Post-Fukushima accident

Bulgaria

# Peer review country report

## Stress tests performed on European nuclear power plants

ENSREG
European Nuclear Safety Regulators Group
Stress Test Peer Review Board

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# 1 GENERAL QUALITY OF NATIONAL REPORT AND NATIONAL ASSESSMENTS

The National reports developed within the European Union stress test were prepared in accordance with ENSREG specifications. The Bulgarian National Report (BG-NR) contains the results of the self-assessment performed by licensees, followed by an independent review by the national regulatory bodies.

As the next step, an international peer review was performed. The peer review process was documented in the country review reports, which are one of the specific deliverables. 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 prepared during the topical reviews in Luxembourg, 5-17 February 2012, 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 Partner Country during the topical reviews, due to only limited time available for each country, have required a follow-up discussions in more detail, both between the topical reviews and the country reviews, and during the country reviews. The peer review team has finalized the Country Report at the end of the country review visit on 12-15 March 2012, after final discussion with the Partner Country and visit of the nuclear power plant (NPP).

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

BG-NR has been prepared on the basis of the Final Kozloduy NPP Report on Reassessment of Plant Safety [Ref. 3 of BG-NR], in accordance with the ENSREG specifications. The required data and main characteristics of the nuclear units are presented at a level that allows overview of the plant response to the events specified in the report.

All nuclear facilities located on the Kozloduy NPP site, which is the only site in Bulgaria, in which nuclear fuel is used or stored, are covered, in particular:

- Nuclear reactors of units 5 and 6
- Spent fuel pool (SFP) of units 5 and 6
- Spent fuel pool of the shut down units 3 and 4
- Storage for spent nuclear fuel
- Dry fuel storage facility (DSFSF).

The information provided in BG-NR, including the identification of safety margins is in general consistent with the ENSREG methodology. The Partner Country provided comprehensive answers and clarifications to the written comments from the topical review as well as to questions asked during the country presentation that completed the information provided in the BG-NR.

## 1.2 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 Partner Country declares that the NPP is in compliance with the current licensing basis represented by the Bulgarian national standards, rules and regulations on nuclear energy and radiation safety. The Partner Country regulations are of a high level, for which detailed implementation shall be defined by the licensee. The approach to the seismic design basis appears to be very thorough and in line with international recommendations. The result from the probabilistic safety assessment (PSA) does not include external flooding or extreme weather.

The legal requirements for plant design and safety assessment are fully harmonized with the Western European Nuclear Regulators' Association (WENRA) Reference Levels (RLs) for existing reactors.

As it was clarified during the country visit the new Bulgarian regulations in general will apply also to existing plants. The scope of relevant plant upgrading is discussed individually between the regulator and operator, usually as a part of the Periodic Safety Review (PSR).

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

BG-NR presents the results of the assessments of structures, systems and components (SSC) margins for earthquake, flooding and extreme meteorological conditions anticipated at Kozloduy site. Station Blackout (SBO) and loss of Ultimate Heat Sink (UHS), as well as their combination was assessed for power as well as shut down modes. The coping time for different scenarios with loss of power and/or UHS, is provided in the report, as well as the time periods to boiling and the beginning of fuel uncovering in the spent fuel pools.

BG-NR addressed all the elements, which are essential for the management of severe accidents, including organizational arrangements of accident management and emergency planning, hardware measures to be used in case of severe accidents (depressurization, hydrogen management, corium stabilization etc). Procedures (emergency operating procedures (EOPs) and severe accident management guidelines (SAMG) are in the process of implementation at Kozloduy nuclear power plant (KNPP) Units 5 and 6. EOPs for the full power and shutdown states with closed reactors are already implemented.

### 1.4 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,…)

The Bulgarian Nuclear Regulatory Authority (BNRA) has reviewed the licensee reports in terms of completeness, and the adequate application of the ENSREG methodology. In summary, the adequate application of the ENSREG methodology was confirmed.

Based on evaluation of the Fukushima accident and lessons learned, BNRA has established the scope and time frame for implementation of corrective measures in line with their importance and urgency. BNRA has also identified a number of further safety improvements for severe accident management, in addition to those proposed by the licensee. Consequently, an improvement programme was developed, approved by the regulator, and is currently under implementation.

The results of the on-going process of prioritization and planning of the improvement measures, which were initiated or accelerated after the Fukushima accident, as well as the expected lessons learned from the stress tests will have to be taken into account in this context. The Peer review team has acknowledged the safety improvements that have been implemented so far or are planned.

## 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 present regulation regarding external hazard (CMD n° 172/19.07.2004), in general requires that seismic, flooding and extreme weather conditions shall be addressed in the plant design, as well as that the initiating events, including external hazard using probable combinations, shall be considered for the demonstration of safety. In this regulation, the scope of deterministic safety analysis comprises the identification of postulated initiating event characteristics, including those, specific to the selected site. The probabilistic safety analysis shall deal with all modes of operation, all postulated events including fire and flooding, severe weather conditions and seismic events.

BG-NR did not give details on the requirements applied at the time of the design and construction of the plant, but it makes clear that requirements concerning the seismic issue were applied. The classification of the SSCs was required by the regulation at the design stage. The requirements contained in the new regulation for the definition of the Design Basis Earthquake (DBE) are compatible with International Atomic Energy Agency (IAEA) safety standards.
The national report does not describe whether a seismic event, beyond which an inspection of the plant is required, is specified by the regulation. This issue was discussed during the country visit, and the review team notices that this specification is not required by the regulation, but it is covered in the KNPP instructions for the post earthquake actions of the personnel. These plant instructions were reviewed during the previous IAEA mission.

#### *2.1.1.2 Derivation of DBE*

BG-NR provides the values for the original DBE. The operator has conducted comprehensive studies to define an up to date seismic hazard, with the assistance of the IAEA. Current seismic characteristics were defined during the period 1990 - 1992 and were reviewed and confirmed by the IAEA experts during the period 1992 – 2008. Current seismic characteristics are valid for all the SSC's in the site. By using probabilistic and deterministic methods, the seismic levels have been defined for the recurrence period of 100 and 10000 years respectively, based on the tectonic, geological, geomorphologic, seismic and geophysical data. Thus, the following has been identified for the KNPP site:

- For level with a recurring period of 100 years Peak Ground Acceleration (PGA) is 0.10 g (IAEA SL1)
- For level with a recurring period of 10000 years PGA is 0.20 g (IAEA SL2)
- Design floor response spectra and respective 3D accelerograms with duration of 61 s.

The used earthquake catalogue covers the period from 375 to 1990. Study of the KNPP site showed that there are no major fault structures with high energy potential (no evidence of capable fault).

#### *2.1.1.3 Main requirements applied to this specific area*

The safe shutdown has to be assured under Safe Shutdown Earthquake (SSE) conditions. This implies that the shutdown function and the cooling function have to be assured during and after a major earthquake and requires definition of a Safe Shutdown Equipment List (SSEL).

- **Provisions for Review level earthquake, Kozloduy 3-4**

The review level earthquake (RLE) is determined at which all 1$^{st}$ seismic category SSC are reviewed for the plants already designed. The country report describes an extensive list of equipments and structures that have seismic qualification requirements.
The operator identified that with an earthquake level exceeding RLE, a part of the chimney of the auxiliary building could possibly fall down. With this regard, BNRA confirms that there is neither class 1 nor class 2 system in the auxiliary building.
A list of beyond design accident scenario for Unit 3 and 4 and a program of training has been defined.

- BG-NR identifies that a supplementary mobile diesel generator is required to cope with common cause type failures due to the earthquake, in regard to loss of electrical power. It also indicates that the emergency bank pump station was built to ensure a redundancy to address the loss of the UHS.

**Provisions for Review level earthquake, Kozloduy 5-6**

BG-NR identifies that buildings have been checked for their stability in the framework of a modernization program and that seismic qualification of the main building was demonstrated. The final list of equipment that has not been qualified is established. The qualification or replacement by qualified equipment is underway. An assessment on the impact of potential failures of SSC which are not seismically qualified (and which can compromise heat removal to the ultimate heat sink by mechanical impact or internal flooding) was made; the obtained results lead to development of a complementary action plan (complementary studies and modifications).

- **Provisions for review level earthquake, spent fuel storage facility**

The operator has established a list of SSC that require qualification; the SSC qualification status shall be justified; if qualification is not possible the component shall be replaced. BNRA monitors the completion of seismic SSC qualification.

- **Provisions for review level earthquake, dry fuel storage facility**

The operation of this dry fuel storage facility is passive. The report assesses the stability of the DSFSF building with an inelastic behaviour for DBE and an elastic behaviour for DBE.

- **Potential destruction outside the site leading to prevention or blocking of personnel or equipment access to the site.**

BG-NR does not provide information on seismic qualification of the fire detection and mitigation systems. During the country visit it was clarified that these systems are qualified except for the wet spent fuel storage facility.
Concerning indirect effects of the earthquake it seems that the operator has studied the consequences of the impact of non seismic classified structures on classified structures.
Automatic reactor trip is implemented for the earthquakes exceeding the threshold of 0.05g, and is associated with relevant operating procedures.
BG-NR demonstrates that a considerable amount of work has been provided to improve the seismic resistance of the NPP.

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

BG-NR demonstrates that from the beginning of 90's, the knowledge concerning the exposition of the site to the seismic risk is under constant review. The DBE is determined by PSHA with a logic-tree approach that is said to account for geological, geophysical geodetic, geomorphological and seismic data. The IAEA references implement experience feedback in their definition. The seismic reassessment is based on improvement of design requirements and checks using the design methods.
SSC margins are evaluated according to fragility curves. The approach to margins assessment included systematic inspections made by expert engineers organized in a formal plant "walk-down" to provide periodic verifications of SSC. In the margin analysis, the report indicates that some safety functions could be lost because of soil liquefaction due to seismic events far over seismic level 2 (SL2).
Concerning liquefaction, disturbances could occur below the triggering criteria of liquefaction (such as ground packing or differential displacement). This issue was discussed during the country visit. It was stated that according to the available information these issues of differential ground packing is not relevant for KNPP up to RLE.

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

PSRs are performed and include seismic requirements.

*2.1.1.6 Conclusions on adequacy of design basis*

The references for design basis have been updated, compared and evaluated against the IAEA guidance. The safety demonstration includes qualification of SSC. Periodic maintenance is implemented and evaluated. Inspections and testing of SSC that require seismic qualification are performed. Testing is conducted by qualified personnel according to the general regulation. A Seismic monitoring system has been implemented. Procedure and personnel training are planned in accordance with the applicable regulations.
The needs for mobile equipment supplies considered in the emergency arrangements are identified. Some of the equipment procurements are to be completed. Some deviations in seismic qualification are recognized by the plant. A plan for equipment qualification is yet to be completed.

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

Units 3 and 4 are no longer in power operation, but spent fuel is still contained in the SFP (adjacent to the reactor vessel). Units 5 and 6 are in operation. Following the reassessment of the seismic input, an upgrading program has been established. Completion of the program is underway and, when completed, the plant will comply with the reviewed design basis.

### 2.1.2 Assessment of robustness of plants beyond the design basis

#### *2.1.2.1 Approach used for safety margins assessment*

For the earthquake assessment, an approach based on seismic probability has been used. For example a safety margin exists, which is 0.16 g greater than the RLE PGA (0.2 g) for units 3 and 4.
A procedure has been developed for events leading to severe damage of the fuel, containment integrity and spent fuel pool integrity. Indirect effects of the earthquake are taken into account: the failure of SSC's; loss of external power supply; situations outside the plant, including preventing or delaying access of personnel and equipment to the site; fire and explosion.
Scenarios with beyond design earthquake causing a flooding have also been considered but these scenarios do not lead to additional effects. However, for assessment of safety margins, a coincident occurrence of beyond design earthquake (PGA up to 0.32 g) and water level above the Design Basis Flood (DBF) have been considered.

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

A safety margin to fuel damage exists, which is 0.16 g greater than the RLE PGA (0.2 g) for units 3 and 4. In the range between 0.26 and 0.36 g the possibility of falling of heavy objects on the SFP is envisaged and at 0.36 g possible liquefaction phenomena under some buildings are also expected. For Units 5 and 6, the safety margin obtained with the same methodology is 0.13 g above the RLE PGA (0.2 g). Higher margins are obtained for containment integrity. When considering the simultaneous occurrence of beyond design earthquake (PGA up to 0.32 g) and water level above the DBF (33.20 m), the loss of off site power and damages to the cooling function cannot be ruled out.

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

In the last 20 years, the plant has undergone a continuous improvement process. The IAEA standards were used as a reference in the seismic assessments. Important modifications to the plant have been implemented, especially concerning the heat sink and the implementation of an alternative feedwater pump, powered by the mobile Emergency Diesel Generator (EDG) to cool the reactor in particular situations.
Additional mobile means have been installed, including a mobile diesel generator and several vehicles that shall be able to withstand the external hazards.
The plant has evident autonomy, and local warehouses are available accommodating equipment to face emergency situations.
The site has some autonomy to restore the access to the plant in case of external hazards.
The design basis requirement has been updated. The process to maintain the conformity is clearly presented.
Considering that the storage of SF in SFP of units 3 and 4 will end by mid 2012, no specific measures to improve robustness have been proposed for those facilities.

#### *2.1.2.4 Possible measures to increase robustness*

The measures for improvement of plant robustness relate only to KNPP units 5 & 6 are as follows:

- Provision of an additional mobile diesel generator for each unit;
- Studying the possibilities for alterative options for Units 5 and 6 decay heat removal using the existing Steam Generator (SG) emergency makeup system (EMS) of Units 3 and 4;
- Securing the availability of at least one tank of the SG Emergency Feedwater System in shutdown mode in order to provide for the use of the SG as an alternative for the residual heat removal.

The plant walkdown of the above measures, which is performed on annual basis (as discussed during the country visit) is considered as a good practice.

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

Some complementary measures to be taken or decided are identified in the country report. In addition, the "Programme for Implementation of Recommendations following the Stress Tests carried out on Nuclear Facilities at KNPP" was presented during the country visit. BNRA should consider reassessing the Programme based on the final outcomes of the Stress Tests and Peer Review at the European level, and monitor implementation of the Programme.

### 2.1.3 Peer review conclusions and recommendations specific to this area

The establishment of the Design Basis has been explained and is widely acceptable in comparison with international standards. There is satisfactory evidence provided that the Bulgarian licensee is compliant with the design basis requirements. Additional steps are underway to complete the qualification of some equipment in accordance with the updated requirements.
During the peer review the issue of adequate paleoseismological studies was raised. During the Country visit it was stated that throughout the periodic updates of the seismic PSA and in the PSR, on the basis of the information available and verified, evaluations are made of the need of re-assessment of the seismic hazard on site. This approach should continue in the future.
A beyond design basis capability is evaluated and quantified on a probabilistic basis. Evidence is provided that margins to cliff edges and potential specific improvements have been considered. A deadline for the improvements to increase the available margins have been identified and been fixed.
The protection of mobile equipment to external hazards has been examined during the country visit. Regarding the storage conditions, the sheltering structure of the mobile generator is light, and has a low damaging capability in case of earthquake. The Action Plan considers delivering of the two additional mobile generators. As long as these mobile generators will be considered for beyond design basis events, they should be adequately protected for such events.

## 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,…)*

According to national regulations a maximum water level (MWL) has to be defined for the plant site, taking into account rainfall, intensive snow melting, high level water in water basins, river blocking by ice, avalanche and slide; for the plant site the possible maximum runoff floods from watercourses with a frequency of 10-4 events / year combined with high tides and waves caused by wind, upstream dam failure should be considered.
The PSA results presented in BG-NR for units 5 and 6 do not address the external flooding and extreme weather; it should be considered for the future PSA update. The full scope probabilistic safety assessment for Spent Fuel Storage (SFS) has not been completed; there is a safety analysis for the whole range of potential initiating events performed using potential hazard and operability analysis method (HAZOP).

*2.2.1.2 Derivation of DBF*

Flooding against which the plant is designed.

| Potential to reach | 1% | 0,1% | 0.01 % |
|---|---|---|---|
| Initial water level [m] | 29.93 | 30.87 | 31.73 |
| Updated water level [m] | 30.58 | 31.47 | 32.23 |

The level 0.00 at the plant site that corresponds to elevation of 35.00 m of Baltic Sea level was adopted.
The flooding is associated with: inundation, the rise in water at the site; influence of heavy rainfalls, water retention due to ice, waving, clogging of water intake and outlet due to sedimentation and debris.
Due to persistent high level of ground water over a large area in the lowlands near Kozloduy site, a plant drainage system is required. The main drain system brings together a wastewater and rainwater, and it also includes the water coming from local slopes.
The site has a regular and automated monitoring of water level and flooding alarms including regular interaction with the agency for exploration and maintenance of the Danube River in the town of Ruse.
A probabilistic assessment regarding flooding has been used. The possible combination of the effects of several causes is examined. BG-NR states that the potential instability of the river channel due to erosion or sedimentation is not considered a safety issue due to the redundancy of heat sink. Information related to upstream water control structure is analysed to determine whether the nuclear installation would be able to withstand the effects resulting from the failure of one or more of the upstream structures. A possibility of water accumulation as a result of the temporary blockage of rivers upstream or downstream by ice which may cause the flooding and associated phenomena is examined. In the determination of hazards, the site-specific data are used.

#### *2.2.1.3 Main requirements applied to this specific area*

The definition of the maximum water level for low probability events comprises the impact of heavy rainfalls and waving. The use of updated methods leads to the increase of the water height by 0.5 meters from 31.73 m to 32.23 m for a 10-4 return period.
The plant flooding analysis is performed with maximum water level of 32.93 m without information on the uncertainties. As a verification method, BG-NR considers other hazard combination and concludes that according to these combinations, the maximum water level would not be higher than 33.42 m with a probability of occurrence of 10-7/year.
BG-NR concludes that the plant site is not vulnerable to flooding. The potential impact on the cable channel between diesel generators and reactor buildings (T5 and T6) of water level was questioned during the peer review. During the country visit this issue was discussed and it was stated that there are no consequences of flooding of this channel.
The main provisions to protect the plant against the DBF are

- Site location;
- Drainage system of the flat-land;
- Site sewage network.

BG-NR identifies the key SSC needed for achieving the plant safe shutdown state; they are supposed to remain available after the flooding. BG-NR considers the progressive loss of equipment according the water level increase beyond the design bases.
Thus in some buildings, where the lowest elevation of rainwater or domestic sewer is below 32.93 m, water penetration from outside may be possible. Some function can be lost because some locations can be flooded by water coming from sewer collectors (loss of alternative makeup of spray pools for unit 5 and 6, alternative for spent fuel cooling via SG, with fuel in the reactor for Unit 3 and 4).
BNRA should further consider the sensitivity of equipment to flooding, in particular regarding the sensitivity of actuators, electrical devices and Instrumentation and Control (I&C) systems to excessive humidity. A cautious approach should be considered when the safety related equipment in a flooded location can be lost.

A modification of the drain and sewage system is planned. The report does not include information on installation of additional barriers (dam boards) nor the closure or watertight gates in anticipation of flooding nor the regular inspection of the drainage channel, but this item is included in the approved Action Plan.

During the country visit it was noticed that periodic and frequent walk downs are performed, this is considered as a good practice.

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

A plant walk down has been performed by the operator to provide a final verification of the design against floods. As stated during the country visit, the regular walk downs also include flooding provisions. The regulation determines probabilistic goals in terms of possible maximum runoff flood from water courses, combined with some external events. The updated data have generated an increase in the maximum water level to take into account.
A warning system able to detect a potential flooding of the site and the emergency procedures are available. A detection system of water inside rooms below the ground level and appropriate operating procedures, completed by specific walk down are claimed to be implemented.
Some possible improvements are identified to reinforce the robustness of installations towards flooding. The national regulator should consider monitoring the implementation of recommended modifications in an action plan.

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

In accordance with the discussion during the country visit, the PSRs are performed and include provisions against flooding.

#### 2.2.1.6 *Conclusions on adequacy of design basis*

The approach to defining flood requirement is broadly consistent with international standards.

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

The plant is in compliance with the current design basis. BG-NR identifies modifications for further enhancements as discussed in section 2.2.2.4.

### 2.2.2 Assessment of robustness of plants beyond the design basis

#### 2.2.2.1 *Approach used for safety margins assessment*

The level of potential flooding was assessed based on probabilistic approach with the frequencies of $10^{-4}$ up to $10^{-7}$ per year. This approach is not entirely identical to the ENSREG specifications. However, the plant robustness to deal with floods beyond the design basis is demonstrated in the BG-NR.

#### 2.2.2.2 *Main results on safety margins and cliff edge effects*

The peer review noted that the plant is compliant with updated design basis requirements, i.e. there is no risk of flooding the rooms with the safety related equipment. Nonetheless for beyond design basis flood, some locations could be flooded due to the sewage and drain system capacity. The country report considers the loss of equipment according to water level in flooded rooms. The plant considers further upgrading measures by implementing measures to prevent penetration of drainage system.

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

Following identification of plant weaknesses, possible measures to enhance and ensure plant robustness against external flooding are proposed.
A combination of the probabilistic assessment of flooding and site elevation provides additional assurance that the site flooding is very unlikely.

#### 2.2.2.4 *Possible measures to increase robustness*

BG-NR identifies modifications for further enhancements. The most important are:

- Development of measures for prevention of water intake in the plant drainage network in case of valley flooding.

- Development of an emergency procedure for personnel actions in case of wall ruptures of water-power dams (Jelezni Vrata 1 and 2).
- Modernization of the draining and sewage systems in accordance with the planned design for reconstruction of the system from the modernization program of KNPP unit 5 & 6.
- Investigation of possibilities to protect the equipment of Bank Pumping Station (BPS) 2 and 3 of external flooding with maximum water level equal to 32.93 m.

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

See above.

### 2.2.3 Peer review conclusions and recommendations specific to this area

The peer review, including the country visit has noted that that plant is adequately protected against flood hazard. For beyond design basis conditions the Action Plan identifies some complementary measures to be implemented, such as improvement of the leak tightness of the certain rooms below the ground level.
During the country visit it was stated that the following earlier recommendations were already implemented.

- Implementation of mobile means to mitigate flooding;
- Confirmation, that regular walk down is performed to assess good operability of drainage systems that shall also be modified to avoid water penetration inside the rooms sheltering safety functions.

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

BG-NR considers extreme temperature, extreme precipitation, extreme wind, lightning, snowfalls, sand spouts (tornado), ice phenomena, low standing of the Danube River, humidity and freezing, and potential combination of some extreme meteorological phenomena.
A probability of occurrence per year is proposed. Events with a probability over $10^{-4}$ per year are considered in the safety demonstration. Uncertainties on theses values are not provided (we can notice that temperature over the design value has already been observed).
Information on some combinations of hazards from the safety demonstration file is provided. The regulatory criteria for these combinations are not contained in the regulation.
The potential for the occurrence of tornadoes in the region is assessed. Some dysfunction of spray pools were identified, however, the consequences of this phenomenon are not impacting the ultimate heat sink function.
In the safety demonstration, the consideration of the possible duration of extreme events was not considered; this should be reconsidered in the future assessment.

### 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,…)*

BNRA requirements comprise high-level requirements. BG-NR does not provide technical requirements regarding consideration of some phenomenon, nor their combination.

##### 2.3.1.2 *Derivation of extreme weather loads*

BG-NR presents loads on structures for the considered hazards used in the safety demonstration and considered margins between the loading generated by hazards and bearing capacity of the structures. It was realized that the BG-NR was not sufficiently clear in this regard, but the issue was clarified during the country visit.

#### 2.3.1.3 *Main requirements applied to this specific area*

BG-NR provides specific requirements; SSC needed for safe shutdown, exposed (directly or indirectly) to extreme weather conditions, have to remain functional.

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

Specific information on technical backgrounds directly linked with extreme weather or the results from the operational experience are not reported.

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

Periodic safety reviews are regularly performed.

#### 2.3.1.6 *Conclusions on adequacy of design basis*

The regulatory requirements and criteria regarding the extreme weather are defined, however the combinations of extreme weather conditions still needs to be considered.

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

According to the lack of regulatory criteria regarding the extreme weather or combinations of hazards, the adequacy of the design basis toward regulation is not described in BG-NR.
Nonetheless, the buildings in which safety related systems and components are located are seismic category I and are not directly affected by extreme weather phenomena.

### 2.3.2 Assessment of robustness of plants beyond the design basis

BG-NR shows that extreme temperature over the design temperature has already occurred; reassessment of the design values is considered in the established programme.

#### 2.3.2.1 *Approach used for safety margins assessment*

Loads caused by extreme weather conditions are compared with the resistance of the SSCs. A number of margins are identified but a synthesis view is not provided. In some cases (for example water freezing) impact on functionality is considered.

#### 2.3.2.2 *Main results on safety margins and cliff edge effects*

Assessments of structures margins are based on the use of conservative approaches. BG-NR concludes that the considered civil structures have the necessary bearing capacity to withstand the high loads from external events with the a few exceptions (mostly due extreme snow load for a limited period of time which BNRA considers acceptable).
BNRA considers that the weaknesses and strengths obtained from the reassessment of margins of on-site facilities in respect to extreme meteorological impact have been properly identified as well as the margins of civil structures and facilities.

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

There were identified weaknesses concerning the surface parts of circulating pump stations 3 and 4 and the roof structures of circulation pump stations 3 and 4 with possibility in some case of damage of the spent fuel storage facility cooling, however (as discussed during the country visit) that function has redundancy 200 % by another qualified system.

#### 2.3.2.4 *Possible measures to increase robustness*

BNRA should consider provision of a monitoring and alert system concerning extreme weather as well as adequate related operating procedures.

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

Specific measures already decided are not indicated in the report.

### 2.3.3 Peer review conclusions and recommendations specific to this area

A combination of extreme weather conditions still needs to be considered. With this regard, BNRA requested the plant to perform a consolidated review of extreme weather hazards in line with IAEA guidance and development of a plan to monitor identified improvements.

# 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, …)

The regulatory framework for nuclear safety and radiation protection in Bulgaria is based on the Act on the Safe Use of Nuclear Energy (ASUNE), which is in force since June 2002. It contains the fundamental principles of independence and competency of the regulatory authority, definition of clear and predictable regulatory environment through the development of obligatory-implementation requirements on nuclear safety, radiation protection, physical protection and emergency planning and preparedness as well as implementation of the strict licensing regime, based on the in-depth evaluation of all safety aspects, regulatory inspections and implementation of administrative measures.

Regulations related to the application of the ASUNE, nuclear safety, and radiation protection provide detailed guidance on specific subjects; for example, the licensing related requirements are contained in the Regulation on the Procedure for Issuing Licenses and Permits for Safe Use of Nuclear Energy, and design safety requirements are contained in the Regulation on Assuring Safety of the Nuclear Plants.

In some cases the regulation requirements are further explained in Regulatory Guides so that to provide licensees with better understanding of the regulatory criteria by which the regulatory authority judges the adequacy of the safety cases. Regulatory Guides follows the best international practices, considering WENRA Reference Levels and applicable safety standards and guides of the IAEA.

### 3.1.2 Main requirement applied to this specific area

The requirements applicable to the plant electrical systems are contained in the Regulation on assuring safety of the nuclear plants, Published in July 2004, and amended SG in June 2008. This regulation sets the requirements to the design of systems important to safety, including supporting safety systems and the systems providing the ultimate heat sink. The legal requirements to the plant design and safety assessment are fully harmonized with the WENRA Reference levels for existing reactors.

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

The Partner Country informs that deterministic as well as probabilistic assessment studies have been developed for all operational units in order to confirm the design basis and the defence-in-depth.

PSA Level-1 studies are regularly updated and have been used as standard tools in the licensing-related safety assessment. The PSA Level-2 for Units 5 and 6 is being currently updated in order to reflect the safety upgrading measures.

A full-scope PSA study for the spent fuel storage facilities has not been completed yet. There is, however, a safety analysis for the whole range of potential initiating events, performed using the potential HAZOP.

Operating experience feedback (OEF) is regularly collected and includes those events occurring in Bulgaria and abroad with pertinence to enhancing nuclear safety or radiation protection.

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

The plant design and operation are periodically reviewed in the light of the operational experience and new safety significant information for the identification of deviations from the current requirements and the internationally recognized operational experience.
The last PSR of the Kozloduy Units 5 and 6 has been performed in 2010. Based on the results, the licensee has developed a program for improvement of the nuclear safety and radiation protection; the long-term measures of this program are still under implementation.

### 3.1.5 Compliance of plants with current requirements

The Partner Country declares that the NPP is in compliance with the current licensing basis represented by the Bulgarian national standards, rules and regulations on nuclear energy and radiation safety. The particular regulations applicable to the topics of the Stress Tests are given in the corresponding chapters of the BG-NR.

## 3.2 Assessment of robustness of plants

### 3.2.1 Approach used for safety margins assessment

In assessing the safety margins with respect to Loss of off-site power (LOOP) and loss of UHS the deterministic approach was used. All situations were analyzed, which were required by the Stress Tests specifications.

- **Reactor Units**

The time periods to fuel damage were calculated for the following cases (various operation modes of Units 5 and 6):

- LOOP supply and loss of EDGs;
- LOOP, EDG and Additional diesel generator (DG);
- LOOP, EDGs, Additional DG and Mobile DG;
- Loss of UHS and loss of alternative heat sink;
- Loss of UHS, in combination with SBO (i.e. loss of off-site and emergency power supply to the site).

- **Fuel Pools**

The threshold values were calculated for the following cases:

- for the SFL of units 5 and 6 – LOOP supply; LOOP supply and loss of EDG; Loss of UHS;
- for the SFP of units 3 and 4 - LOOP supply and loss of EDGs;
- for the SFSF - LOOP supply: LOOP supply and loss of emergency power; Loss of UHS.

The coping times for LOOP, SBO and UHS without any external support have been calculated analytically in terms of time periods to fuel damage, for different operation modes of the reactors; the threshold values were calculated for SFP and SFSF also.

#### *3.2.1.1 Loss of off-site power (LOOP)*

The Kozloduy site is connected to the electric energy system (EES) of Bulgaria at the Outdoor Switch Yard (OSY) at voltage levels of 400 kV, 220 kV and 110 kV. Cross connections between these are made through autotransformers. The total number of the transmission lines to which the Kozloduy site can be connected is 17, among which 13 are transit lines and four are radial ones.
Normal and safety buses of Units 5 and 6 are powered from the main generator, through the auxiliary transformers. A standby power supply is provided from OSY-220 kV. The second standby power to the units is provided from the standby power supply busbars of the other power unit (Unit 5 is powered from Unit 6 and vice versa). Off-site power supply to the bank pumping stations is provided from OSY-220 kV, and the redundancy is provided from the Bukyovtsy substation of 110 kV.

Generally, a design solution for LOOP is to transfer the house load to the reserve lines from the 220 or 110 kV power grid. The switchover is automatic. If the 110 kV grid is available but the automatic switchover fails, operators can make the connection manually.
In principle, house load operation is possible as the first defence line against the loss of the 400 kV grid connections. However, the plant tested the house-load capability and came to the conclusion that this mode of operation is rather unstable and therefore is not considered by the plant as a reliable source for emergency situations.
If this automatic switchover is successful, the plant can continue the house-load operation. If the main grid, backup grid or house-load operation are not possible, the plant safety buses are powered from the EDGs. Each train of the emergency power supply system is capable of ensuring a safe shutdown state in all design basis accidents. The EDGs are Class-3[1] equipment in accordance with OPB-88/97, and seismic category 1. In case of LOOP, an automatic signal for EDG start-up is given independently for each EDG. Just two EDG in operation (one per unit) can provide sufficient power supply; the operator performed series of tests to confirm that fuel and lubrication oil are sufficient for more than 38 days of continuous operation.
The BPS has DG, which supply the emergency service water pumps, shaft pumping stations, fire-annunciation installation and fire extinguishing in the BPS and their supporting systems. The BPS is equipped with two DG sets. Two accumulator batteries are installed in the BPS to guarantee uninterrupted power supply to the most important consumers. The fuel and oil available at the BPS site ensure continuous operation of both DGs for about 57 hours. The SFPs rely essentially on the same cooling and electric supply systems as the reactor.

#### *3.2.1.2 Loss of off-site power and loss of the ordinary back-up AC power sources*

Each of Units 5 and 6 has one Additional independent DG with nominal power of 5.2 MW. These DGs are located in a container located on a platform, 1m above ground and belong to Class-4 equipment in accordance with OPB-88/97, and in seismic category 2. The Additional DGs are in hot-stand-by mode. These DGs can power consumers to allow for heat removal from the primary as well as the secondary systems (more details can be found in the section Loss of UHS). Total fuel and oil reserve of the Additional DGs ensure continuous operation for more than 4 days.

#### *3.2.1.3 Station Blackout (SBO)*

In case all Alternating Current (AC) power is lost, the accumulator battery can supply Direct Current (DC)/AC power to the category-1 safety buses, i.e. for which uninterruptible power supply (UPS) shall be ensured. There are three batteries ensuring 3x100% redundancy at each Unit. In addition to the station batteries with discharge time of 10 hours, there is a common plant accumulator battery, which powers a computer-based information system, and which can be charged from the additional DG.The battery discharge time was tested with real loads (the second train of the Unit 5 safety system) with connected consumers anticipated to operate under SBO conditions. The battery discharge time was 10 hours and 18 minutes.
The BG-NR states that the battery discharge capacity is more than 10 hours under full load. In such case, in about 10 hours after complete loss of AC sources, the batteries may be discharged. Before that, the valves required for accident management (feed and bleed) shall be positioned (safety valves of the pressurizer, steam dump valve to atmosphere (BRUA), steam/gas mixture emergency removal line, etc.). Discharged batteries, however, do not terminate already started processes of heat removal (motor-driven valves will maintain their position). Although 10 hours discharge time might be sufficient, recharging the accumulator batteries from the mobile DG is envisaged.
The Partner Country informed that a mobile DG is available for SBO scenarios, which is located in the area of Units 1 and 2 of the KNPP. It is a container-type 6kV DG with 1130 kW power output, mounted on a platform jointly with the fuel tank, control board and the power cable wound on a coil. Transportation to the platform is provided by a truck. The mobile DG is used to provide electrical power to the pump of the steam generator alternative make-up system (SG EMS) through its own electric bus bar. The MDG may be connected only to one of the Units 5 or 6, although its power

[1] This corresponds to Class E1 by IEEE standard.

output is sufficient to energize the pumps of both units. The MDG can be deployed and made fully operational in two hours. Total reserve of fuel and oil ensures its uninterrupted operation at nominal power for about 22 hours. In case when only the SG alternative make-up system pump is energized, the fuel reserve is sufficient for 60 hours.
The Partner Country informs that procedures are available and dedicated personnel are trained to transport and align the MDG to the electric bus bars at the rooms of the SG EMS pumps. The time less than 2 hours is an established success criterion from SBO till the MDG is transported, connected and ready for operation.
The Partner Country assessed a coping time (time to core damage following SBO) for various scenarios (sequential loss of power supply sources), and reactor operating mode before the initiating events. Results are summarized in Tables 5.1-1 to 5.1-3 of the BG-NR. It can be seen that the coping time strongly depends on the reactor operating mode before the initiating event, and the availability of power sources (loss of normal and standby power supply, failure of all EDG, failure of Additional DG, failure of Mobile DG) which can ensure power supply to its dedicated consumers and thus ensuring at least limited heat removal.
The Partner Country identified as the most adverse condition the period shortly after reactor shut down, in planned cool down at depressurized primary circuit (considering drainage of three Emergency Core Cooling System (ECCS) hydro accumulators) when the coping time is about 7.5 hours. Just for comparison, if the reactor is at power before the SBO event, the coping time is more than doubled, i.e. about 16 hours.

- **Spent Fuel Pools**

The Partner Country assessed the conditions in all the SFPs at the Kozloduy site following SBO. The most adverse conditions were identified at the SFP of Units 5 and 6 (see Table 5.2-1 of the BG-NR), where a coping time is about 17 hours for the fully unloaded core to the SFP, and during which the fuel assemblies start heating from an initial temperature of 70ºC to the start of fuel uncovery. If the Additional DG is available, durations specified in the table can be prolonged at least to 19 hours with use of water reserves from the boron system tanks.
Assessments performed for changes of temperature and water steaming in the SFP of Units 3 and 4 following SBO indicate that time needed to start of fuel assembly uncovery at power of decay heat up as of 1st August 2011 is 6.8 days for Unit 3, and 9.2 days for Unit 4.
The Partner Country defined that at loss of power supply the time-window is more than 29 days before the spent fuel assembles in SFSF will be uncovered.

#### *3.2.1.4 Loss of ultimate heat sink (UHS)*

The main ultimate heat sink for the nuclear installations at the KNPP is the Danube River. Connection to this UHS is provided through a pair of open-air channels. Water from the Danube River is delivered to the cold channel by pumps, located at bank pump stations. The volume of the cold channel provides a reserve of fresh water.
There is a redundant connection to the Danube River through the emergency pump station, which ensures independent water supply in emergency reserve from the cold channel by two independent pressure steel water pipes. A number of design measures have already been implemented to prevent loss of connection to the Danube River, i.e. preventing loss of the pumping stations, tools preventing the blocking of the main cooling water inlet, alternative ways of water supply, etc.
The BPS is located on a platform at +33 m elevation (above Baltic sea level). The water level in the Danube river considered in the stress tests was in the interval of +20m (minimum) to +25m (maximum with frequency of 1/100 years). According to analysis, there is enough margin to prevent BPS flooding even for the flood occurring with frequency of 1/10 000years. The BPS is designed to withstand anticipated common-mode failures such as earthquakes, flooding and fire.
A second UHS is provided by spray ponds that provide cooling for the essential service water system (ESWS) of Units 5 and 6. A water supply to the spray pools is provided from six shaft wells (bottom at +17m) and six shaft pumping stations. The amount of water that is delivered from the shaft pumping stations to the spray pools is sufficient to replenish for losses from the six spray pools due to steaming and entrainment under quiet weather conditions (wind speed of 2 m/s). Each spray pool is designed to

remove the entire heat released from the unit during normal and emergency operations (Design Basis Accident (DBA)), and to maintain the inlet temperature of the ESWS within the allowed range.
When the Danube river and the BPS are lost for whatever reason, the spray pools provide Units 5 and 6 with sufficient cooling (maximum initial water level, wind speed less than 2 m/s) without refilling during 30 hours. The spray pools may be replenished by:

- motor-driven pumps of the service water system for cooling of normal operation system consumers, two per unit, each with flow rate of 1440$m^3$/h,
- diesel-pumps, two per unit, each with flow rate of 290 ÷ 500 $m^3$/h, and
- pumps in shaft pumping stations, each with flow rate of 180 $m^3$/h.

The spray pools operation is ensured for 197 hours (8.2 days) under the assumption that the emergency water reserve at central Circulation pump stations CPS-3 and CPS-4 is 74026 $m^3$. As a result, the required off-site actions to refill couple of spray pools shall be taken up to 8 days after the initiating event.

#### *3.2.1.5 Loss of ultimate and alternate heat sink*

The Partner Country provides an assessment of the time period to fuel damage at initiating events with loss of UHS (Table 5.1-4); which varies between 12.4 days in the best case to just 19.45 hours in case of loss of primary circuit cooling due to failure of emergency and planned cool down system with depressurized primary circuit. Coping times in case of complete loss of all the possibilities to cool and fill-up of SFP-3, 4 before uncovery of fuel assemblies are the same, as in the case of SBO.

- **Spent Fuel Storage Facility**

In case of a hypothetic earthquake which could cause a complete drainage of SFSF due to breaks in the pool concrete structure, the temperature of the fuel assemblies will increase to 600°C (the condition of fuel damage will not be achieved). A simultaneous failure of all heat removal systems (including ventilation) would lead to beginning of fuel uncovery in 29 days (see last paragraph of section 3.2.1.3 in this report).

#### *3.2.1.6 Loss of ultimate heat sink and SBO*

This situation can occur when all the off-site, as well as the stationary AC sources at the NPP site (Emergency and Additional DGs) are lost, in combination with simultaneous loss of the Danube river water intake structures.
The Partner Country assessed the time to core damage for various Unit 5 and 6 operating modes before the initiating event, e.g. at power and shut down modes. The results are given in Table 5.1-5 of the BG-NR. It was found that the shortest time to core damage of 7.5 hours is the one for the reactor shut down in planned cool down, with depressurized primary circuit; time of 45-49 hours for power operation, and approximately 69 hours for the reactor shut down in planned cool down with pressurized primary circuit and non-drained SG.
The following equipment can be used to cope with the situation, in combination with accident management procedures:

- Mobile DG and its powered facilities;
- Emergency water volume reserve in the cold channel;
- Pumps with their own diesel motor, including fire-protection pumps;
- Category-1 consumers of the safety systems connected to accumulator batteries;
- Manually-operated valves;
- Other equipment which is not affected by the initiating event.

### 3.2.2 Main results on safety margins and cliff edge effects

The results of the analyses conducted to determine the safety margins to the cliff-edge effects were included in the discussion of Section 3.2.1; only the findings of the most important SBO and Loss of UHS cases will be included in this section. The states of the plant assumed at initiation of the various failures are listed in Section 3.2.1. The main results can be found in Tables 5.1-1 to 5.1-3 of the BG-NR.

- **Station blackout (SBO)**

In case of SBO, the units suffer after the battery discharge times (in about 10 hours) from the inability to control the systems and lack of information from the instrumentation.

As stated in the BG-NR, Section 5.1.1.3.2, “MDG may be connected to energize SG EMS on one of the two units, though its power is sufficient to energize the pumps of both units.” As external threats may act in as “common-mode” on both units, this seems to be an unnecessary limitation. This was realized by the utility, remedial actions will be discussed in Section 3.2.3.

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

- **Loss of off-site power**

The fact that only two units of the total of six built at the Kozloduy site are operating and the presence of two units at the site ads to the redundancy of the electric power supplies to the operating units. The site is well connected to the national grid via a multiplicity of 440, 220 and 110 kV lines. The 400 kV open switchyard has a direct connection to the Rumanian grid. Measures to increase the robustness of the plant against SBO are discussed in Section 3.2.4.

- **Ultimate heat sinks**

There are diverse modes of cooling and supplies of cooling water on site (multiple water intake points at the Danube River, spray ponds and wells at Danube bank).

As stated in the BG-NR, Section 5.1.3.2*, ”at initial water level in the given spray pool, correspondent to maximum, and at wind speed less than 2 m/s, the pool can operate without filling during 30 hours.”* After this period of time the spray pond can be refilled by the emergency water reserve in the cold channel for another 8 days.

As the alternative heat sink connections to existing “Shishmanov Val” dam are considered.

### 3.2.4 Possible measures to increase robustness

The coping times for SBO and UHS scenarios show that there is enough time available to implement preventive (EOPs), and if not successful or possible, the mitigative measures (SAMG). Nevertheless, the Partner Country identified several vulnerabilities that require further attention. These are linked to failure to all power sources (main, backup, EDG, Additional DG, and Mobile DG) and involve the heat removal from the SFP at Unit 5 and 6, and the heat removal from the (shortly) shut down reactor in planned cool down at depressurized primary circuit.

The Unit-5 and -6 reactors are vulnerable to loss of heat removal function in cold depressurized primary circuit. In this case the UHS is atmospheric air, and the connection to it is ensured only through the spray pools while none of the systems can be powered from the Mobile DG to ensure heat removal from the primary circuit or to fill it. However, during the country visit it was stated that the power supply can be ensured from the additional DG.

The worst case scenario for loss of UHS is a disconnection of both Units from the ESWS spray pools.

Owing to above, the Partner Country proposed in the BG-NR to increase existing robustness of the plant in the following direction:

- Technical solutions to prevent loss of water from spray pools;
- Alternative means to replenish spray pools from independent sources;
- Technical solutions to enhance the reliability of tunnels and pipelines connecting the EDG with the spray pools.

In accordance with these directions, the following measures are decided to apply for improving the robustness of KNPP at loss of power and UHS:

- Assess the status, effectiveness and availability of emergency systems for water supply from dam "Shishmanov Val";

- Deliver two new Mobile DGs in order to provide for charging of the station batteries in case of SBO conditions (chagrining the station batteries are currently unavailable). A power supply routes to charge one of the batteries of safety systems from Mobile DG;
- Analyze a possibility of installation of independent water-cooling system to the SFSF, with independent power supply.

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

Measures to improve the robustness of the plant against SBO are identified in the BG-NR as follows:

- Two new Mobile DGs will be delivered, and the existing one will remain as standby for the remaining structures at the NPP area;
- Power supply is provided for charging of the one accumulator batteries of the safety systems from Mobile DG.

The regulatory review of the licensee stress-tests report concludes that the strong as well as the weak plant features have been identified and that the proposed measures to increase the robustness to the loss of power supply and of the ultimate heat sink are acceptable.

BNRA deems necessary that the following design provisions to address the plant weaknesses need to be further considered:

- Ensuring the power supply to systems that implement primary decay heat removal or make-up functions in shutdown state with open primary circuit by a Mobile DG;
- Ensuring the possibility of primary make-up during shutdown states with EDG unavailable, e.g. implementation of power supply by the batteries of the valve motors at the hydroaccumulators connecting pipes;
- Ensuring the power supply by the Additional DG or Mobile DG to systems that implement the heat removal or make-up functions at SFP of units 5 and 6.

## 3.3 Peer review conclusions and recommendations specific to this area

There is redundancy and diversity in the electric and cooling capabilities to ensure safety functions. During the site visit these redundant facilities were visited. It was observed that they are well managed. Besides that there are plans to increase system robustness to cope with SBO and loss of UHS.

Complete discharge of batteries could represent a cliff-edge in case of SBO. Therefore, although the batteries have 10 hours discharge time, it was proposed to provide a possibility of their recharging from a mobile DG.

As stated in the BG-NR, Section 5.1.2 Measures to improve robustness at loss of power supply, “Two new mobile DGs will be delivered, and the existing one will be maintained in standby conditions for the remaining structures at the NPP area; Power supply is provided for charging of the one accumulator batteries of the safety systems from Mobile DG;”. These indeed seem to be the correct remedial actions.

# 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 Bulgarian regulations relevant for the respective topic are summarized at the beginning of each of the main sections of BG-NR. The Bulgarian “Regulation on Ensuring the Safety of Nuclear Power Plants” includes quantitative criteria for severe accidents - limits for releases as well as for core damage frequency and for the frequency of a large release requiring immediate protective measures.

These criteria as specified in the main body of the regulation apply for new NPPs. For existing NPPs (KNPP Units 5 and 6), values which are higher by a factor of 10 are given for core damage frequency and for large releases, according to the "Transitional and final provisions" of the regulation. The PSA results for KNPP Units 5 and 6, provided in the BG-NR, show that the core damage frequency and the large early release frequency are higher than the criteria for new plants, but below the criteria for existing ones. It also has to be noted that the results for the frequency of large early release correspond to the plant status of 2001. The safety improvements implemented since then (some of which are still ongoing) may have a significant positive impact on the calculated risks. An update of Level 2 PSA is at present being developed.

The Bulgarian regulation mentioned above also caters for aspects such as core melt at high pressure, basemat melt-through and for the management of combustible gases.

It appears that the Bulgarian regulation for severe accident management is generally appropriate and well elaborated, including requirements for instrumentation and relevant safety analysis (as discussed during the Country visit). However, although the regulation described above contains the requirements for EOPs, there is only brief mentioning of SAMGs.

### 4.1.2 Main requirements applied to this specific area

Requirements related to the management of severe accidents are part of two Bulgarian nuclear regulations: "Regulation on Ensuring the Safety of Nuclear Power Plants" and the Regulation on emergency planning and emergency preparedness in case of nuclear and radiological emergency. The requirements include probabilistic criteria (for existing plants: core damage frequency $<10^{-4}$/yr, large early release frequency $<10^{-5}$/yr), design provisions, provisions for symptom-based EOPs, on-site and off-site emergency planning and emergency preparedness. Emergency operating procedures are also briefly mentioned in the requirements quoted in the BG-NR (regarding verification and validation, and checking the up-to-date status); these appear to cover the SAMGs, although this term is not explicitly mentioned.

The regulations also state that, should analysis show that the probabilistic criteria are not fulfilled; additional technical measures have to be considered.

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

The scope and main results of PSA performed for the Bulgarian NPPs are presented in the BG-NR.

The results for fuel damage frequency for the spent fuel pool at Units 3 and 4 (PSA Level 1, including internal initiating events, seismic impact (no other external events) and fire impact), which is regarded as conservative for the current state, are given in the BG-NR.

For Units 5 and +6 (type Water-Water Energy Reactor VVER-1000/V320), results of Level 1 and Level 2 PSAs are provided. They cover all operational states of the reactor as well as the SFP. They cover internal initiating events, internal fires and flooding, and seismic impact (no other external events). The values are below the probabilistic criteria established in the current Bulgarian nuclear regulations (see section 4.1.2). Furthermore, as noted above, the regulator expects that the ongoing and subsequent modernization programme will have had a significant impact regarding containment failure and release probabilities; this remains to be seen when the new results are available.

The Level 2 PSA is being updated at present; the work is to be concluded by mid-2013. It is mentioned in BG-NR that there is a regulatory guide on deterministic safety assessment, and the use of deterministic assessments is frequently mentioned in the report. The OEF in connection with the SAM was discussed during the Country visit. The regulations require periodic review of plant design and operation in the light of operating experience, including the internationally recognized operating experience, thus covering also the area of SAM, as demonstrated by participation of Bulgaria in the stress tests.

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

The PSR process is established in Bulgaria, followed by safety upgrading of the plants. It is stated in the BG-NR that the last PSR for Units 5+6 was completed in 2008 and that, based on the results of this review, the licensee has developed a programme for improvement of nuclear safety and radiation protection, the long-term elements of which are still under implementation. The report also refers to the PSR improvement measures associated with SAMG development, as well as other SAM measures which were identified as a result of this review; implementation of these measures is still in progress.

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

According to PSA results (as noted above, based on the 2001 plant status), the national requirements for core damage frequency and large release frequency are fulfilled by Units 5+6. Modernization has taken place since that and is still on-going.
The implementation of WENRA Reference Levels could not be checked in full detail within the scope of this review. According to a recent publication from the WENRA-RHWG [Progress towards harmonization of safety for existing reactors in WENRA countries, January 2011], the process of implementation has been established in Bulgaria. However, BG-NR noted that due to the volume and the complexity of some measures, their implementation had not been yet completed by the end of 2010.
Measures concerning SAM that were scheduled beyond 2010 were: verification, validation and implementation of SAMGs; prevention of early containment bypass; and updating and extension of the scope of the Level 2 PSA. Based on BG-NR, the programmes to complete this work appear to be still underway at the cut-off date for the stress tests (June 30, 2011).

## 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 organization is described in BG-NR. The roles of normal plant staff, as well as well as of the emergency team (which is additionally drawn on) are explained. The structure and organization of Emergency Response are also described in appropriate detail, including the scheme for interaction with national and regional authorities.
Heavy vehicles are provided to support the site organization for accident management in case of physical isolation of the site. Alternative transportation routes are available; 10 fire engines are available at the site, as well as pools, cooling channels and tanks. The fire engines are located remotely from the NPPs, in order to reduce the risk of them also being damaged by a common initiating event.
The use of off-site technical support for accident management is described, with a table presenting the general time schedule for the implementation of measures. This off-site support mostly concerns external emergency planning which is out of scope of the EU stress tests.
The units on the site are equipped with a main control room (MCR) and emergency control room (ECR) and on-site accident management centre (AMC). Construction of an additional AMC, which is to be located off-site is being planned as one of the post-Fukushima improvements. Habitability and accessibility of MCRs, ECRs and on-site AMC is discussed in section 4.2.1.5. According to the information provided, the operator has a defined organisation to manage severe accidents. This appears to cover all the relevant components (in particular, those required in the WENRA Reference Levels) as far as could be determined in a review of this scope. The issue of regulatory inspections of the operator organization to manage severe accidents was not dealt within BG-NR. However, during the country visit it was clarified that the periodic inspections covered by the regulatory body inspection plan include:

- Emergency procedures;
- On-site emergency plan;
- Emergency drills (last one was in October 2011).

The emergency drills are performed 6-times a year in cooperation of the operator with BNRA, and there are two general emergency drills and one national emergency drill. The regulatory body also approves the KNPP organization structure if it impacts the safety.

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

Symptom-based emergency operating procedures (SBEOPs) have been developed for Units 5+6 (equipped with VVER-1000/V320 reactors) adopting the approach similar to that of Westinghouse Owners Group. The structure of the procedures is described in BG-NR. SBEOPs for power operation and shutdown states with the closed reactor are fully implemented. SBEOPs for shutdown states with an open primary circuit are developed, but they still require verification and validation at the NPP. The SBEOPs include instructions for responding to emergency conditions in the SFP. Implementation of the full set of SBEOPs at Units 5 and 6 is scheduled to be completed by January 2013. The training of the operators of the MCR includes refresher training twice annually.

SAMGs have been also developed for Units 5+6, including criteria for the transition from the SBEOPs. The SAMGs have yet to be verified and validated at the NPP; this will be followed by operator training and implementation by the end of 2012. SAMG strategies are listed in BG-NR. The SAMGs neither fully cover specific issues of shutdown states, particularly those with an open reactor, nor they cover the spent fuel pools of Units 5+6. Actions related to accident management at these SFPs are at present covered by EOPs. For Units 3+4 (VVER-440/V213), emergency instructions have been developed and introduced for emergency conditions in the SFPs. There are however neither EOPs nor SAMGs; this is considered as acceptable since it is planned to move the remaining spent fuel out of these Units by mid-2012. Routine exercises to manage severe accidents are performed by the operating organization. This includes exercising the EOPs and SAMGs.

In conclusion, many activities concerning implementation EOPs and SAMGs have been performed and are on-going. However, it appears insufficient that SAMGs are not fully covering the shutdown states, and that they are not covering the initiating events initiated in or affecting the SFPs. As has been confirmed during the country visit, development of SAMG for the SFP is included in the recently adopted improvement programme.

It also has to be noted that for SAMGs to be effective the required hardware provisions have to be in place. As discussed during the country visit the SAMGs currently being implemented are based on existing design provisions of the NPP; these should be reconsidered in the future to provide for comprehensiveness of the accident management.

#### *4.2.1.3 Hardware provisions for severe accident management*

There are a number of hardware provisions needed for addressing the severe accidents. These were identified based on systematic evaluation of availability of safety functions required for the accident management under the different circumstances within the PHARE Project BG.01.10.01 “Study of Phenomena and Severe Accident Management Guide Development According to the European Requirements” completed in 2004. The most important provisions are dealt with in this section.

- **Provision of power and make-up water**

A mobile DG is available at the NPP site. It is estimated that this DG can provide power supplies to the pumps of the SG EMS within 2 hours. Fulfilment of this performance criterion has been confirmed, and would be expected to be successful provided there is no coincident destruction of infrastructure as a result of external influences. Fuel supplies sufficient for 60 hours operation are provided on site.

In BG-NR it was stated that currently there is only one single mobile DG at the site. It was however clarified during the country visit that two additional mobile DGs will be provided following the stress tests, leaving the existing one for other functions.

Inventories of boric acid and demineralised water for primary circuit make-up are provided. During the country visit it was clarified that these inventories seem to be sufficient with adequate margin.

- **Management of releases**

Regarding the management of radioactive releases, the management of airborne releases is summarized in BG-NR. There is no discussion of contaminated cooling water which might accumulate at the site as the result of “once-through” cooling measures, since it is not envisaged to have open cooling schemes in case of an accident; cooling water is to stay inside the containment, to be treated in the post-accident stage. The issue was discussed during the country visit and it was suggested that at least some conceptual considerations should be available to address the potential treatment of large volumes of contaminated water.

- **Maintaining containment integrity**

For Unit 5+6, a number of provisions to maintain containment integrity are described in BG-NR. Provisions for the prevention of high pressure Reactor Pressure Vessel (RPV) melt through are described. Three existing plant systems are provided for this purpose. Their operation is covered by SBEOPs.

Passive autocatalytic recombiners (PARs) are installed for managing hydrogen risks. They were originally designed to cope for design basis accidents. According to BG-NR, analysis has shown that their capacity is also sufficient for hydrogen management for the in-vessel phase of a severe accident. No details were provided for this point in BG-NR. The issue was extensively discussed during the country visit. Although it was shown that for certain accident scenarios the number of existing recombiners can cope also with severe accidents, in the opinion of the review team such solution can not assure sufficiently reliable measure for the whole scope of potential accident scenarios. .

It is therefore supported (as already planned) to install additional PARs sufficient to cover also severe accidents in their out-of-vessel phase. The on-going update of Level 2 PSA will provide relevant additional information in this context. The additional PARs should also cover other combustible gases (in particular, carbon monoxide) produced from molten corium-concrete interaction (MCCI).

Design provisions against overpressure of the containment consist of a spray system qualified as safety system and, specifically for severe accident conditions, a system for filtered venting.

Prior to activating the venting system, a specific isolation valve has to be manually opened by the operator in the early phase of the accident. Initiation of venting then appears to be completely passive (a rupture disc set at 5 bar). To terminate the operation of the system the isolation valve has to be closed by the operator (this can be done e.g. if the pressure falls below a certain point). No power is needed for opening and closing this valve – if required, this can be done manually, since the valve is located outside the containment. In other respects, the venting system will operate completely passively for 16 hours. The exact procedure for initiation and termination of venting was not completely clear from BG-NR, it was therefore additionally clarified during the country visit.

The venting system is inerted with nitrogen in a standby mode; when it operates, high steam concentrations and non-detonable mixtures are expected. Hence, no problems with hydrogen are foreseen. The outlet of the venting is at high elevation (off-gas stack), hence the radiological effects on the surrounding buildings should be limited.

Time to failure of containment due to overpressure cannot be specified since it depends on the respective accident scenario. In case of SBO without operator measures however, the time was estimated to be well above 24 hrs.

Regarding prevention of basemat melt-through, the analysis suggests that the corium will be retained within the reactor vessel by the SAM measures (which are however depending on the availability of power supply). Nevertheless, in some cases, damage to the reactor pressure vessel cannot be avoided. At present, this issue cannot be specified further; strategies of corium cooling both in-vessel and ex-vessel are under consideration and being analysed. SAMGs do not cover this point; it is included in the on-going Level 2 PSA.

Regarding I&C, Units 5+6 at present do not have a system for monitoring of steam and oxygen within the containment; however, it is planned to install such a system. The I&C system has dedicated batteries with a capacity for cca 12 hours; the post-accident monitoring system also has its own power supply (dedicated batteries).

There was no discussion in BG-NR regarding the capability of SAM to cope the case of simultaneous core melt/fuel damage accidents at different units at the site. The issue was discussed during the country visit. At present the plant systems envisaged for mitigation of severe accidents are considered individually for each of the units. It was stated in the discussion that if in the future some sharing of systems or manpower between the units will be considered, the capacity and resistance of such systems will be established accordingly.

- **Conclusion on hardware provisions**

The current units do have certain design features to prevent fuel damage, depressurize the reactor coolant system, mitigate hydrogen to limited extent, prevent containment overpressure and prevent re-criticality. The installation of a filtered venting system constitutes a good practice for a VVER-1000/V320. A detailed evaluation of effectiveness and reliability of the features mentioned was not part of the peer review. The issue of basemat melt-through is still open; analyses are under way and a decision on the feasible strategy should be made in the future.

Assessment of the seismic impacts on unqualified equipment as applicable for mitigation of severe accidents is among the future planned actions. For the seismically qualified equipment it was stated during the country visit, that the equipment will preserve its functionality until PGA=0.4 g.

Analyses by the operator to justify the design features mentioned above are frequently mentioned in the report. Review and approval of these design features, routine inspections by the operator or by the regulator were not explicitly discussed in BG-NR.

However, during the country visit it was stated that:

- The routine regulatory review process is in place based on regulations on ensuring the safety of NPPs, regulatory guides of deterministic and probabilistic safety analysis and applicable IAEA Safety Standards;
- Review of the design of the filtered venting system and of the recombiners was included in the regulatory activities including assessment by the external technical support organisations;
- The SAM systems are part of the overall inspection programme.

#### *4.2.1.4 Accident management for events in the spent fuel pools*

At the Kozloduy site, spent fuel is stored in the pools of Units 3+4 (where there is no fuel in the reactor), the pools of the operating Units 5+6 and in a separate fuel storage facility (SFS, a pool storage). In addition, there is a dry storage facility (cask storage) which is in the process of being commissioned and so does not yet contains any spent fuel.

There are no measures for hydrogen management potentially produced in the pools of Units 3+4. This is considered sufficient, in view of the long decay times of the spent fuel stored there. For Units 5+6, the SFPs are located inside the containment. There, hydrogen generation from the SFP is to be addressed by the PARs, when the planned additional recombining units have been installed. Specific calculations regarding the amount of hydrogen generated in case of SFP severe accident were not performed so far. However, an analysis of severe accidents in the SFP is part of the on-going Level 2 PSA.

Provisions for adequate shielding in Units 3+4 and Units 5+6 were discussed in the BG-NR very briefly. For Units 5+6, it is stated that releases will remain within the containment. Radiation fields created by releases from the pools could markedly differ from those due to releases from the reactor core, because of different distribution of radio-nuclides. BG-NR has so far not analyzed potential differences between the releases from the SFPs and from the reactor core (e.g. quantities and distribution of radionuclides released into the containment, consequences for radiation levels in the building and its surroundings). This issue was addressed during the country visit; with this regard, the plant confirmed a plan to perform additional SFP analysis as part of justification case for using the new fuel.

It was also mentioned that in case of an accident with open containment, there are actions envisaged for personnel evacuation and containment isolation.

The time periods to boiling and the beginning of fuel uncovering in the spent fuel pools are provided in BG-NR. For Units 5+6, the shortest period to fuel uncovery is 17 hrs (due to the long decay times of the fuel, and this period is more than 20 days for Units 3+4) after recent transferring the half of the fuel to the storage facility.

Issue of additional means for supplying the delivery of coolant into the SFP was discussed during the Country visit. It was stated by the Operator that there are existing lines for supplying borated water to the SFP from the auxiliary building. In addition, within the framework of Unit 5&6 modernization programme additional connections will be provided for connecting the mobile sources.

SFPs are considered in a comprehensive manner in EOPs; they are not currently covered by SAMGs. There are no plans to speed up the removal of spent fuel elements from the pools to the dry store to reduce the potential hazards of pool storage since such removal of the elements with the lowest residual power would not contribute significantly to increase of the time margins.

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

It is stated in BG-NR that in case of an earthquake beyond the design basis, there can be extensive destruction of infrastructure. Administrative buildings, hospitals, fire protection buildings etc. on and in the vicinity of the site will not be available. There is no discussion of the damage to be expected to non-seismically qualified buildings in case of an earthquake at or below the design basis. Nevertheless it was stated during the country visit that such buildings do not contain any seismically qualified (category 1 or 2) equipment.

Possible adverse effects of earthquakes to the infrastructure are not described in BG-NR in detail. A number of weaknesses in case of flooding beyond the design basis are listed though and external impacts due to flooding are addressed to a reasonable extent. The plans to conduct analysis of seismic impacts on the infrastructure and associated potential for impeding Accident Management actions have been confirmed during the country visit.

Regarding impairment of work performance on the site due to high local dose rates etc., there is no specific planning since it is not considered possible to foresee details of possible situations. To address these specific issues the Emergency Action Plan provides for a specific dose assessment as part of decision process for each particular action to be taken when required.

The measures to provide habitability of the MCRs, ECRs and AMC are briefly specified and discussed. It is stated that MCRs may become inhabitable in case of melt penetrating the base of the containment. Because MCRs and ECRs are in different locations with respect to the reactor core, the radiological conditions will be different and it is expected that at least one of them will be accessible in case of a severe accident. For radiation accidents the MCR and ECR are equipped with the emergency ventilation systems. Applicability if the emergency ventilation system for the severe accidents should be further assessed.

Habitability of the on-site AMC under SBO is ensured for relatively long period. Besides, there are the plans for establishment of an additional off-site AMC. This centre could be used in case of unavailability of all on-site centres.

The feasibility of SAM measures under conditions of external hazards is discussed in BG-NR. High margins for earthquakes are reported. It is stated that analyses show that safety functions can be performed with surviving equipment in case of combined beyond design earthquake and flooding; no detailed explanation was given.

Regarding instrumentation, it is stated that for Units 3+4, all measurement channels are qualified for correspondent seismic and environmental conditions. For Units 5+6, all SAM equipment is seismically qualified (1$^{st}$ category).

The effects from neighbouring installations are not discussed in the report. There is only a general statement that only actions related to the liquidation of accident consequences can be implemented at the site in any case, as far as the particular situation permits.

The requirements for the operating organisation to explicitly consider multiple unit events as well as loss of infrastructure in SAM have not been sufficiently discussed in BG-NR. Although during the country visit it was explained, that all corresponding measures are planned individually for each of the units the issue needs further consideration until the comprehensive programme for mitigation of severe accidents will be developed and implemented.

### 4.2.2 Margins, cliff edge effects and areas for improvements

The time period to fuel damage in the reactor core, for different scenarios with loss of power and/or UHS, is discussed in BG-NR, as well as the time periods to boiling and the beginning of fuel uncovering in the SFPs. Time margins between shutdown of the reactor and core melting for several accident sequences are also provided. The lowest value given is 4.5 hrs (for large-break loss of coolant accident plus SBO).

A number of measures contributing to the robustness of the design to manage severe accidents have been proposed in the programme for implementation of additional measures which was already reviewed and approved by the regulatory body. It is expected that implementation of the measures will be accelerated.

#### *4.2.2.1 Strong points, good practices*

The installation of an independent filtered venting system at Units 5+6 about 5 years ago constitutes a good practice for VVER-1000.

There are a number of on-going improvements, some of which were identified before the PSR of 2008, some identified as a result of this PSR, and some of which are new improvements identified by the licensee and the regulatory authority as an outcome of the stress tests. These improvements show competence and awareness of the problems associated with accident management.

#### *4.2.2.2 Weak points, deficiencies (areas for improvements)*

Based on BG-NR and its peer review, taking into account the results of discussion during the country visit, the following areas for further improvements could be identified:

- Acceleration of implementation of measures in the area of accident management, such as mitigation of hydrogen risk and prevention of containment basemat melt-through, should be considered;
- Conceptual solutions for the management of liquid releases in the event of a severe accident should be investigated;
- Effectiveness of SAMGs with currently available hardware provisions for mitigation of severe accidents should be further assessed;
- The consequences of possible adverse effects of earthquakes to the infrastructure for SAM should be investigated in more detail;
- Although simultaneous core melt/fuel damage accidents in different units/installations at the site have been considered, it needs to be reconsidered during or after decisions on complete list of measures for mitigation of severe accidents;
- SAMGs fully covering shutdown states, including those with open reactor, are not yet developed;
- Accidents in spent fuel pools appear not to have been analysed in detail; at present there are no SAMGs for SFP accidents, but they development is envisaged by the recently adopted improvement programme.

### 4.2.3 Possible measures to increase robustness

#### *4.2.3.1 Upgrading of the plants since the original design*

General data for the plants according to the current situation are provided in the National Report. There is no specific discussion of the upgrading which took place before the modernization programme which started in 1999; the peer review has assumed these improvements have been included in the general description provided. Further modernization programme relevant for accident management has been implemented at Units 5+6 during the period from 1999 to 2008.

#### *4.2.3.2 Ongoing upgrading programmes in the area of accident management*

In addition to the programmes mentioned in the previous section, a further modernization programme was begun in 2008, based on the PSR of Units 5+6 completed in that year. Regarding severe accidents, the programme consists of measures which were identified earlier and confirmed during the PSR:

- Installation of temperature sensors for monitoring the temperature of the reactor vessel.
- Closing the ionization chamber channels in the walls of the reactor vessel shaft, which constitute a weak point for potential penetration of molten corium in case of a severe accident.

Furthermore, this upgrading programme also includes measures which were identified as a result of the PSR by the licensees:

- Implementation of SAMGs, according to a developed programme;

- Implementation of SBEOPs for reactor shutdown conditions with closed and open primary circuit;
- Updating, verification and enforcement of SAMGs, taking plant improvements into account.

### 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*

From the stress tests analysis of a combination of beyond design basis earthquake and flooding, several measures to increase general robustness at Units 3+4 were identified.
Furthermore, for Units 5+6, additional improvements for SAM are envisaged as a result of the stress tests. The improvements are covered by the "Program for Implementation of Recommendations Following the Stress Tests Carried Out on Nuclear Facilities at Kozloduy NPP plc". The scope and implementation schedule of the programme was presented to the peer review team during the country visit. Based on the peer review discussions and the country visit it can be summarized that the improvements include:

- Implementation of the SBEOPs for the shutdown states with open reactor, for Units 5+6;
- Implementation of SAMGs for Units 5+6;
- Development of technical means for direct water supply to the stem generators, SFPs and the containment using mobile fire equipment;
- Development of technical means for direct water supply to the spent nuclear fuel ponds in the SFSF using mobile fire equipment;
- Installation of additional hydrogen recombiners in the containment;
- Installation of measuring channels for monitoring of vapour and oxygen concentrations in the containment;
- Closing the ionizing chamber channels located in the walls of the reactor cavity;
- Installation of a wide range temperature sensors for monitoring the temperature of the reactor vessel;
- Updating on-site and off-site emergency plans, taking into account (a) difficulties in accessing the ECRs of Units 5+6; (b) possible drying out of the SFS basin compartments, with subsequent increase of dose rates; and (c) providing alternative routes for evacuation, transport of fuels and materials and access of staff;
- Construction of a new EMC, outside the Kozloduy site;
- Study of the options for localizing the molten core in case of a severe accident;
- Development and implementation of the SFP SAMGs.

*4.2.4.2 Further studies envisaged*

Implementation of the measures covered by the programme mentioned in 4.2.4.1 is currently initiated and is ongoing in accordance with the approved schedule. The programme includes also further studies; in the area of accident management a study of the options for localization of core melt in case of severe accidents will be developed.

*4.2.4.3 Decisions regarding future operation of plants*

Taking into account the results of the stress tests, the BNRA sees no reason to limit the operating lifetimes of Units 5+6.

## 4.3 Peer review conclusions and recommendations specific to this area

BG-NR provides a good overview for the topic of SAM at the Kozloduy site. The Bulgarian regulations for SAM are generally appropriate and well elaborated. The regulations are fully harmonized with the WENRA Reference Levels for existing reactors. The implementation process of the Reference Levels in the NPP is under way, but not yet fully completed. In some cases, the information provided in BG-NR was not sufficiently detailed; this has been noted in the corresponding sections of this review report. However, missing information was provided during the country visit. There are some activities which are recommended to be performed in addition to what is planned so far as result of the stress tests.

An important question in the context of SAM is under which conditions implementation of the different SAM measures is feasible, e.g. due to possible lacking some hardware provisions for mitigation of severe accidents. The scope of the peer review did not permit a systematic overview in this respect. It was not clear to what extent a systematic evaluation of this issue has been performed so far in Bulgaria.

The developed comprehensive programme encompassing all the improvements currently on-going or planned should be monitored and regularly updated to guarantee good co-ordination and harmonization of all activities, and their timely completion.

The following recommended activities should also be pursued within the framework of this programme:

- The issue of the management of large volume of liquid releases in the event of a severe accident should be investigated further – it should be evaluated whether the available provisions would be adequate.
- Considerations and analyses for mitigation of hydrogen risk and prevention of basemat melt-through should be pursued with high priority.
- The consequences of possible adverse effects of earthquakes to the national infrastructure for severe accident management should be further investigated.
- Simultaneous core melt/fuel damage accidents in different units/installations at the site should be further investigated and assessed regarding interactions and the resulting special requirements that would arise for severe accident management.
- SAMGs fully covering shutdown states, including those with open reactor, should be developed.
- Accidents in spent fuel pools should be analysed in detail (for example, as part of the planned activity on the SAMG SFP development).

## *List of acronyms*

| | |
|---|---|
| AMC | Accident Management Centre |
| ASUNE | Act on the Safe Use of Nuclear Energy |
| BG-NR | Bulgarian National Report |
| BNRA | Bulgarian Nuclear Regulatory Authority |
| BPS | Bank Pumping Station |
| BRU-A | Fast Active Steam Dump to the Atmosphere |
| CPS | Circulation Pump Station |
| DBA | Design Basis Accident |
| DBE | Design Basis Earthquake |
| DBF | Design Basis Flood |
| DG | Diesel Generator |
| DSFSF | Dry Spent Fuel Storage Facility |
| ECCS | Emergency Core Cooling System |
| ECR | Emergency Control Room |
| EDG | Emergency Diesel Generator |
| EES | Electric Energy System |
| EMS | Emergency Management System |
| EOP | Emergency Operating Procedures |
| ESWS | Essential Service Water System |
| I&C | Instrumentation and Control |
| IAEA | International Atomic Energy Agency |
| HAZOP | Hazard and Operability Analysis Method |
| KNPP | Kozloduy Nuclear Power Plant |
| LOOP | Loss of Off-site Power |
| MCR | Main Control Room |
| MWL | Maximum Water Level |
| NPP | Nuclear Power Plant |
| OEF | Operating Experience Feedback |
| OSY | Outdoor (Open) Switchyard |
| PAR | Passive Autocatalytic Recombiner |
| PGA | Peak Ground Acceleration |
| PSA | Probabilistic Safety Assessment |
| PSR | Periodic Safety Review |
| RHWG | Reactor Harmonization Working Group, WENRA |
| RLE | Review Level Earthquake |
| RPV | Reactor Pressure Vessel |
| SAM(G) | Severe Accident Management (Guidelines) |
| SBEOPs | Symptom Based Emergency Operating Procedures |
| SBO | Station Blackout |
| SFP | Spent Fuel Pool |
| SFSF | Spent Fuel Storage Facility |
| SG | Steam Generator |
| SG EMS | Steam Generators Emergency Makeup System |
| SL | Seismic Level |
| SSCs | Structures, Systems and Components |
| SSE | Safe Shutdown Earthquake |
| SSEL | Safe Shutdown Equipment List |
| UHS | Ultimate Heat Sink |
| UPS | Uninterruptible Power Supply |
| VVER | Water-Water Energy Reactor |
| WENRA | Western European Nuclear Regulators' Association |