarding future operation of plants

CNCAN noted that a significant effort has been made by the licensee to respond to the lessons learned from the Fukushima accident in a timely manner. No concerns have been raised from the regulatory reviews performed to date. The conclusion of the review conducted by CNCAN is that the risk to the public from beyond design basis accidents at Cernavoda NPPs is low and is kept under control.

4.3 Peer review conclusions and recommendations specific to this area

After the topical review of national reports and the country visit, the good progress in the implementation of SAMGs, associated with a significant number of hardware modifications during a short time period was noted.

The following points are provided for Romania's consideration;

- The licensee should examine, for particular plant shutdown states, any possible weaknesses of the Cernavoda NPPs in agreement with the stress test specifications.
- SAMGs for shutdown states should be developed (it is noted that it is under consideration)
- Verify the completeness of event-based and symptom-based EOPs for all accidental situations
- CNCAN should finalize the incorporation of severe accident management requirements in the Romanian regulation and, if possible, some qualitative or quantitative safety objectives related to the protection of the population. This should be done for existing power plants. Such objectives should then, in response to the continuous plant safety improvement, be incremented at each PSR,

Acronyms

AFW - Auxiliary Feedwater Pump
APOP - Abnormal plant operating procedures
ASDV - Atmospheric Steam Discharge Valves
BCW - Raw Service Water (system)
BMW - Boiler Make-up Water (system)
CCW - Condenser Cooling Water
CDF - Core Damage Frequency
COG - CANDU Owners Group
CNCAN - Romanian National Commission for Nuclear Activities Control
DBA - Design Basis Accident
DBE - Design Base Earthquake
DBF - The design basis flood
DG - Diesel Generators
DTM - Digital Topographic Model
D2O - Heavy Water
ECCS - Emergency Core Cooling System
ENSREG - European Nuclear Safety Regulators Group
EOP - Emergency Operation Procedures
EPS - Emergency Power Supply
EU - European Union
EWS - Emergency Water Supply
GMRS - Ground Motion Response Spectrum
HCLPF - High Confidence Low Probability of Failure
HPECC - High Pressure Emergency Core Cooling
IAEA – International Atomic Energy Agency
LOOP - Loss of off-site power
MCCI –Molten Core-Concrete Interaction
mBSL - meters Baltic Sea Level
MSSV - Main Steam Safety Valves
NPP – Nuclear Power Plant
PAR – Passive Autocatalytic Recombiners
PGA – Peak ground acceleration
PHT - Primary Heat Transport system
PLiM - Plant Life Management
PSA - Probabilistic Safety Analysis
PSHA - Probabilistic Seismic Hazard Assessment
PSR - Periodic Safety Review
RCW - Recirculating Cooling Water
RL - WENRA Reactor Safety Reference Levels
RLE - Review Level Earthquake
RSW - Raw Service Water system
SA - Severe Accident
SAM - Severe Accident Managment
SAMG - Severe Accident Management Guidelines
SBO - Station Blackout
SDCS - Shutdown Cooling System
SDG - Stand-by Diesel Generator

SFB - Spent Fuel Bay
SG - Steam Generator
SGTR - Steam Generator Tube Rupture
SSEL - Safe Shutdown Equipment List
SSC - Structures, Systems and Components
U1 – Cernavoda NPP Unit 1
U2 – Cernavoda NPP Unit 2
UHS - Ultimate Heat Sink
WENRA – Western European Nuclear Regulator Association
WTP - Water Treatment Plant