Post-
Fukushima
accident

Belgium

Peer review country report

Stress tests performed on European nuclear power plants

ENSREG
European Nuclear Safety Regulators Group
Stress Test Peer Review Board

1 GENERAL QUALITY OF NATIONAL REPORT AND NATIONAL ASSESSMENTS

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

Country review reports are one of the specific deliverables of the EU stress tests peer review process. They provide information based on the present situation with respect to the three main 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. The draft country review reports were initiated during the Topical Reviews in Luxembourg based on discussions with the country involved in the three topics and on the generic discussions within each of the three Topical Reviews. Issues identified for each country during the topical reviews, due to only limited time available for each country, have required follow-up discussions in more detail, both between the Topical Reviews and the Country Reviews, and during the individual Country Reviews.

The current Country Report was finalized at the end of the Country Review visit, after final discussion with the reviewed country and visit of a nuclear power plant. The results of the Topical Reviews and the 17 individual Country Reviews will be combined and they will form the essential part of the ENSREG Final Report.

The Belgian nuclear power plants are located on two distinct sites: Doel and Tihange. They are operated by Electrabel, a company of the GDF-SUEZ Energy and Services Group.

The Doel NPP is located in the port of Antwerp, on the left bank of the Scheldt River, 15 km northwest of Antwerp (Flanders) and only 3 km from the border between Belgium and the Netherlands. The site houses the following facilities:

- Doel 1/2 twin reactors units,
- Doel 3 reactor unit,
- Doel 4 reactor unit,
- SCG building (spent fuel dry storage).

The Tihange NPP site is located on the territory of the former municipality of Tihange along the right bank of the Meuse River. Tihange is now part of the City of Huy at a distance of 25 km from Liege. The site houses the following facilities:

- Tihange 1 reactor unit,
- Tihange 2 reactor unit,
- Tihange 3 reactor unit,
- DE building (spent fuel wet storage).

For all nuclear safety related matters, the licensee’s activities are under the control of the Belgian regulatory body, which is composed of:

- the Federal Agency for Nuclear Control (FANC),
- and Bel V, its technical subsidiary.

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

The Belgian National Report (BE-NR) is consistent with the content and structure recommended by the European Commission and ENSREG, and it covers all requested topics in detail. The report also identifies potential safety improvements proposed by the licensee, and it presents the position of the regulatory body, including additional requirements. Furthermore, it contains a supplementary assessment of “loss of primary ultimate heat sink (UHS) together with loss of off-site power (LOOP) supply and combined with Design Basis earthquake (DBE)”, which is an additional scenario to the ENSREG specifications.

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

The information provided in the BE-NR regarding the response of the Belgian NPP units is generally in compliance with the guidance provided for the stress tests. The report is quite comprehensive, with sufficient amount of details, schemes and tables.

All required accident scenarios are reviewed carefully and supported by necessary measures proposed for implementation, with a schedule of implementation provided. The assessment of the BE-NR resulted in a number of questions that were sent to the Belgian regulatory body. During the Topical Review meeting in Luxembourg, they provided detailed and sufficient answers and clarifications to the desktop review questions, as well as to the questions asked by the reviewers during the country presentations. The open issues that remained unresolved after the Topical Review meeting were clarified during the subsequent Country Visit, which also included a visit at the Doel site.

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

The assessment of the compliance of the plants with their current licensing basis for the events within the scope of the stress tests was performed by the licensee using a deterministic approach. Compliance is maintained regularly by the oversight system in place and by the modifications requested by the Belgian regulatory body, FANC and Bel V.

During the country visit the review team was given copies of the Royal Decree concerning safety prescriptions for nuclear installations published at the end of December 2011, applicable to the Belgian NPPs. This Royal Decree was issued in response to the Reactor Harmonization working group set up by the Western European Nuclear Regulators’ Association (WENRA) and the commitments of the regulatory body to include the applicable WENRA Reference Levels into the Belgian regulations. The Royal Decree includes, among others, the requirement to perform Periodic Safety Reviews (PSRs) for the purpose of assessing and improving nuclear safety at each NPP. The Periodic Safety Review is considered a complementary regulatory tool to the regularly oversight system in place and was already included as an original license condition for the Belgian NPPs.

The assessment of compliance of the plants with their current licensing basis within the scope of the stress test seems to be adequate.

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

The assessments of the robustness of the plants and situations taken into account are considered adequate. In general, the robustness of the facilities is considered satisfactory by Belgian regulatory body. Robustness of the plants against all of the analyzed external hazards has been assessed. However, a more systematic assessment of robustness of the plants with respect to earthquake and some extreme weather conditions should be done.

The licensee reassessed the events, and combinations of events, stipulated by the ENSREG specifications as loss of electrical power and loss of ultimate heat sink, as a consequence of an earthquake, flooding or extreme weather conditions. The assessment considers scenarios involving both single and multiple unit events, giving the description of timelines and potential cliff edge effects. The assessment was performed in a deterministic way for scenarios relevant to three plant basic operational states: “steam generators are available”, “primary circuit is open” and “fuel inventory of the core is transferred to spent fuel pool”.

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

It is evident from the structure of the report that Belgian regulatory body very clearly separates the assessment of the licensee from that of the regulatory body. Each of the topics is summarised separately from the Belgian regulatory body point of view and priority is given to conclusions in identifying additional demands and recommendations for further improvements of the facilities. Indicative deadlines for particular actions are also included.

The assessment performed by Belgian regulatory body on the approach and results as provided by the licensee included detailed examination of the licensee’s stress tests reports and the supporting documents, technical meetings with the licensee, and on-site inspections to check on the field the reality, relevance and robustness of the key data cited in the licensee’s safety demonstrations.

The “Synthesis of the main results presented by the Licensee” and “Assessment and conclusions of the regulatory body” provided in the BE-NR for each topic show the regulatory body position with respect to the assessments performed and the improvements proposed by the licensee. The latter contains a number of additional requirements and recommendations by the Belgian regulatory body to further improve the robustness of all NPP units. For the implementation of the proposed improvements, the licensee has submitted an action plan to the regulatory body for review and approval. On this basis, the regulatory body will set up a dedicated follow-up of the action plan implementation.

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 Design Basis Earthquake (DBE)

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

No specific information is provided in the BE-NR about regulatory basis for safety assessment and regulatory oversight. It has been presented during the topical peer review that Belgium generally tends to follow the Unite States Nuclear Regulatory Commission (US NRC) standards and guides. For Belgian NPPs, US NRC regulations are followed to the extent possible and identified in the Safety Analysis Report (SAR). In the SAR, the applicable rules and reference rules (including Code of Federal Regulations 10 CFR 100, Regulatory Guides, etc.) are indicated and all deviations from these rules are identified and explained. Hence, the SAR of each unit contains all regulatory requirements and is legally binding.

2.1.1.2 Derivation of DBE

The first assessment of the DBE for Tihange 1 derived from a deterministic study defining the design base with peak ground acceleration (PGA) =0.1g. This level was raised to 0.17g during the first Periodic Safety Review of Tihange 1 in 1985. For Tihange 2&3, the initial design was 0.1g, then it was changed to 0.17g during the construction.

The original design of Doel 1/2 did not account for seismic loads, as the site was considered aseismic according to its location at the London-Brabant Massif. During the first Periodic Safety Review in 1985 the DBE was set at 0.058g for Doel 1/2 by deterministic assessment of the strongest known near-by earthquake. Doel 3&4 are designed for a DBE of 0.1g in accordance with US NRC Regulations (10 CFR 100).

2.1.1.3 Main requirements applied to this specific area

The requirements are mainly based on US regulations. They are determined for each site on a case-specific basis. During the country visit it was presented that WENRA reference levels are also considered in national regulations.

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

Originally, two different deterministic approaches were used to define the DBE of the Doel and Tihange NPPs: the seismotectonic deterministic method and an alternative historical deterministic method. For both deterministic approaches, the peak ground acceleration is given by correlation curves between intensity and peak ground acceleration. In 2011 new seismic hazard reassessment took place using a state-of-the-art probabilistic seismic hazard analysis (PSHA) methodology revealing new values of PGA for a mean occurrence probability of 10^{-4} per year.

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

Periodic safety reviews were used to reassess seismic hazards of both sites.

During the country visit it was presented that in the framework of the third PSR for Doel 1/2 and Tihange 1, and the second PSR for Doel 3&4 and Tihange 2&3, a re-evaluation of the seismic levels has been initiated, but the results were not validated. For the new PSR (3rd PSR for Doel 3&4, Tihange 2&3, and 4th PSR for Doel 1/2 and Tihange 1), the licensee will address the seismic hazard with focus on the seismic margins available in the installations.

2.1.1.6 Conclusions on adequacy of design basis

The original design basis was reviewed and accepted by the regulator.

A new study of seismic hazard based on a probabilistic seismic hazard analysis taking into account of the most recent information and data has been requested to be conducted following the incident in Fukushima. This study estimates values of the seismic hazard for return periods of 1,000 and 10,000 years. This approach is in accordance with state of the art methodology and latest practice used. Reassessment of seismic hazard in 2011 showed that for an earthquake with a 10,000-year return period:

- For the Doel NPP, the results obtained are still in conformity with the values used in the design basis of the four units.
- For the Tihange NPP, the assessment resulted in a slight increase of the peak ground acceleration in comparison with the design base levels.

The new PSHA will be validated and refined. The results will be considered for the future seismic assessments.

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

The regulator confirmed that the plant is compliant with the current design basis, although, some minor deviations from the seismic concept for the equipment have been identified.

2.1.2 Assessment of robustness of plants beyond the design basis

2.1.2.1 Approach used for safety margins assessment

Assessment of safety margins was performed using two elements:

- Seismic Margin Assessment to quantify the available margins for beyond design seismic level following methodology developed by the Electric Power Research Institute (EPRI) described in the document NP-6041.
- Seismic Margin Review based on the judgment of experienced engineers during walkdown inspections.

The BE-NR claims that margins can be derived from conservatisms used in the design of NPPs thanks to strict codes and regulations.

2.1.2.2 Main results on safety margins and cliff edge effects

The method chosen does not look for the seismic robustness of the structures, systems, and components (SSCs), rather looks at the probability of the SSCs to withstand a certain Review Level Earthquake (RLE). The RLE values were estimated to envelope those calculated by the recent PSHA (RLE for Tihange = 0.3g, RLE for Doel = 0.17g).

In generally, results demonstrate the capacity of Tihange and Doel NPPs to resist also earthquake of higher intensity than the one considered in the design albeit for a limited number of SSCs it was identified that these would sustain RLE with low probability.

An ~~a~~nalysis has been conducted of the seismic behavior of the containment and penetrations of the units for the RLE using an "expert judgment" approach, based on the EPRI-NP-6041. The following earthquake values expressed in PGA were presented as having high potential for maintaining respective structures integrity:

Tihange 1, 2, 3: primary containment, secondary containment foundations and mechanical penetrations – 0.3g.

Doel 1/2: primary containment, secondary containment foundations and mechanical penetrations – 0.17g.

Doel 3, 4: primary containment and mechanical penetrations - 0.3g, secondary containment and foundations – 0.17g.

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

Additional studies showed that the majority of the relevant SSCs would withstand the RLE with high level of confidence. Nevertheless, the SSCs, which are identified to have low probability to meet the RLE, will be strengthened.

2.1.2.4 Possible measures to increase robustness

Those components that showed the resistance to RLE with low probability will be subject to more precise calculations and modifications will be realised. A feasibility study for strengthening the Electrical Auxiliary Building at Tihange 1 is required.

During the country visit it was presented to the review team that the fuel tank CVAB01C of unit 1 of Tihange, containing 500 m^3 of fuel is not seismically qualified. It is recommended to verify that the analyses are covering the impact of failure of this tank (e.g., fires, flood) induced by an earthquake.

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

Measures include:

- To perform walkdowns concerning the SSCs in the reactor building of the four most recent units. (walkdowns inside the reactor buildings for the three oldest units have already been performed).
- To realize corrective actions to solve identified weaknesses of the SSCs.
- To perform more detailed seismic hazard studies and take into account wider scope of relevant factors.

The licensee must continue its efforts towards fostering awareness of potential seismic interaction inside the facilities.

During the country visit the draft action plan prepared by the licensee was presented, including changes relevant to the topic of earthquakes. This plan has been submitted to the regulator for review.

2.1.3 Peer review conclusions and recommendations specific to this area

The topic of DBE has been addressed at all Belgian NPPs regularly taking into account its re-evaluation during conducted PSR studies since 1985. All relevant SSCs are designed to withstand the currently estimated DBE.

Reviewers acknowledge the licensee's decision to initiate a state-of-the art PSHA immediately following the Fukushima accident. This PSHA study updates the seismic hazard performed earlier by deterministic methods. It is highly appreciated that the results of the 2011 ad-hoc study by the Royal Observatory of Belgium have been made available for the Stress Test Reports in a very short time. FANC's request to further update this recent PSHA by a more elaborate one and the decision to include external reviews by international experts in that process may serve as an example of a good practice.

As a result of the peer review it is recommended that the national regulator monitors the completion of the updated PSHA, the implementation of the consequential measures and the updated assessment of safety margins. These updates may benefit from a harmonization of the seismic hazard assessment on an international level. Experience exchange, namely among the neighbouring countries is recommended, in order to avoid discrepancies for sites with comparable seismic activity.

The seismic instrumentation which was observed during the plant visit appeared to offer an opportunity for improvement with respect to the number of accelerometers and to the evaluation procedure. An immediate evaluation of the recorded signals, allowing the comparison of response spectra with the design basis spectra and a direct access to this information is recommended in order to facilitate and to accelerate the measures to be initiated after a seismic event.

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

2.2.1 Design Basis Flood (DBF)

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

No specific references or information is provided in the BE-NR regarding the regulatory basis for safety assessment in this area. It has been presented during the topical peer review that Belgium generally tends to follow US NRC standards and guides. For Belgian NPPs, US NRC regulations are followed to the extent possible and identified in the Safety Analysis Report (SAR). In the SAR, the applicable rules and reference rules (including 10 CFR 100, Regulatory Guides, etc.) are indicated and all deviations from these rules are identified and explained. Hence, the SAR of each unit contains all regulatory requirements and is legally binding.

2.2.1.2 Derivation of DBF

DBF for Tihange site was originally derived as the highest historically recorded flood level of the surrounding river increased by 20% (i.e. 2200 m^3/s). Based on the flood in 1995 this value was revised to 1995 flood + 20% margin (i.e. 2615 m^3 /s)).

The Doel NPP is not considered to be flooded due to the fact that the NPP is situated on a raised platform and, secondly, the nearby river has an artificial embankment, which serves as a barrier for the site.

During the latest reassessment within the latest PSR, new DBF parameters have been derived using the probabilistic approach. Values with return periods of 10,000 years are taken as new design basis values. During the country visit it was reported, that for Tihange the new DBF value has been assessed to be 3488 m3/s as the best estimate value.

2.2.1.3 Main requirements applied to this specific area

It is understood from the report that current safety assessment approach is based on calculating flood parameters using historical data plus additional margin. These values are well beyond the 10^{-4} probability for the Doel site, but apparently correspond to 10^{-2} probability for Tihange site only. It is clearly stated that the recently estimated 10,000 year values are expected to be taken as the new design basis for Tihange.

The defence in depth approach for the protection of the Tihange site against exceptional external flood (new DBF and even beyond DBF) was explained during the country visit.

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

The original DBF parameters have been estimated with a deterministic approach ,based on the floods experience and have been increased by additional margins. These values were reassessed with a probabilistic approach during the latest periodic safety review.

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

Design basis parameters for floods of both sites have been reassessed during the latest PSR on the basis of most recent data.

2.2.1.6 Conclusions on adequacy of design basis

The combination of deterministic approach used to estimate DBF in the past and the probabilistic approach for DBF as a function of return period provides for high level of confidence to the adequacy of design basis with respect to floods and is in compliance with current best practice and state of the art international standards.

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

The Tihange site is currently protected by its design against a reference flood with a statistical return period up to 400 years. The reference flood with a statistical return period up to 10,000 years will be implemented as a new DBF. The Tihange NPP currently does not fully comply with this new requirement, but measures are foreseen, as defined in the action plan.

Protection against external flooding of the Doel site is adequate also for floods with 10,000 years return period.

2.2.2 Assessment of robustness of plants beyond the design basis

2.2.2.1 Approach used for safety margins assessment

For Tihange NPP analysis is based on the height of water reached in the various places on the site and, for each location, analysing consequences on the equipment present there and likely to be affected. All equipment that can assist the cooling of the fuel in the core or in the pool is examined.

For Doel NPP the buildings which are flooded first or quickest in the case of wave overtopping or embankment failure were identified. For the most important SSCs and their physical location, it was checked whether there are any thresholds, plinths, etc. present to protect against the consequences of flooding in case of wave overtopping or embankment failure.

2.2.2.2 Main results on safety margins and cliff edge effects

The results for Tihange NPP show that there are weak margins for floods exceeding those with 400 years return period. Significant damage to equipment would be caused already by floods with return periods of 600 to 1,000 years, worsening the consequences with increasing return periods (higher river flow rates). The value at which no safety related systems would be operational is clearly estimated. Related cliff edge effects are described and linked to respective river flow rates.

Safety margins for Doel site are larger due to the topography of the site. Even in case of the river embankment failure near the site when a 20 cm water layer on the site would be expected there is still at least one safety system level (1st or 2nd level) available for each unit that would not be flooded.

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

The topographical conditions at the Doel site can be regarded as strong design feature. The organizational provisions in place and the relevant safety equipment available create good potential for an adequate response in case of an unexpected beyond design basis floods.

Several areas for safety improvement related to weak points were identified. These include water tightness of buildings, peripheral physical protection of the Tihange site and the reinforcement of the river embankment of the Doel site.

It is recommended to implement all suggested measures for the Tihange site since the analysis shows relatively low protection of the site against flooding. These measures are

- Peripheral protection of the Tihange site;
- Volumetric protection of safety related buildings;
- Non conventional means;

and associated organizational measures.

2.2.2.4 *Possible measures to increase robustness*

Several possible measures are envisaged with the aim to create several lines of defence against external flooding. These correspond to identified weak points and include design modifications as well as procedural and organizational improvements.

During the country visit the draft action plan prepared by the licensee was presented, including changes relevant to the topic of flooding. This plan has been submitted to the regulator for review.

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

There are several measures worked out in the report to improve the robustness of Belgian NPPs against external flooding. The scope and nature of proposed improvements provides protection against even extreme floods potentially occurring with extremely low probabilities.

2.2.3 Peer review conclusions and recommendations specific to this area

The issue of protection against external flood is obviously more relevant for the Tihange site. Taking into account the relatively weak safety margins and the reconsideration of DBF values, it is recommended that the national regulator should focus on the implementation of all safety improvements proposed by the licensee, as well as those prescribed by the regulator.

Regarding the Doel site, it is recommended that the national regulator monitor the implementation of the measures proposed in the action plan.

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

2.3.1 Design Basis for Extreme Weather Conditions

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

No specific references or information is provided in the BE-NR regarding the regulatory basis for safety assessment in this area. It has been presented during the topical peer review that Belgium generally tends to follow US NRC standards and guides. For Belgian NPPs, US NRC regulations are followed to the extent possible and identified in the Safety Analysis Report (SAR). In the SAR, the applicable rules and reference rules (including 10 CFR 100, Regulatory Guides, etc.) are indicated and all deviations from these rules are identified and explained. Hence, the SAR of each unit contains all regulatory requirements and is legally binding.

2.3.1.2 *Derivation of extreme weather loads*

Derivation of design parameters for extreme weather loads has been done mainly from observations and recorded historical data. Nevertheless only in limited number of cases (taking into account all analysed weather phenomena and both sites) a clear design basis value is provided. A reference to FSAR is made at certain points. The following weather phenomena are addressed in the report: heavy rainfalls, high winds, tornadoes, lightning, snowfalls, hail and extreme temperatures.

2.3.1.3 *Main requirements applied to this specific area*

No specific references or information is provided regarding the main requirements applied to this specific area. Nevertheless from some parts of the report and mainly from the regulatory body conclusion can be derived that as contrary to earthquake and flooding regulatory expectations are to satisfy design basis parameters with values corresponding to 10^{-2} probability.

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

Observations and recorded historical data were used. These values were consequently associated with probabilities as values with respective return periods for some of the weather phenomena. Extreme weather temperatures are not addressed in the report at all, but it has been mentioned that this phenomena is analysed in the Final Safety Analysis Report (FSAR).

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

The report indicates that extreme weather conditions were subject to reassessment during previously performed PSRs resulting in confirmation of validity of the original design basis values or implementing modifications if needed. Nevertheless the report does not provide any further details or examples of the design basis (DB) re-evaluation as a result of performed PSRs.

2.3.1.6 *Conclusions on adequacy of design basis*

The design basis was reviewed by the regulator. Some recommendations for improvement were issued by the regulatory body (e.g., heavy rains, tornados).

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

No inconsistency in compliance with current requirements for design basis was indicated.

2.3.2 Assessment of robustness of plants beyond the design basis

2.3.2.1 *Approach used for safety margins assessment*

There has been no uniform approach observed that would be applied to estimate safety margins for the extreme weather conditions. An exception is the analysis made for tornado effects that includes analysis of three intensities and their impact on relevant equipment.

During the country visit more information was provided on heavy rainfall (sewer capacity), strong winds and snow hazard. Extreme temperatures are reviewed in the framework of the PSRs.

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

No general results of safety margins evaluation can be derived from the report from reasons described above (see 2.3.2.1). No cliff edge effects were identified.

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

Areas for safety improvement correspond to proposed measures to increase robustness listed in the following paragraph (see 2.3.2.4).

2.3.2.4 *Possible measures to increase robustness*

There were several measures identified to increase robustness of plants against heavy rainfalls, lightning and snowfalls.

During the country visit the draft action plan prepared by the licensee was presented, including changes relevant to the topic of extreme weather. This plan has been submitted to the regulator for review.

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

Apart from the measures decided by the operator that are listed in the previous paragraph (see 2.3.2.4) two additional measures were prescribed by the regulatory body for heavy rainfalls protection and for protection against tornados (for Tihange 1 and Doel 1/2).

2.3.3 Peer review conclusions and recommendations specific to this area

The design parameters for extreme weather conditions are mainly based on historic data and therefore on a return period in the order of 100 years.

The derivation of design basis parameters with 10,000 years return periods is recommended to be considered. Attention should be dedicated also to extreme temperatures.

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, ,…)

For Belgian NPPs, US NRC regulations are followed to the extent possible and identified in the Safety Analysis Report (SAR). In the SAR, the applicable rules and reference rules (including 10 CFR, Regulatory Guides, etc.) are indicated and all deviations from these rules are identified and explained. Hence, the SAR of each unit contains all regulatory requirements and is legally binding.

Recently, the Belgian legislation has been improved to account for the WENRA Reference Levels and the European Union Directive 2009/71/Euratom of 25 June 2009. In this order, the Royal Decree on Safety Requirements for Nuclear Installations was published in 30 November 2011 and will be implemented this year.

3.1.2 Main requirements applied to this specific area

The basic safety principles, such as defence in depth, redundancy of important safety equipment, their physical or geographic separation (however this principle is not fully implemented in the Doel 1/2 units), as well as their diversification, were applied from the design phase, and upgrades were performed on the earliest units to enhance their robustness when faced with scenarios not considered originally. Some structural reinforcements were also implemented, where appropriate.

The general requirements used by Belgian regulatory body for electrical supply systems are contained in the US NRC regulations "General Design Criteria (GDC), Appendix A to 10 CFR Part 50", in particular, GDC 17, 18, while the specific requirements are those contained in the following Regulatory Guides: RG 1.9 (design and qualification, testing of diesel generators), RG 1.32 (Class 1E electric systems), RG 1.75 (Independence) and associated IEEE standards, and the NUREG 800 Standard Review Plan (SRP) Chapter 8 (Electrical systems).

With respect to the ultimate heat sink, Belgian regulatory body uses the requirements of the following US NRC documents: GDC 44, 45; RG 1.13, RG 1.27, SRP 9.1.3, SRP 9.2.5.

According to the above mentioned regulations, all the units have two independent offsite power supplies.

The Belgian plants have two levels of safety systems: the first level safety systems are designed to cope with accidents of internal origin (e.g., loss of coolant accident (LOCA), steam line break (SLB), feed water line break (FWLB)), and the second level to cope with external hazards.

Concerning the second level of protection, the safety principles and rules to be applied were defined following the authorization orders for the most recent units. For the oldest units (Tihange 1 and Doel 1/2), the safety requirements were discussed and specified in agreement with the safety authorities during the first periodic safety review.

During each PSR, the new regulations published within the last 10 years are examined and new reference rules are identified in order to apply to the Belgian NPPs. For specific projects the last version of the regulation is taken into consideration and applied if needed (e.g., new diesels installed in Doel 1/2).

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

In section 5.7 of the BE-NR it is specified that the different scenarios analyzed to comply with the stress tests requirements (i.e. loss of power, loss of heat sinks and combinations of these events) either are part of the initial design basis, or were reassessed during the first periodic safety review, or are "beyond design basis" scenarios.

The scenarios of "Loss of offsite power (LOOP)" and "Loss of primary ultimate heat sink (UHS)" are part of the initial design basis of all the Belgian units. The scenario "Loss of primary UHS, LOOP and earthquake DBE" is part of the initial design for all the Belgian units except for the Doel 1/2 units.

For the four most recent units (Tihange 2&3 and Doel 3&4), the scenarios "Station Black out (SBO)" and "Loss of primary UHS and SBO" are also considered in the initial design basis of these units. A second level of protection called the "Bunker" allows facing these situations. For the oldest units (Tihange 1 and Doel 1/2), the scenarios "Station Black out (SBO)" and "Loss of primary UHS and SBO", "Loss of primary UHS, LOOP and earthquake DBE" (only for Doel 1/2 because of the DBE aspects) were not taken into account during the initial design. Based on conclusions of the first periodic safety review of these units, a new building with a second level of protection was added for the cooling sources and the electrical power supply, called SUR (emergency system) for Tihange 1 and GNS (emergency systems building) for Doel 1/2, which is able to cope with the mentioned scenarios.

The scenarios "Total SBO", "Loss of primary and alternate UHS", "Loss of primary UHS and total SBO" are considered as beyond design situations for all the Belgian units.

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

Ten-yearly periodic safety review is performed for each Belgian unit. Based on PSR, plant modifications have been made, such as the implementation of the second level of safety systems at the Doel 1/2 and Tihange 1 plant units. Nevertheless, some issues identified during the last PSR are not addressed yet. In the light of the Fukushima event, the regulator has requested to speed up implementation of corrective measures based on the last PSR.

3.1.5 Compliance of plants with current requirements

Based on the assessment of the licensee's reports and the supporting documents, the subsequent technical meetings and the on-site inspections, the regulatory body considers that the resulting action plan is adequate. However, the Belgian regulatory body has identified additional demands and recommendations to further improve the robustness of all the Belgian units, as presented in Sections 3.2.4 and 3.2.5 below.

Based on the reassessments performed in the wake of the Fukushima accident Belgian regulatory body considers that in all scenarios considered, the essential safety functions are preserved.

3.2 Assessment of the robustness of plants

3.2.1 Approach used for safety margins assessment

The general approach adopted in assessing the safety margins with respect to the loss of electrical power and loss of heat sink is firstly to describe the relevant systems available together with the associated level of redundancy and diversity of equipment. Secondly, the systems that can compensate the loss described in the scenario analyzed are presented. Thirdly, a short description of the scenario is provided, and the response of each unit, according to the specific design provisions and the reactor state in the moment of the event.

Three different initial states of the unit are considered:

- Steam Generators (SGs) available: the primary circuit is closed which allows the use of the SGs to cool the reactor core;
- open primary system: the reactor coolant system is open (during outage) and the SGs are not available to cool the fuel which is still in the open reactor vessel;
- core in the Spent Fuel Pool (SFP): the unit is in outage and all the fuel is removed from the core and placed into the SFP.

Data related to the autonomy of the unit, in each case analyzed, are also presented in the BE-NR and established the times by which different equipment are expected to be available to perform the various safety functions. The autonomy of diesel generators has been established based on the licensee's calculations. Depletion of the water tanks and the time of fuel failure (considered at the fuel uncovering moment) were established based on calculations, operating experience and expert judgment, too). Specific analyses were performed for accidents evaluated in SAR (design bases accidents), and for the beyond design basis accidents both calculations and engineering judgment were used in the assessment process.

3.2.1.1 Loss of off-site power (LOOP)

Design provisions for AC power supply

All the Belgian plant units have at least two independent off-site power supplies of very high voltage and high voltage. In case of a failed switch to house load operation and loss of all off-site connections, all units have internal safety power supply sources, back-up diesel electricity generators organized in two levels of protection.

The first level of protection to cope with design basis accidents of internal origin (e.g., loss of coolant accident, steam line break, feed water line break) consists of:

- Tihange 1: 2 DGs (2 x 100%), DBE resistant,
- Doel 1/2 (twin units): 4 DGs shared by both units, non DBE resistant, supplying all needed specific and shared safety equipment taken into account at least a Single Failure,
- Tihange 2&3, Doel 3&4: 3 DGs (which each supply power to one of the 3 first level safety trains), DBE resistant; 2 DGs are sufficient taking into account at least a Single Failure,
- If one diesel fails or is unavailable, one spare back-up diesel can be manually connected to Tihange 1, 2 and 3 (1 for the site); 1 for Doel 3 and 4; and 1 for to Doel 1/2 (will be provided, by the middle of 2012).

The second level of protection (including power supplies, control rooms, water supplies, compressed air for instrumentation and control (I&C), primary pumps seals injection, SG feedwater) that is entirely independent of the first level of protection:

- Tihange 1 : SUR systems
    - one emergency turbo alternator (GUS), powered by steam from the SGs,
    - one air-cooled emergency diesel generator (DUR),
- Doel 1/2: (GNS systems): one air-cooled DG per unit, shared by units,
- Tihange 2&3, Doel 3&4: 3 DGs (which each supply power to one of the 3 second level emergency trains) in each plant unit, independent of the primary UHS.

The autonomy time depends on the event considered, since some of the fuel tanks are not seismically qualified and not credited in case the loss of power is caused by an earthquake. The autonomy varies between 3.5 days (at Tihange 1- for each diesel generator) to a few weeks (7 days for Tihange 2&3 in all scenarios considered). The capacity of the DUR diesel fuel tank (container holding 500 litre in the Tihange 1 emergency building (BUR), which is a second level, seismic qualified fuel tank, provides autonomy of 7.5 hours only. Manual diesel fuel transfer achieved by gravity from the auxiliary steam system (CVA) B01Hc tank (500 m^3, not DBE qualified) is possible and can increase autonomy to more than 200 days.

Loss of Off-site Power (LOOP) - description of the event

Automatic actions following LOOP ensure the protection of the reactor and the evacuation of the residual heat: shutdown of the reactor, start-up of the auxiliary feedwater supply and cooling through the SGs.

Design provisions are that the LOOP is covered by the design basis of the all units (first level of protection), with autonomy of the first level DGs of more than 72 hours.

For the feedwater supply, there are two motor-driven pumps and a turbo pump (which does not need electricity); for the other safety functions, emergency power supply is necessary. In case of an earthquake, the first level diesel generators (DBE resistant) would not be degraded (except presently in Doel 1/2, but in the near future – mid 2012 the new replacement diesels will be DBE resistant as well).

3.2.1.2 Station blackout (SBO) scenarios

Station Black-Out event

The "Station Black-out" scenario considers the loss of off-site power and loss of the ordinary back-up AC power sources. The situation with the core in the reactor pressure vessel is part of the design of all units. In this situation, the diesel generators of the second level emergency systems will ensure that the safety functions are fulfilled. These emergency diesel generators and the systems they power are protected against external hazards, where the autonomy of the units in this case, considering that all units on a site are affected is: at least 72 hours for Tihange 1 and one week for Tihange 2&3, 5 days for Doel 1/2 and 10 days for Doel 3&4. At Tihange 1, there is also a turbo-alternator (GUS), which can supply AC if the SGs can be used to provide steam to power it.

The batteries of the first level safety systems may still be relied on. The batteries of the first level systems are able to ensure power for the instrumentation and control for some time which period vary between 4 to 16 hours at Doel 1/2, between 3 to 27 hours at Doel 3&4, and between 4 to 17 hours in the Tihange units, and it can be extended by loads shedding.

Other additional means to ensure the reactor cooling function can be also used, as the auxiliary feedwater (AF) turbo pumps for feeding the SGs.

Total Station Black-out event

This scenario considers the loss of all alternating current (AC) sources of electric power, external or internal, first-level and second-level. This scenario was not studied in the design basis of the Belgian units .

In this situation, only those systems that do not need AC power supply remain operable. These include batteries, turbo pumps and water reserves that can be moved by gravity or by non-conventional means. The batteries of both the first and second level safety systems can be relied on and Tihange units, the first-level batteries have the minimum capacity of 3 h (in practice 4 - 17 hrs) and the second-level batteries have an estimated capacity of 7 hrs. At Doel units 1&2, both the first and second-level batteries have the capacity of 4 - 16 hrs, and at Doel units 3&4, 3 - 27 hrs. This scenario is managed to a large extent by the use of "Non-Conventional Means" (NCM) equipment. Three situations have been analyzed: SGs available, primary circuit open, and core in the SFP.

3.2.1.3 Loss of Ultimate heat sinks (UHS)

Heat sinks description

<u>Site of Tihange:</u>

The primary UHS is Meuse River. Units 2&3 have also emergency water intakes in the Meuse River (in case of slow drop of the Meuse level and during the very dry periods). All systems are DBE resistant. Autonomy of the primary UHS is unlimited.

The alternate UHS (the alternate UHS is used when the primary UHS is lost) are groundwater wells (second level of protection) (DBE) and new groundwater wells found in the site independent of the existing groundwater wells. The autonomy of the existing groundwater wells is 30 days when one unit of the site is affected by the loss of the primary UHS.

Site of Doel:

The primary UHS is Scheldt River. No emergency water intakes are provided for this site. The autonomy of the primary UHS at Doel is unlimited.

In this case, the alternate UHSs (two alternate heat sinks) are the cooling towers, and as second level of protection, also the emergency cooling ponds (LU-ponds) for units Doel 3 and 4. For twin units Doel 1/2: the GNS building (constructed after the first PSR) with air coolers (SFP cooling and emergency cooling (EC) residual heat removal). The autonomy of the alternate UHS is 12 hours for the cooling towers and at least 26 days for the LU-ponds when one unit of the site is affected by the loss of the primary UHS.

Loss of primary UHS event

This event has been analyzed considering either only one unit in the site affected (case by case) or considering all units affected. Different initial states of the units have been also considered at the initiation of the event: SGs are available, primary system open, core in the pool.

Tihange NPP:

The worst case, loss of heat sink in the three units, is considered to be the limiting case and autonomy is then at least 30 days for Tihange 1 (by the groundwater) and unlimited for Tihange 2 and 3 (if the deep river water intakes are available). If the deep river water intakes are all lost, the three units would be resupplied from the groundwater table. Autonomy is then three weeks.

If Tihange 3 is one of the units affected by a total loss of river water, the pool in the DE building is no longer cooled by the conventional systems. To limit groundwater consumption, the cooling will then be achieved by water make-up provided by the various NCMs present on site. They can be deployed within few hours, and this is long before damage of the fuel assemblies start, which is more than by 20 days.

Doel NPP:

There are two separated water intakes for Doel 1/2 and for Doel 3&4 respectively. There is possibility to pump water from Doel 1/2 to Doel 3&4. This alignment requires local manual actions and takes few hours.

In the case of the loss of the primary ultimate heat sink at Doel 1/2, the cooling of the component cooling circuit is assured by the raw water system (RW) where refilling is assured automatically during approximately 12 hours by gravity from the TW- and RW- tanks. Manual actions are needed for the other refilling options (e.g. from the LU-ponds - 3 x 30000 m^3 at Doel 3&4).

In each unit the cooling water is pumped up from the corresponding LU-pond. The autonomy of these units is of a few weeks.

If the entire site is affected and the water reserves of Doel 1/2 become exhausted, then Doel 3&4 has to share the LU-ponds with Doel 1/2. The water reserve in the ponds is sufficient to provide Doel 1/2 with water as well.

Loss of the primary ultimate heat sink and alternate ultimate heat sink(s)

Tihange NPP:

The simultaneous loss of primary and alternate ultimate heat sink is not part of the design bases of Tihange units. However, the plant has emergency means and sufficient autonomy to manage this type of accident compatible with the time for deployment of non-conventional means from outside the site in addition of those available on site. In the analysis of this scenario it was assumed that each unit uses its own reserves of water and equipment. In case of an accident affecting less than three units, transfers of water are always possible, after connection of one unit to the other units in order to increase the autonomy of the affected unit(s).

Given the loss of all heat sinks, the cliff edge effect occurs upon the loss of water for the SG cooling (after approximately 1.5 days at Tihange 1, at least 3.5 days in Tihange 2, and 5 days in Tihange 3, with SGs available). The "feed and bleed" of the secondary side is used for the cooling of the primary system. It is also possible to add make-up water into the SGs by using non-conventional means. By the application of NCM, this cliff edge effect can be avoided.

In the spent fuel evaporation starts approximately 8 hours after the loss of the normal cooling systems. Non-conventional means may be deployed to ensure a water make-up in a few hours, that is, well before the assemblies begin to uncover which occurs at least 2 days in Tihange 2, 3 days in Tihange 3 and 4 days in Tihange 1, after loss of normal cooling (fuel transfer tube closed). If several units are affected at the same time, there will be no additional constraints since, in the short term, as each unit uses its own means and reserves.

Doel NPP:

At Doel 1/2 and Doel 3&4 two alternate ultimate heat sinks are available. The loss of both systems simultaneously is not a part of the design basis. However, cooling of the nuclear fuel and maintaining the sub-criticality can still be guaranteed.

The reactors are cooled by the first and second level systems via the SGs. In this scenario the (self-cooled) AFW-pumps (2 motor pumps & 1 turbo pump) are available to feed the steam generators (with SGs available). The water reserves at the Doel site give the autonomy of more than ten days per unit for Doel 1/2 and 2 weeks for Doel 3&4 .

3.2.1.4 Loss of primary UHS combined with SBO

Loss of the primary ultimate heat sink combined with a total Station Black-out

Tihange NPP:

Such a scenario is not part of the design bases of Tihange units. The units still have water from the groundwater or deep water intakes but can no longer use it due to lack of electric power.

Doel NPP:

In the event of a total station black-out, the CW-pumps of Doel 1/2 and the make-up pumps of the RN-cooling towers of Doel 3&4 will not be powered. For that reason a total SBO automatically implies the loss of the primary ultimate heat sink.

The conclusions of the scenario ”LOOP and loss of all onsite back-up power (total SBO)” therefore remain valid also in this scenario both for Tihange and Doel NPPs (Section 3.2.1.2).

Loss of the primary UHS combined with the LOOP and Design Basis Earthquake

This scenario is not specified in the ENSREG specification, but it is a potential consequence of a DBE. It is a part of the plants' design basis and all units can manage it with autonomy times of at least 3.5 days. The scenario is based on consideration, that after DBE the external electricity grid and the primary UHS are lost.

3.2.2 Main results on safety margins and cliff edge effects

The most critical scenarios analyzed are the cases of "Total SBO", "Loss of primary UHS and total SBO" and "Loss of primary and alternate UHSs" when the primary circuit is open, during the reduced inventory phase, as in these cases the water in the reactor will start to boil within an interval of 0.5 (mid-loop operation) to 1 hour.

The following conclusions related to safety margins and cliff edge effects resulted from the analyzed scenarios:

Loss of electrical power supply

Loss of Off-site Power:

- For any of the Belgian NPP units, the LOOP doesn't lead to the nuclear fuel failure, in reactors or in the SFPs, as sufficient alternative power sources are available on the site.

Station Black-out:

- The assessment of the SBO scenario revealed that all units can cope with the event. No cliff edge effects were identified for this scenario. Some modifications regarding the situation with the core in the SFP are foreseen for Tihange 1: SUR procedures to provide make-up and steam evacuation.

The total SBO:

- If the steam-generators are available: The cliff edge occurs when the AFW tank is exhausted, which takes place between 3 and 23 hours depending on the plant unit. The time can be extended, if non-conventional means such as fire water diesel pumps can be used to supply water to the feedwater tanks. If the primary pump seal injection pumps can not be powered from any AC source, an insufficient cooling of the seals of the primary circuit pumps could lead, in the short term, to limited primary leakages.
- If the primary circuit is open, the water in the primary circuit will start to boil within 30 – 60 min, in the worst-case scenario being the mid-loop or reduced inventory phase. Manual local actions are needed to ensure water make-up in the primary system (what would take some 45 minutes) and to prevent containment pressurization, which would block the gravity feed possibilities from the spent fuel pool loop system (CTP) / refuelling water storage tank (RWST) and might lead to reaching the containment failure pressure (in Doel in approx. 3 days) – if no actions are taken. At Tihange 3, gravity feed is not possible and fuel failure would occur after 3 hours - if no actions to replenish the primary circuit are taken (deployment of the NCM for this purpose is envisaged there). At other units, the gravity feed can delay the onset of fuel failures from 8 hours (Tihange 2) to several days (Doel units). Additional strategies for managing this situation are under consideration.
- The situation with the core in the SFP allows for a grace period of several days to organize water-make up, and no cliff edges are foreseen.

<u>Loss of UHS:</u>

Loss of primary UHS:

- There are no cliff edge effects in case of the loss of primary UHS in Tihange 1, 2, and 3. This event is managed by use of the groundwater system after manual realignment in Tihange 1 and automatic realignment in Tihange 2, 3 or by use of the deep water intakes in Tihange 2, 3. The autonomy is 30 days when one unit of the site is affected by the loss of the primary UHS. When all units of the site are affected the autonomy depends on the availability of the emergency water intakes. If those are available, Tihange 1 has an autonomy of 30 days and Tihange 2 and 3 have an unlimited autonomy. If those are not available, the autonomy is 3 weeks for all units.
- Conclusion for Doel 1/2 for every considered scenario: there are no cliff edge effects for this scenario. There is sufficient water supply available at Doel 1/2 for refilling the RW-cooling towers. Furthermore refilling from the LU-ponds (3x30000 m^3) is available at Doel3&4. Cooling of the SFP is assured by the second level systems, if the operational cooling system becomes unavailable in addition to the primary ultimate heat sink.
- Conclusion for Doel 3&4 for every considered scenario: There are no cliff edge effects for this scenario. The LU-ponds contain sufficient amount of water to ensure the autonomy of at least 26 days.

Loss of primary UHS and alternate UHSs

- At Tihange units:
  - If the steam generators are available, the cliff edge effect occurs upon loss of water for the steam generator cooling (after approximately 1.5 days at Tihange 1, at least 3.5 days in Tihange 2, and 5 days in Tihange 3).
  - In case the primary system is open, the cliff edge effect occurs when all the borated water tanks (which supply make-up water to the primary system) are empty. In this case the refueling water storage tank (B01Bi) at Tihange 1 and the CTP tanks at Tihange 2&3 give autonomy well beyond 72 hours. If no make-up water is added, the reactor water starts to boil. The reactor building is in this case sealed and the pressure inside the reactor building will start to increase and can reach the failure containment pressure after 3 to 4 days, if nothing is done for the pressure control.
  - In the spent fuel pool, evaporation starts approximately 8 hours after the loss of the normal cooling systems, if no make-up water is added.
- At Doel units:
  - If the steam generators are available, there are no cliff edge effects.

- In case the primary system is open and all the UHSs are lost (including both alternate UHSs) and no make-up water is added, the reactor water starts to boil within an hour. The reactor building is in this case sealed and the pressure inside the reactor building will start to increase and can reach the failure containment pressure after 3 days, if nothing is done for the pressure control.
- For the spent fuel pool, if all heat sinks are lost (including both alternate UHSs) and no make-up water is added, the spent fuel pool will start to boil after approximately 8 to 10 hours (Doel 3&4) or 15 hours (Doel 1/2).

Loss of primary UHS with total SBO:

– The conclusions of the scenario "LOOP and loss of all onsite back-up power (total SBO)" remain valid in this scenario, both for Tihange and Doel NPPs (Section 3.2.1.2).

Loss of the primary UHS combined with the LOOP and Design Basis Earthquake:

– There are no cliff edge effects identified for this scenario.

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

The following strong safety features were identified:

– Multiple external power supply links (two independent power supplies)
– Underground cable 6,6 kV lines (after transformers) linking 150 kV on-site sub-stations with the units at both sites
– Two-level redundant safety systems, including in particular: 1st and 2nd level emergency diesel generators and power supply systems, seismically qualified for all units at both sites (with the exception of the 1st level DGs in Doel 1/2, which will be completed by mid 2012)
– Auxiliary feedwater turbo-pumps (in each unit)
– Emergency steam-driven turbo-alternator (Tihange 1)
– Primary and alternate UHS available at both sites
– Diverse other water sources (including unconventional) and inter-connection possibilities available at the plant sites
– Many NCMs (mobile/portable equipment) available, including mobile diesel-driven pumps and mobile diesel generators and already implemented connections (for electrical power and water supply)
– Long autonomy of AC power sources and batteries.

Some areas for safety improvement:

– Enhancement of the external power supply reliability in the Tihange NPP through a better separation of the high-voltage (380 and 150 kV) lines
– Anti-flood protection of the Tihange NPP, in particular its emergency power supply systems, in order to cope with the new requirements for flooding.
– Reviewed and validated procedures, in accordance with the results of the assessment performed for the scenarios considered

3.2.4 Possible measures to increase robustness

Some possible measures to increase the plants' robustness identified in the BE-NR and during the country visit are:

– Reinforcement of the second level of protection for Tihange 1 (electrical supply of Spent Fuel Pool cooling pumps and Shutdown Cooling pumps from the second level of protection).
– Increasing the capacity of AFW-tank and adding a AFW motor-driven pump in Tihange 1
– Solving the problem of refilling the primary circuit during mid-loop operation in case of the total SBO when the primary circuit is open in Tihange 3.
– Installation of the necessary nozzles on the intake and discharge of the spraying pumps in order to achieve an alternative spraying flow with a mobile spraying pump at Doel 3& 4 units.
– Increase of autonomy of the 2-nd level DG in Tihange 1 in case of DBE (currently the capacity of seismic resistant tanks is for 7.5 hours only).
– Seismic qualification of the refuelling water storage tanks (RWSTs) of Doel 1/2 units.

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

An action plan has been sent on 15th of March 2012 by the licensee to the FANC for verification, completion and approval. This plan contains both licensee proposals and also measures identified by the FANC and it comprises around 350 actions. These measures are structured into levels (family, sub-section of family, sub-sub sections of family) and deliverables (studies, procedures, organization, realization and training). The proposed action plan is in the process of verification by the FANC and needs to be approved to start the implementation. The schedule of these actions is between 2012 and 2014.

The actions proposed by the licensee, to increase the robustness of the plants include:

1. Enhanced protection against external hazards (earthquake, flooding, weather conditions):

- Assessment of strengthening the electrical building (“BAE”) of Tihange 1 unit
- Strengthening non conventional devices/resources at Tihange and Doel
- Enhancement anti-flood protection measures at Tihange assuming the decamillennial flooding (to prevent the loss of safety functions).

2. Enhanced power supply:

- Alternative power supply (380 V) for NCM or safety equipment
- Alternative power supply (380 V) for rectifiers; this measure ensures the possibility to recharge the batteries before their total depletion during an SBO event;
- Introduction of a procedure for minimizing the diesel generators fuel consumption
- Purchase of a fuel tanker truck for the on-site transportation of diesel fuel and identification of the required nozzles (Doel) - already done

3. Non conventional means:

- In addition to the already implemented NCMs (or in progress), a feasibility study will provide a technical solution for water make-up to the primary system of Tihange 3 unit in “primary system open” configuration (motor-driven pump powered by a non conventional diesel generator).
- At the Doel NPP, the construction of a new seismically qualified building which is also protected against flooding, is planned; this building will be used as a location for storage of NCM (including fire trucks) that are expected to ensure the safety function fulfilment in case of extreme external hazards.

Other actions are already decided, in progress or done, as:

- At Tihange, the construction of a new demineralised water production circuit;
- New procedures or new revisions of the existing operating procedures are to be issued in order to take into account events as: loss of the primary UHS affecting more than one unit, total SBO, loads shedding to increase the batteries autonomy, etc.;
- Seismic upgrade of the AFW-turbo pumps and their tanks (small storage tank – 100 m^3) is foreseen at Doel 1/2;
- Implementation of the continuous measurement of the level in the Spent Fuel Pool in the Tihange NPP units where this is not already in place.

3.3 Peer review conclusions and recommendations specific to this area

During the peer review process, the reviewers found that there is adequate redundancy and diversity in the electric power supply and cooling capabilities of the Belgian NPPs to ensure safety functions.

During the country visit of the peer review team it was also observed that non-conventional means (including mobile equipment and connections already implemented) are present on the sites and can be used to perform the safety functions following the events due to external hazards, to avoid a severe accident and to keep the plant in a safe state, for both Doel and Tihange sites.

In addition to the existing features, there is also an action plan containing specific measures, proposed by the licensee or identified by the regulatory body to increase the plants’ robustness to cope with the loss of electrical power supply and loss of UHS (or combinations of these events). Some of the NCM, indicated in the action plan, have been already procured and/or their implementation is in progress.

The most limiting cases that resulted from the assessments performed for the scenarios recommended by ENSREG specifications, from the point of view of safety functions fulfilment, for the Belgian NPP units are the “Total SBO”, “Loss of primary UHS and total SBO” and “Loss of primary and alternate UHSs” when the primary circuit is open during the reduced inventory phase. In these situations, cliff edge effects were identified and the management of these situations is possible with the alignment of the plant systems to be performed by local operator actions and also with the use of NCM equipment. Even if the situations when the primary system is open and operating with reduced inventory are limited in time (short period of time during the outage of an unit), still the events of the Total SBO and the Loss of primary and alternate UHS are complex and difficult to manage, due to short time available (in particular during mid-loop operation) to take countermeasures before the water in reactor will start to boil and the containment become pressurized (what may result in blocking the gravity feed of the primary circuit). The reviewers found that a specific operating procedure to manage these situations existed at Doel NPP and this is scheduled to be validated during the next outage with respect to the feasibility of executing operator actions in due time. FANC will ensure that the situations described above are properly managed in Tihange NPP as well.

The reviewers have found that the autonomy of the Belgian NPPs complies with the ENSREG specifications (at least 72 hours without external support). However, in case of DBE, the autonomy of the emergency diesel generators of the 2nd level safety systems at the Tihange 1 is only 7.5 hours (the capacity of the their seismically qualified fuel tanks) and the CVA B01Hc fuel tank (500 m^3), that is designed to make-up with fuel in the EDGs fuel tanks, is not DBE qualified.

The peer review team recommends Belgian regulatory body to take into consideration the benefits of the increasing of the autonomy of the mentioned EDGs at Tihange 1 for events determined by DBE, possibly by enhancing the robustness of the CVA B01Hc fuel tank to DBE.

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, ,…)

Recently a Royal Decree concerning safety prescriptions for nuclear installations has been published end of December 2011. This Royal Decree does not target Emergency Operating Procedures (EOP) or Severe Accident Management Guidelines (SAMG) specifically, but includes the requirements for dealing with (severe) accidents. Article 27 of the decree makes a distinction between procedures for accidents and guidelines for severe accidents and requires them to be up-to-date and verified and validated.

4.1.2 Main requirements applied to this specific area

The verification and validation of existing SAMGs or BKs (as they are called at Doel) have been performed in the framework of the Periodic Safety Reviews. The results of the validation by table-top exercises have been documented and were shown to the peer reviewers during the country visit.

The Belgian requirements (i.e. article 27 of the decree) aim at maintaining containment integrity and limiting radioactive releases during severe accidents as much as possible and stipulate that a control room should be present in order to run the plant safely in all working modes, to keep the plant safe or to return it to a safe condition in case of a postulated accident. Furthermore it prescribes that the licensee should have one or more coordination centres other than the control room for the management of a crisis on site. In these coordination centres access should be available to important data concerning the nuclear installation and concerning the radiological situation on-site and in the surroundings.

4.1.3 Technical background for requirement, safety assessment and regulatory oversight

The technical background for requirement, safety assessment and regulatory oversight is the use of probabilistic safety assessments (PSA) as part of the safety assessment. PSAs have been initiated to evaluate the risk of fire and flooding on all Belgian units. So far, the PSA for the Belgian units have not considered any accident of external origin or initiating event related to the spent fuel pools.

The probabilistic safety assessments were started on the initiative of the licensee prior to their integration in the ten-yearly reviews.

The PSA studies contain level 1 PSA and level 2 PSA. The assessments cover the following nuclear power plant conditions: power operation, shutdown (shutdown cooling system available), operation with low water inventory (mid-loop operation).

In the past, these three plant operating states have been considered in level 1 PSA, whereas only power operation was considered in level 2 PSA. In the recently completed and planned updates of the PSA, all plant operating states (including more detailed low-power and shutdown states) are considered in both level 1 PSA and level 2 PSA.

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

All Belgian NPPs feature 10-yearly PSR. Doel 1 and 2 have performed their 3rd PSR, the other NPPs their 2nd PSR. The objectives and scope of the PSRs regarding severe accidents have been presented to the peer reviewers during the country visit. The PSRs have led to improvements in relation to the management of severe accidents. Examples are:

- Installation of Passive Autocatalytic Recombiners in each unit;
- Modification to allow cavity flooding for Doel NPPs;
- Development of SAM strategy documents and implementation of plant-specific SAMG for each unit;
- Partial Level 2 PSA for Doel 3 and Tihange 2 to assess containment failure modes;
- Level 2 PSA for Doel 1/2 and Tihange 1 to assess containment failure modes;
- The validation of SAMGs for Tihange and Doel NPPs;

The extension of Level 2 PSA to all units, covering evaluation of fission product releases, shutdown states and implemented SAMGs, is currently in progress.

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

National requirements on severe accidents are only recently published. The compliance with new requirements considering severe accidents (including WENRA Reference Levels) has been presented to the peer reviewers during the country visit. The WENRA RLs for severe accidents (i.e. issue F and LM) are covered by the articles 21 and 27 of the Royal Decree (dated November 30, 2011) on Safety Requirements for nuclear installations. In order to achieve compliance with the WENRA RLs a Belgian Action Plan was established in November 2006. The execution of this plan started in 2007. The current status of the implementation of the action plan with regard to severe accidents is that for issue F regarding Design Basis Envelope for Existing Reactors two RLs (i.e. 4.5 and 4.7) are still open. As for issue LM regarding EOPs and SAMGs, one RL (i.e. 4.1) is still open.

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

At Tihange, the management of an emergency is ensured from three separate places:

- from the unit control room where shift crew operators are working in normal and accidental conditions;
- from the "unit operation centre" (COT) at Tihange (located next to the control room and designed with the same resistance features as the control room), where the first part of the emergency management team meets and from which the technical management of the event takes place;
- from the "site operation centre" (COS) at Tihange (physically distant from the control room) where the second part of the emergency management team gathers and from which communication and external relations with the outside world are managed.

In addition, an off-site reception and fall-back centre called (CARA) is located in Les Awirs, at 12 km from the Tihange NPP.

Current COS has no specific seismic design basis (administrative building). New COS is under construction with the same seismic level as the units. The main control room (MCR) and COT have the same seismic design basis as the reactor unit (0.17 g).

At Doel, the management of an emergency is performed from four separate places:

- in the unit control room, shift crew operators are working in normal and accidental conditions;
- the unit annex control room ("BK"), located in the same place as the control room, is the nerve centre of the severe accident management ("SAM"); from this centre, actions affecting the installations are performed;
- in the on-site technical support centre ("OTSC"), interventions and operations in the installations and long-term actions are prepared. The Doel 1/2 OTSC is part of the Doel 1/2 machine room; in this place, the most important operational parameters are monitored. The Doel 3 and Doel 4 OTSC is part of the Electrical Services Building ("GEH") of Doel 4; in this place, the most important core status parameters are monitored. The Doel 3 and Doel 4 OTSC can function as a back-up for the Doel 1/2 OTSC;
- in the site emergency operations facility ("NPK"), the data are consolidated, the communication with the authorities is coordinated, and the possible dissemination of radioactivity in the environment is calculated.

For Doel 1 and 2 the OTSC has no specific seismic design basis. For Doel 3&4 the OTSC is part of the building with the electrical auxiliaries of reactor unit Doel 4 and thus has the same seismic design basis as the reactor unit (0.1 g).

Operating procedures, drills and training courses, including frequencies, differ between the plants. Increased coherence has been requested by the regulator.

Technical resources available on the sites include:

- fire brigade garages equipped with equipment and consumables for the suppression of a wide range of events (fire, explosion, flooding, release of products with dangerous characteristics);
- logistic equipment: sandbags, compressors
- fully equipped monitoring vehicles to perform radiological measurements on site and off site;
- stocks of packages of personal protection equipment;
- medical posts with equipped nursing and doctors' practice and triage zones;
- helicopter landing places;
- guards for the protection against unauthorized access to the site.

The functionality, accessibility and habitability during extreme external events of the emergency response centres and the storage buildings have been examined by the peer reviewers during the plant visit at Doel.

The buildings that host the emergency response centres have a defined resistance to extreme external events. If under certain circumstances locations become inaccessible, back-up locations are available. For Tihange a new site operation centre (COS) is under construction and should be operational by the end of 2013.

The restoration of power to the ventilation circuits is being evaluated, autonomous breathing apparatus as well as iodine pills are present in all emergency response centres. The licensee will replace personnel in order to respect the maximum dose of 250 mSv.

The storage room for non-conventional means planned by the end of 2013 will be made to resist extreme external events.

Use of off-site technical support for accident management is ensured by Electrabel corporate emergency organisation, support by contractors, hospitals, public authorities, etc.

Non conventional means (mobile diesel generators, pumps, hoses, etc.) are available at different locations. Many connection points to establish supporting connections (e.g. gas/power/water) have already been tested, others will be tested in the near future by the licensee. The equipment foreseen for implementation is different in Tihange and Doel. A closer coordination is suggested.

The use of the non conventional means is to be integrated in accident management procedures & SAMG and to be benchmarked with US NRC Extensive Damage Mitigation Guidelines. This benchmark can be seen as a strong point.

By mid 2012 licensee will have a plan for strengthening the site organisation for (multi-unit) accident management. This plan will have to be implemented in 2013.

4.2.1.2 Procedures and guidelines for accident management

The Westinghouse Owners Group EOP/SAMG approach is adapted to Tihange and Doel NPPs. EOPs are used by the shift personnel and shift technical advisor (STA) in the main control room or in the emergency control room. SAMG and BK procedures are used by COT/BK personnel (on-call personnel not needed in the main control room). During the plant visit at Doel, the BK procedure for estimating the radiation levels in the reactor building and adjacent buildings was presented to the peer reviewers.

SAMGs are validated and verified during periodical exercises. The transition from EOPs to SAMGs is performed by the control room staff when core damage occurs in accordance with the generic Westinghouse Owners Group (WOG) SAMG. The main transition criterion is the core exit thermocouple temperature greater than 650°C (700°C for Tihange 1 for consistency with specific EOPs) coupled with the inefficiency of the application of recovery actions instructed in the EOPs. The transition is made via an instruction reported in 3 emergency response guidelines (ERGs) (FR-C.1 "Response to Inadequate Core Cooling", FR-S.1 "Response to Nuclear Power Generation - anticipated transient without scram (ATWS)" and ECA-0.0 "Loss of All AC Power") or in SPI-N2 (procedure specific to Tihange 1). Plant-specific severe accident calculations have been performed in the framework of SAMG validation and the adequacy of this transition criterion has been confirmed by these calculations.

In case core exit thermocouples are unavailable, an alternative criterion is proposed based on containment activity as a feedback from validation reports for SAMG.

Severe accident (SA) procedures exist for all reactor units and for all relevant situations. The only exception to this is the scenario of a multi-unit SA, for which the SAMG and/or the emergency plan have to be adapted. This will be done in the framework of the action defined by the licensee.

There are different procedures for the Tihange and Doel sites to prevent basemat melt through. The regulatory body has formulated in the National Report an additional measure (no. 3) to follow-up on the ongoing steam explosion experiments and, if needed, current strategies for flooding of the reactor pit before rupture of the reactor vessel should be adapted. The licensee is presently following the ongoing steam explosion experiments via the OECD dedicated project called SERENA phase 2 (SERENA standing for Steam Explosion Resolution for Nuclear Applications).

SERENA phase 1 project concludes that in-vessel FCI (Fuel Coolant Interaction) would not challenge the integrity of the containment whereas this cannot be excluded for ex-vessel FCI. Uncertainties concerning the role of void, the corium melt properties and the propagation of the explosion are the key issues to be resolved in the phase 2 of the SERENA project. A limited number of well designed tests with advanced instrumentation have been performed between 2008 and 2012 (the last one in March 2012) to bring the code capabilities to a sufficient level for use in reactor case analyses. The licensee participates to this project to grant more knowledge in the steam explosion phenomenon.

In complement with the experimental phase, an Analytical Working Group (AWG) has been established with the main aim of increasing the capabilities of the FCI models/codes for use in reactor analyses. The licensee and the CEA (Commissariat à l'Energie Atomique – France) agreed to be part together of this AWG by performing calculations with the MC3D code.

As part of the agreement with the CEA regarding analytical activities, the CEA has performed in 2011 reactor case calculations for Doel 1/2 and Doel 3 units. Thanks to the global understanding of the MC3D code acquired by the licensee during the analytical activities performed in collaboration with CEA for the SERENA AWG, the licensee was able during the level 2 PSA studies of Doel 1/2 and Doel 3 units to interpret and use the results of the reactor case calculations in the framework of the quantification of some specific phenomena linked to FCI.

4.2.1.3 Hardware provisions for severe accident management

All plants, both in Doel and in Tihange, have two types of safety systems: the first level safety systems designed for incidents and accidents of internal origin and earthquakes, and the second level emergency systems dedicated to external hazards. The first level systems are operated from the main control room and the second level systems are operated from a separate control room in a protected (bunkered) building.

The first level and the second level are entirely independent from one another. This applies to the electrical diesel power supplies, control rooms, water supplies, instrumentation, compressed air, primary pumps' seals injection, steam generators feedwater, shutdown cooling systems.

To summarize, some hardware modifications have been implemented to mitigate severe accidents, for example the installation of passive autocatalytic recombiners (PARs). One important measure under investigation is the filtered containment venting system.

In the event of a severe accident, the following means are essential:

- water for injection into the steam generators;
- borated water for injection into the primary circuit of the reactor building;
- electricity to supply the vital pumps.

All the existing equipment on site can be used in order to restore potential failures, through particular equipment connections where required. The SAMG guides describe how to use the existing equipment.

In case of unavailability or failure of this equipment, non-conventional means can be implemented. These devices were not considered when designing the units but are available on site.

4.2.1.4 Accident management for events in the spent fuel pools

The spent nuclear fuel of Doel 1/2 is stored in shared pools housed in the nuclear auxiliary services building (GNH). The spent nuclear fuel of Doel 3&4 is stored in pools on each unit. The pools, as well as the cooling systems, are housed in the bunkered spent fuel building (SPG). After a sufficient cooling period in the pools, the spent fuel from Doel 1/2, Doel 3&4 is transferred to the spent fuel container building (SCG).

Each of the three reactors at Tihange has a cooling pool designed for the temporary storage of spent fuel assemblies.

The spent fuel pool does not have containment/confinement capabilities in case of loss of pool cooling. On the other hand, the building is protected against plant-specific loads from external accidents.

For the units of Doel and Tihange, a rupture in the SFP leading to a large leak is not part of the design basis, consequently no system has been installed to compensate for a significant water leak. However, the layout and design of the fuel pool loop is such that in a case of a piping rupture sufficient water level above the fuel top remains.

The main aim of the accident management measures is to avoid uncovering the fuel stored in the storage pools, either by re-establishing active cooling of the pools or by ensuring a water supply by any available means (conventional or not). Even without a supply of water, the time before the fuel is uncovered can be calculated in days for spent fuel pools at the Doel and Tihange units and in weeks for the temporary storage facility at Tihange. That leaves sufficient time to install or bring an alternative water supply, if all traditional methods are unavailable.

All spent fuel pools are designed to remain subcritical even when using unborated make-up water. This is still valid for accident conditions, provided that the regular geometry of the spent fuel is maintained. In case regular geometry is not maintained, sub-criticality in the SFP has been evaluated by qualitative assessments.

The licensee states that in the future post-Fukushima WOG SAMG revision should provide guidance including technical background for core damage in the spent fuel pool. Several measures are proposed by licensee to increase the robustness of the water supply, but again the measures are different for each unit.

The impact of potential hydrogen production in the spent fuel pool buildings after an accident causing a total loss of pool cooling is limited. The recovery of the ventilation systems and the available means of supplying the pools with water allow to avoid the risk of hydrogen accumulation. However, an additional study will be initiated in order to assess the residual risk of hydrogen accumulation.

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

Extensive destruction of infrastructure or flooding around the installation that hinders access to the site, including communication systems was studied. As well the impairment of work performance due to high local dose rates, radioactive contamination and destruction of some facilities on site is described.

Given the very large variety in possible severe accident scenarios, the licensee is of the opinion that it is not possible to evaluate whether local (manual) actions will be possible in possibly challenging radiological conditions, as those conditions will strongly depend on the precise severe accident scenario. One of the goals of the SILICA project (related to the improvement of SAM during the last PSR) was to elaborate an approach for a better identification and control of the radioactive containment releases. Some practical improvements have been proposed. They consist, among others, in the addition of complementary information to help the identification of FP releases (i.e., list of existing detectors and location of these detectors).

The licensee stated its intent to follow the WOG recommendations once the WOG will have issued a post-Fukushima SAMG revision.

4.2.2 Margins, cliff edge effects and areas for improvements

4.2.2.1 Strong points, good practices

- The integration of the non conventional means into the accident management procedures and SAMG and benchmark with US NRC Extensive Damage Mitigation Guidelines;
- The time schedule for the upgrade measures, where all measures are to be implemented by (the end of) 2013.

4.2.2.2 Weak points, deficiencies (areas for improvements)

- Robustness to cope with multi-unit events (as identified as an area for improvement by licensee and endorsed by the regulator);
- Filtered containment venting is considered state of the art for some years. For Doel 1 and 2 and Tihange 1 this is included in the ongoing Long Term Operation project.

4.2.3 Possible measures to increase robustness

4.2.3.1 Upgrading of the plants since the original design

With respect to the initiating events considered at the design phase, there are differences between the Doel 1/2 units, and the Doel 3&4 units. A number of systems are shared by the Doel 1/2 twin reactors, while there is a strict physical separation between the redundant safety systems at all other units. During the initial design of Doel 3&4, and Tihange 2&3, the following internal and external hazards were considered: aircraft crash, large-scale fire, explosion (including gas explosion), malicious act and conditions leading to inaccessibility or unavailability of the main control room.

The accidents or events mentioned above as well as some other beyond design basis accidents were taken into consideration within the framework of the ten-yearly periodic safety reviews, and they led for Doel 1/2 to the implementation of specific safety systems, such as the emergency systems building (GNS) which is seismically qualified.

The second level emergency systems had not been considered in the initial design of Tihange 1. However, as a result of the first periodic safety review (in 1986), an emergency system (SUR) was installed to respond to several beyond design basis accidents (e.g., SBO and unavailability of the main control room).

4.2.3.2 Ongoing upgrading programmes in the area of accident management

The objectives of the current PSR (ongoing for Doel 3 and Tihange 2 and started for the other units) are multiple. First objective is that the licensee should assess the status of the installation and the organization with respect to international legislation, standards and good practices. On request of the regulator the licensee has based this Periodic Safety Review on the International Atomic Energy Agency (IAEA) Safety Guide NS-G-2.10 ("Periodic Safety Review of Nuclear Power Plants") as a reference guide. Both the scope and the methodology are based on the approach adopted by the IAEA by the use of 14 Safety Factors, followed by a Global Assessment. In this PSR severe accidents are dealt with in two Safety Factors:

- Safety Factor 5 "Deterministic Safety Analysis": the objective of the review of the deterministic safety analysis (SF5) is to determine to what extent the existing deterministic safety analysis (mainly for DBA) remains valid when the following aspects have been taken into account: actual plant design; the actual condition of SSCs and their predicted state at the end of the period covered by the PSR; current deterministic methods; and current safety standards and knowledge. The review of the analysis of beyond design basis accidents (BDBA) and severe accidents (SA) has also been included in this Safety Factor;
- Safety Factor 6 "PSA": it consists in a peer review of Level 1 and Level 2 PSA methodology (already performed) with elaboration of an improvement plan (under development). The results of the PSA methodology review are documented and were shown to the peer reviewers during the country visit.

The Long Term Operation (LTO) project for Doel 1/2 and Tihange 1 units also includes a design upgrade related to severe accident management (filtered containment venting). The pre-feasibility studies, for the implementation of Containment Filtered Venting System for these units, are on-going. This topic will also be studied for all other units in the framework of the stress test project. During the country visit the peer reviewers recommended to consider the case of sub-atmospheric pressures in the containment after venting.

The third upgrading programme is the ongoing revision of the SAMGs as feedback from validation done in the previous PSR.

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

4.2.4.1 Upgrading programmes initiated/accelerated after Fukushima

Licensee has proposed the following list of measures:

- Enhance the organisation and logistics of the internal emergency plan to include "multi-unit" events
- Transfer of the site operation centre COS in the new entrance building
- Preliminary study for installing a filtered vent system on each unit (already included in the LTO project for Tihange 1 and Doel 1/2 units)
- Evaluation of the need to extend the non conventional means based on the analysis of the extensive damage mitigation guidelines (EDMG)
- Assessment of the residual risk of hydrogen production and accumulation in spent fuel pool buildings
- Feasibility study for the implementation of additional water injection into the reactor pit

- Follow-up of R&D activities related to the corium-concrete interaction issue
- Study for improving water level monitoring in the pool of every unit

The regulator has endorsed these proposals and has made the following additional demands and recommendations:

- Improvement of SAMG with (among others) decision support tools, long term monitoring and exit guidelines
- Increase consistency between Tihange and Doel NPP on SAMG training for operators
- Possibly adapt (based on R&D) strategies for flooding reactor pit before reactor vessel rupture
- Additional instrumentation (e.g. pH sump, bottom reactor vessel)
- Need to identify effective means to control pH inside containment
- Optimal battery load shedding strategy and a calculation and decision tool to determine the loads that can be shed, the extra battery autonomy gained by shedding a specific load, etc.
- Review Technical Specifications to improve availability of 2nd level emergency systems
- Apply specific provisions (maintenance, inspections, testing) to non conventional means credited in analyses

Licensee has submitted a consolidated stress tests action plan to the regulatory body. The action plan is now being reviewed by the regulator.

4.2.4.2 Further studies envisaged

See paragraph 4.2.4.1 above.

4.2.4.3 Decisions regarding future operation of plants

The Fukushima accident and subsequent analyses of the robustness of severe accident management provisions (e.g. the stress tests) have not led to any issues that require early (immediate) closure of the Belgian plants.

4.3 Peer review conclusions and recommendations specific to this area

The Belgian National Report gives a comprehensive overview of the installed concepts for severe accident management in the plants. The performed assessments under the limiting time conditions meet the requirements. Improvements to further increase the robustness of the concept for severe accident management at the plants have been found by the licensee and the regulatory body.

Although the ENSREG topical peer review has not produced any significant demand or request for improvements in addition to the ones already identified in the BE NR, the country visit resulted in the following recommendations:

- The preliminary study for the filtered venting system on each unit to be finished in 2012 should consider sub-atmospheric pressures in the containment;
- Regardless of the outcome of the assessment of the residual risk of hydrogen generation and accumulation in the spent fuel pool buildings, the installation of PARs should be considered;
- The additional measure by the regulatory body to increase the consistency between Tihange NPP and Doel NPP of the emergency training and refresher training programs should be broadened to the total concept for severe accident management (hardware provisions, procedures and guidelines) as much as possible.

List of Acronyms

AC	Alternating Current
AFW	Auxiliary Feedwater
ATWS	Anticipated Transient Without Scram
AWG	Analytical Working Group
BDBA	Beyond Design Basis Accidents
BENR	Belgian National Report
BUR	Emergency Building (Tihange 1)
CARA	Emergency And Reception centre at Awirs
CEA	Commissariat à l'Energie Atomique – France
CFR	Code of Federal Regulations
COT	Unit operation centre (Tihange)
COS	Site operation centre (Tihange)
CTP	Spent fuel pool loop system (Tihange 1)
CVA	Auxiliary steam system
DB	Design Basis
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DUR	Aircooled Emergency Diesel Generator (Tihange 1)
EC	Emergency Cooling
EDMG	Extensive Damage Mitigation Guidelines
ENSREG	European Nuclear Safety Regulators Group
EOP	Emergency Operating Procedures
EPRI	Electric Power Research Institute
EU	European Union
FANC	Federal Agency for Nuclear Control (in Belgium)
FCI	Fuel coolant interaction
FP	Fission Product
FSAR	Final Safety Analysis Report
FWLB	Feed Water Line Break
GDC	General Design Criteria
GNH	Nuclear auxiliary Services building
GNS	Emergency Systems building in Doel 1/2
GUS	Emergency turbo alternator (Tihange 1)
IAEA	International Atomic Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
I&C	Instrumentation and control
LOCA	Loss of Coolant Accident
LOOP	Loss of Offsite Power
LTO	Long Term Operation
LU	Emergency Cooling Ponds
LUHS	Loss of Ultimate Heat Sink
MCR	Main Control Room
NCM	Nonconventional Means
NPP	Nuclear Power Plant
NUREG	Nuclear Regulation Guides
OECD	Organisation for Economic Cooperation and Development
PAR	Passive Autocatalytic Recombiner
PGA	Peak ground Acceleration
PSA	Probabilistic Safety Assessment
PSHA	Probabilistic Seismic Hazard Analysis
PSR	Periodic Safety Review

R&D	Research and Development
RG	Regulatory Guide
RL	Reference Level
RLE	Review level Earthquake
RW	Raw water System
RWST	Refueling water Storage tank
SA	Severe Accident
SAMG	Severe Accident Management Guidelines
SAR	Safety analysis Report
SBO	Station Blackout
SC	Shutdown Cooling System
SCG	Spent Fuel Container Building
SERENA	Steam Explosion Resolution for Nuclear Applications
SF	Safety Factor
SFP	Spent Fuel Pool
SG	Steam Generator
SLB	Steam Line Break
SPG	Spent Fuel Building
SRP	Standard Review Plan
SSC	Structures, Systems and Components
STA	Shift Technical Advisor
SUR	Emergency System (Tihange 1)
TW	Surface Water in Urban Areas
UHS	Ultimate Heat Sink
US NRC	United States Nuclear Regulatory Commission
WENRA	Western European Nuclear Regulators' Association
WOG	Westinghouse Owners Group