Electrabel
GDF SUEZ

Belgian Stress tests (Project BEST)

-

Electrabel Progress Report applicable to Doel & Tihange nuclear power plants

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1 Introduction

1.1 Safety of the Belgian nuclear power plants

Electrabel operates seven nuclear units of the pressurized water reactor (PWR) type at the Doel (four units) and Tihange (three units) sites. The seven units have been operated by Electrabel since their commissioning, the first unit having been commissioned in 1975.

The initial design of these units has been based on the safety standards of the Nuclear Regulatory Commission of the Unites States (USNRC), which were at that time the most coherent and appropriate standards for that type of reactors. Within that framework, the concept of "defence-in-depth" was (and still is) one of the most important centerpieces of the safety philosophy.
Defence-in-depth is an approach to the design and operation of nuclear facilities that prevents and mitigates accidents that release radioactive materials. This concept centers on several levels of protection including successive barriers between radioactive materials and the environment. It also includes protection of the barriers by averting damages to the installation and to the barriers themselves. Finally, it includes further measures to protect the public and the environment from harm in case these barriers are not fully effective.

It should be borne in mind that Electrabel's main long term objectives for safe nuclear power plant operation are twofold :

1) prevent occurrence of accidents;
2) limit radiological releases[1], should the successive preventive measures be defeated and should the containment integrity be challenged.

As a result, since the beginning of the design and the operation of its nuclear power plants, Electrabel has strived for operational excellence, giving the overall priority to nuclear safety. To achieve this, nuclear safety requirements and policies have been developed and embedded in the overall management of the plants, covering all processes that are impacting nuclear safety like operation, maintenance, plant modification or design reevaluation.

Continuous improvement has been integrated in those processes, with experience feedback being one of its backbones. In addition to this process of continuous experience feedback, periodic safety reviews (PSRs) are conducted every ten years in accordance with the applicable IAEA[2] guidelines[3] and as required by the Belgian regulations. It is worthwhile to mention that Belgium has been amongst the pioneers to introduce the periodic safety review requirements for its plants.

1.2 The Fukushima accident and its impact on safety assessment in Europe

The Fukushima accident is not yet completely over, and all causes have not yet been analyzed in depth. Hence, all lessons learned have not yet been drawn.

However one can say right now that this accident, just as past major accidents like Three-Mile-Island or Chernobyl, will be integrated in the experience feedback, in order to ensure that all lessons learned are identified and actions are taken on this basis to improve the nuclear safety of all operating plants.

[1] With due regard to their potential impact in time and space
[2] IAEA : International Atomic Energy Agency
[3] IAEA Safety Standard Series NS-G-2.10 : "Periodic Safety Review of Nuclear Power Plants".

1.2.1 The position of the European Council

Considering the accident at the Fukushima nuclear power plant in Japan, the European Council of March 24th and 25th declared that

> *"the safety of all EU nuclear plants should be reviewed, on the basis of a comprehensive and transparent risk assessment ("stress tests"); the European Nuclear Safety Regulatory Group (ENSREG) and the Commission are invited to develop as soon as possible the scope and modalities of these tests in a coordinated framework in the light of lessons learned from the accident in Japan and with the full involvement of Member States, making full use of available expertise (notably from the Western European Nuclear Regulators Association, WENRA); the assessments will be conducted by independent national authorities and through peer review; their outcome and any necessary subsequent measures that will be taken should be shared with the Commission and within the ENSREG and should be made public; the European Council will assess initial findings by the end of 2011, on the basis of a report from the Commission."*

1.2.2 The "Stress tests" specifications of WENRA and ENSREG

During their plenary meeting on the 22nd and 23rd of March 2011, WENRA members decided to provide *"an independent regulatory technical definition of a "stress test" and how it should be applied to nuclear facilities across Europe"*. This led to a proposal of "stress tests" specifications by the WENRA Task Force. Several versions were drafted and the version dated April 21, 2011 was used by Electrabel as a starting point for its stress tests exercise.

In this document, "stress tests" are defined as *"a targeted reassessment of the safety margins of nuclear power plants in the light of the events which occurred at Fukushima : extreme natural events challenging the plant safety functions and leading to a severe accident."*

The WENRA texts were used as the basis for specifications, issued by ENSREG on May 13, 2011. These specifications were endorsed by the European Commissioner Oettinger on May 24, and will be used throughout Europe as a basis for performing the stress tests.

1.2.3 The "stress tests" specifications of the Belgian Federal Agency for Nuclear Control

On May 17, 2011, the Belgian Federal Agency for Nuclear Control (FANC) issued the ""Belgian Stress tests" specifications - Applicable to power reactors". This document was endorsed by the Belgian Parliament on July 4, 2011 and is considered by the FANC as a basis for a complementary safety review within the PSR framework [1].

The document of the FANC is based on the ENSREG specifications but it is worthwhile to note that, compared to ENSREG, the FANC requires to take into account additional initiating events : terrorists attacks (aircraft crash) and other man-made events (toxic and explosive gas clouds, external attacks on computer-based controls and systems).

1.2.4 The position of Electrabel

Electrabel, as licensee holder, is accountable for the safety of its installations. Hence, it has to ensure that the plants are reassessed in the light of what has occurred in Fukushima.

A first step will be achieved by fulfilling the requirements expressed by the Belgian FANC in its document referred in § 1.2.3.

1.3 Objective of the present document

The objective of the present Electrabel Stress tests Progress Report[5] is to describe

1) the methodology that Electrabel intends to follow in order to fulfill the requirements expressed by the FANC in its document referred in § 1.2.3 above,
2) the organization of the project that has been implemented by Electrabel in order to carry out the Belgian Stress tests,
3) the state of progress, at the date of the present report, of:
   - the activities undertaken by Electrabel in order to realize the required Final Report;
   - the various improvement actions that were launched, in parallel with the stress tests exercise,
     shortly after the Fukushima accident, and
4) a proposal for the table of content of the Final Report of each nuclear site.

As far as the methodology is concerned, the section 2 hereafter defines more precisely, when necessary, the options retained by Electrabel to respond to the FANC requirements.

2 Methodology

2.1 Preliminary remarks

2.1.1 Integration of the Lessons Learned from the Fukushima-Daiichi accident

The reassessment described below is being conducted although the Fukushima-Daiichi lessons learned have not yet all been drawn.

The reassessment will nevertheless integrate all available feedback. The feedback will be used, if applicable, as an input for the verifications that have to be carried out, for both the design assessments and the margin assessments, and as a guide for establishing the complementary measures that will ultimately increase the robustness of both plant and emergency response organization when facing extreme situations.

It should be noted that Electrabel has not awaited the detailed results of the Stress tests to study, plan and implement improvement actions in order to increase its capabilities to prevent and to cope with extreme "Fukushima-like" scenarios. This will be treated in more detail in § 2.1.4.

2.1.2 A "targeted assessment"

In compliance with the "Belgian Stress tests" specifications, a "*targeted reassessment of the safety margins of nuclear power plants in the light of the events which occurred at Fukushima*" will be carried out.

As mentioned in the "Belgian Stress tests" specifications, *"the reassessment will consist in an evaluation of a nuclear power plant when facing a set of extreme situations [...] and in a verification of the preventive and mitigative measures chosen following the defence-in-depth logic*".

It will also "*report on the response of the plant and on the effectiveness of the preventive measures, noting any potential weak point and cliff-edge effect, for each of the considered extreme situations*".

Given the stringent time-frame that is given to respond to the "Belgian Stress tests" specifications, the reassessment has a limited scope and does not call for additional licensing studies.

[5] In the following pages, the Electrabel Stress tests Progress Report and Electrabel Stress tests Final Report will be respectively called "Progress Report" and "Final Report" for short.

In accordance with these specifications, the scope of the reassessment embraces the "*initiating events conceivable at the plant site*", i.e. earthquake, flooding, other extreme natural events, terrorist attacks and other man made events. The assessment will be based on available data and studies, as well as on engineering judgment. In the case additional studies are needed, these studies will be identified in terms of scope and planning in the final report.

2.1.3 Valorization of planned safety upgrades

As mentioned in paragraph 1.1, there exist on-going processes to improve safety, e.g. continuous improvement and periodic safety reviews. Maintaining the safety of nuclear installations is given the highest priority at Electrabel, and the improvement process leads to several improvement studies or projects (ageing management, periodic safety reviews, long term operation,...). The targeted reassessment will refer to the plants as they are currently built and operated on June 30, 2011 as requested in the "Belgian Stress tests" specifications. Nevertheless, the final report will mention the safety upgrades that have been already launched or were already studied in the framework of the continuous safety improvement process as mentioned above.

2.1.4 Actions undertaken due to the Fukushima accident

Shortly after the Fukushima accident, efforts were also undertaken to evaluate possible improvements (short term, mid term and long term) related to hardware, organization and procedures, to better cope with the extreme scenarios that are also studied as part of the stress tests project. In doing so, Electrabel wanted to benefit from the initial lessons learned as quickly as possible.

Hence, without waiting for the detailed stress tests results, several short term improvements have been implemented already. Consequently, the robustness of the installations with regard to these extreme scenarios has been immediately enhanced.

Some examples:

- At both sites, complementary means and procedures were developed to refill the Spent Fuel Pools (SFPs) in case of a total Station Black Out (SBO) of long duration, in which these SFPs might start to lose cooling water inventory.
- At both sites, complementary means and procedures were developed to refill certain water reservoirs using newly installed additional equipment in case of a total SBO. These reservoirs provide the cooling water that is injected into the steam generators to evacuate the core decay heat.
- At both sites, some parts of the installation were reinforced to guarantee their correct functioning in case of a beyond design earthquake.

In parallel to this initiative, the World Association of Nuclear Operators (WANO) issued a report with an initial analysis of the event, and a number of recommendations. This "WANO SOER[7]" 2011-02 "Fukushima Daiichi Nuclear Station Fuel Damage caused by Earthquake and Tsunami" was also introduced in the organization, for analysis and response to the WANO questions.

[7] SOER: Significant Operating Experience Report

2.2 Scope of the assessment

2.2.1 Scope

The assessment will consider all Electrabel nuclear power plants (namely Doel 1, Doel 2, Doel 3, Doel 4, Tihange 1, Tihange 2 and Tihange 3) plus the SCG[8] building (Doel site) and the DE[9] building (Tihange site).

The WAB[10] building (Doel site) is excluded from the current assessment. It will be assessed in a second effort according to the "Belgian Stress tests "specifications applicable to all nuclear plants excluding power reactors (22 June 2011) as attached to FANC Letter 2011-06-30-FVW-5-1-13-NL/70859 [1].

2.2.2 Situations

In the following paragraphs, the different situations that have to be considered are given. They are subdivided into three categories:

- the initiating events conceivable at the plant site;
- the loss of safety functions;

and finally,

- the management of severe accidents.

This will lead to different scenarios to be addressed in the assessment. An illustrative overview of the scenarios is given in appendix 1.

2.2.2.1 Initiating events conceivable at the plant site

The following natural or man-made hazards and events conceivable at the plant site will be considered as initial conditions that can lead to extreme scenarios:

(1) Earthquake (including consequential flooding for beyond design earthquake scenario),

(2) External Flooding in combination with bad weather conditions linked to the flooding, i.e. heavy rainfall or strong wind,

(3) Extreme weather conditions (see § 2.4.2.3. for further detail),

(4) Terrorist attacks: aircraft crash[11],

(5) Other man-made events

- o Toxic gases
- o Explosive gases and blast waves
- o Cyberattacks

The impact of the consequential effects (damage) of the initiating hazards or events will be assessed with regard to both the protective measures (vulnerability), as well as the external consequences (e.g. accessibility on and to the site).

In the absence of existing studies, the evaluation of the impact of these consequential effects will be based on engineering judgment and experience feedback.

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[8] SCG : SplijtstofContainerGebouw

[9] DE Building : Bâtiment de DEsactivation:

[10] WAB : Water- en AfvalBehandeling

[11] This event is considered to envelop a *"direct hit by an object"* as an aircraft crash encompasses both large heavy objects and penetrating objects. Justification will be provided in the Final Report.

2.2.2.2 Loss of safety functions

The losses of safety functions that have to be assessed are

(1) Loss of electrical power
   a. Loss of external electrical power supply[12]
   b. Loss of external and internal electrical power supply[13]
   c. Loss of external, internal and back-up electrical power supply[14]

(2) Loss of ultimate heat sink[15]
   a. Loss of primary ultimate heat sink
   b. Loss of primary and back-up ultimate heat sink

(3) Loss of primary ultimate heat sink and
   a. loss of electrical power (external and internal)
   b. loss of electrical power (external, internal and back-up)

Loss of internal electrical power supply (for both the normal and back-up electrical power supply) corresponds to the loss of the electrical supply of both the high-voltage and low-voltage electrical buses (AC/DC[16]).

Loss of primary ultimate heat sink corresponds to the loss of the connection between the plant and the water ("loss of access to the water from the river or the sea").

The losses are considered as unrecoverable. However, alternate means for restoring the lost connections will be evaluated.

2.2.2.3 Severe accident management issues

This chapter deals primarily with mitigating issues. In addition to all existing preventive features and in line with the general safety objective (see § 2.4.1.1.), Non-Conventional Means[17] (NCMs) are used to maintain as far as possible the three fundamental safety functions. These NCMs will be described and additional NCMs will be defined as needed.

Attention will also be given to organizational aspects (resources, habitability, accessibility, off-site technical support), considering that the extreme situations to be addressed might significantly affect on-site and off-site infrastructures and their access , work performance, etc.. Moreover, special attention will be given in terms of emergency preparedness and planning in the particular case several units of the same site are affected.

2.2.3 Initial operating state of the installation

Scenarios will be chosen to maximize the challenge to fundamental safety functions, with specific focus on the cooling function. The choice of these scenarios will be discussed in the final report, based on an overview of possible operating states.

Extreme scenarios affecting a single unit and multiple units of one site will be assessed.

- For extreme scenarios limited to a single unit, the following initial conditions will be considered:
   1. Steam Generators (SGs) available and reactor cooling system closed

[12] Loss of Off-Site Power (LOOP)
[13] Station Black-Out (SBO): Back-up electrical power supply remains available.
[14] Total Station Black-Out
[15] Loss of Ultimate Heat Sink (LUHS)
[16] AC/DC : Alternating Current / Direct Current
[17] NCMs : all additional equipment (such as mobile pumps, diesel generators, battery-fed lighting fixtures, ...) not foreseen in the initial design, but useful to cope with extreme "beyond design" Fukushima-like scenarios

2. SGs not available and reactor cooling system not closable
3. All fuel elements in spent fuel pools (after full core unload)

For a single-unit design basis assessment, the availability and operating conditions of the equipment will be in accordance with the Limiting Conditions for Operation (LCO) of the Technical Specifications. Other equipment available on the site will also be considered (e.g. site diesel generator).

- For multi-unit events, the following realistic combinations of the different states of the units will be considered:
  1. All units in operation (full power)
  2. One unit in outage for refueling (core just unloaded; SGs not available), other units in operation or shut down (SGs available)

  The realistic (but still conservative) character of the considered combinations will be discussed in the final report. Use will be made of the operating experience of the plants and the considered combinations will be in concordance with the outage management policy of the nuclear fleet (only one unit in outage for refueling per site at a time).
- Both single-unit and multi-unit margin assessments will be based on realistic assumptions.

2.3 Aspects to be reported

The general aspects that have to be reported are in line with the principle of Defence-In-Depth, i.e.

1. The provisions taken in the design basis and the conformity of the plant with regard to its design basis (including currently applicable JCOs [18]).
2. The robustness of the plant beyond its design basis
3. The potential modifications (either technical or organizational), and studies to improve the robustness of the plant, such as:
   a. Adaptation or acceleration of on-going studies or modifications (for instance those resulting from PSRs)
   b. New modifications or technical improvements
   c. Additional studies
   d. Organizational changes (resources, emergency preparedness, external support)
   e. Non conventional (mobile) equipment and means, on and off site
   f. Modifications to the related documentation

The general approach is deterministic, i.e. when considering an extreme scenario, it is supposed that the defence lines (preventive and mitigative measures) are sequentially defeated. Starting from a conceivable initiating event, the sequential loss of the preventive measures will eventually lead to fuel damage. As soon as fuel damage is expected or has occurred, strategies have to be put in place to prevent or mitigate radiological releases.

[18] Justification for Continued Operation : licensee's technical basis for requesting authorization to operate in a manner that is prohibited (e.g., outside TS or license) absent such authorization. (Origin of the definition: Attachment 1 to GL91-18 Revision 1, October 8, 1997)

2.4 Assessment method

2.4.1 General aspects

2.4.1.1 General safety objective

The general safety objective is to avoid release of radioactive material to the environment as far as possible by maintaining the three fundamental safety functions (control of reactivity, fuel cooling, confinement of radioactivity), either by using the existing equipment and systems, or by using non conventional (mobile) means.

2.4.1.2 Safe shutdown objective

The aim is to ensure that the unit(s) can be brought and remain as long as necessary in a safe and stable shutdown state, defined as a state wherein the fundamental safety functions are guaranteed. The specific definition of this safe shutdown state depends on the initial state of the unit(s). The equipments that are called upon to reach and to remain in this safe shutdown state may vary. This will be clarified in the final report.

2.4.1.3 Adequacy of support systems

When performing an assessment of the various situations or scenarios, attention will be paid to the adequacy of support systems (such as component cooling), especially when they are required for different purposes (e.g. cooling of reactor and of fuel pools) or units (site event) at the same time. Special attention will be paid to the situation of Doel 1&2 that use shared support systems (twin units).

2.4.1.4 Assessing robustness

The robustness of the plant beyond its design basis will be evaluated by identifying the successive protective and available mitigative measures that come into play when considering the progressive loss of the different protective layers. Robustness of individual layers will be assessed on the basis of redundancy, diversity, physical separation, autonomy of the systems, whereas the independence of the successive layers will be assessed in terms of common cause failures. Common cause failures are to be considered as consequential effects.

Even if loss of protective measures will be (deterministically) postulated, this loss will also be evaluated in terms of likelihood.

Attention will be paid to identify cliff edge effects, i.e. a major step change of the response of the unit to the considered solicitation.

2.4.2 Situation assessment

2.4.2.1 Earthquake

<u>Design Basis, Compliance and Assessment</u>

The lines of defence in terms of the preventive, protective and mitigative measures as foreseen by design will be described.

Robustness of those lines of defence will be assessed in terms of redundancy, diversity and margin (including operator intervention time), with regard to the considered situations.

The evaluation of the conformity of the installation with the design basis is done, both on a continuous basis by means of the existing surveillance program, and by the Periodic Safety Reviews.

In addition, following the Fukushima event, WANO SOER 2011-02 requested a specific design basis conformity evaluation from all nuclear power operators worldwide (see § 2.1.4). Relevant Electrabel results will be integrated in the Final Report.

Evaluation of the margins

In accordance to the "Belgian Stress tests" specifications, the range of earthquake severity that the plant can withstand without severe damage to the fuel will be evaluated. Existing studies do not have this as an explicit objective, as structures, systems and components (SSCs) are designed with regard to recognized codes that aim at ensuring structural integrity or functionality in order to maintain the safety functions.

Therefore, an approach derived from the Seismic Margin Assessment (SMA) methodology will be used. The evaluation will assess the margins available with regard to a Review Level Earthquake (RLE) exceeding the Design Basis Earthquake (DBE).

The assessment will be based on:

- The definition of a specific RLE. The proposed RLE will be defined in line with international requirements and using the most recent seismic data evaluated by the Royal Observatory of Belgium (R.O.B.). The justification of the RLE and its associated spectrum will be provided in the Final Report.
- An analysis of the behavior of plant structures, systems and components (SSCs) beyond their design basis based on existing documentation (e.g. design analyses, SQUG[19] files, pre-SMA studies).
- The use of the engineering judgment of experienced seismic engineers (including international experts). In particular field visits, inside and outside reactor buildings, ("walkdowns") of the plants will be organized, taking into account the outage planning of the units. These visits will therefore continue after the issuance of the Final Report.

Based on the knowledge of the plants and engineering judgment, this assessment will identify the weak points and cliff edge effects.

In case a cliff edge effect or a weak point is identified:

- possible provisions for improvements that could be envisaged will be indicated;
- when possible, a referral will be made, with consideration of non-conventional means, either to the scenarios of loss of safety functions[21], or to a severe accident situation (see § 2.2.2.3 and § 2.4.2.7).

When assessing the possibility of a beyond design basis flooding due to a beyond design earthquake, plant location and plant design will be taken into account to make a judgment on the plausibility of such a situation.

2.4.2.2 Flooding

Design Basis, Compliance and Assessment

The lines of defence in terms of the preventive, protective and mitigative measures as foreseen by design will be described.

Robustness of those lines of defence will be assessed in terms of redundancy, diversity and margin (including operator intervention time), with regard to the considered situations.

The evaluation of the conformity of the installation with the design basis is done, both on a continuous basis by means of the existing surveillance program, and by the Periodic Safety Reviews.

[19] Seismic Qualification Utility Group
[21] Station Black Out (total or not), Loss of Ultimate Heat Sink (total or not) or their combination.

In addition, following the Fukushima event, WANO SOER 2011-02 requested a specific design basis conformity evaluation from all nuclear power operators worldwide (see § 2.1.4). Relevant Electrabel results will be integrated in the Final Report.

Evaluation of the margins

In accordance to the "Belgian Stress tests" specifications, the severity of flooding that the plant can withstand without severe damage to the fuel will be evaluated. Existing studies do not have this as an explicit objective, as structures, systems and components (SSC's) are designed to ensure the safety functions are maintained.

As a consequence, the assessment of the margin to severe damage to the fuel will be essentially based on engineering judgment.

The margins will be evaluated with respect to a stepwise increase of the external water level:

- Evaluation when the margins of Design Basis Flood Protection will be exceeded.
- In case the site is no longer dry, identification of which buildings will be progressively flooded and then, identification if any safety functions would be lost.
- Wherever needed, reference will be made to the evaluation of SBO/LUHS and the reliance on non-conventional means.
- The progressive failure of protection barriers will be postulated and its consequences will be analyzed. The plausible character of hypothetical failure modes will be discussed to assess the robustness of the protection barrier.

Based on the knowledge of the plants and engineering judgment, this assessment will be directly focused on the weak points and cliff edge effects.

In case a cliff edge effect or a weak point is identified:

- possible provisions for improvements that could be envisaged will be indicated;
- when possible, a referral will be made, with consideration of non-conventional means, either to the scenarios of loss of safety functions[22], or to a severe accident situation (see § 2.2.2.3 and § 2.4.2.7)..

2.4.2.3 Extreme weather conditions

Extreme weather conditions have been defined based on IAEA NS-G-3.4[23] and IAEA DS-417[24] documents. The scope of the assessment of extreme weather conditions will be justified, amongst other criteria on the basis of the geographical situation of the plant.

The following extreme weather conditions will be considered:

- Heavy rainfalls
- High speed winds
- Tornadoes
- Lightning
- Snow pack
- Hail

The following extreme weather conditions will not be considered:

- Tropical cyclones, typhoons and hurricanes

[22] Station Black Out (total or not), Loss of Ultimate Heat Sink (total or not) or their combination.
[23] IAEA NS-G-3.4, IAEA Safety Standards Series, "Meteorological Events in Site Evaluation for Nuclear Power Plants", May 2003
[24] DS417-Rev00P-2009-08-20, Draft Safety Guide, "Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations"

- Dust storms and sandstorms
- Waterspouts
- Air temperature (including drought and freezing precipitation)

The final report will contain or specify :

- The justification for non consideration of these last four weather conditions;
- The buildings and equipment which will be impacted;
- The weak points and failure modes leading to unsafe plant conditions and loss of one or more safety functions.

Extreme weather conditions that are enveloped by other situations (earthquake, flooding, station black out, loss of ultimate heat sink,...) will be identified as such.

2.4.2.4 Aircraft crash

The availability and robustness of the vital functions, including the building containing them, in case of an aircraft crash will be reviewed based on existing studies. The existing provisions, as foreseen in the design, will be described.

For situations not foreseen in the design basis, a summary of the assessment carried out following the 9-11 events with regard to design and operational response (e.g. main provisions to protect the unit against fuel fire effects) will be provided. This includes:

(1) An update of the statistics with regard to aircraft frequency and type, carried out by an external contractor (IATA[25]), in order to evaluate the representativeness of the plane(s) that have been considered following the 9-11 events;

(2) The impact of this update on the conclusion of the 9-11 assessment.

Special attention will be given to the situations (aircraft crash on the site) potentially leading to station black-out or loss of ultimate heat sink.

According to the regulation in force, part of the Final Report with regard to this topic will be classified (no public access).

2.4.2.5 Other Man-Made Events

According to the regulation in force, part of the Final Report with regard to this topic will be classified (no public access).

Toxic gases

The discussion of the provisions will be based on the available results of the periodic safety reviews.

The final report will explain or specify :

- The reasons for the choice of the toxic gases taken into account in the design basis;
- The events and combination of events as well as the reasons for the selection (or not) as a design basis;
- The provisions which exist or can be envisaged to prevent the loss of control by the operator of the plant.

[25] International Air Transport Association

Explosive gases and blast wave

The discussion of the provisions will be based on the available results of the periodic safety reviews.

The final report will explain or specify :

- The reasons for the choice of the explosive gases and blast waves taken into account in the design basis;
- The events and combination of events as well as the reasons for the selection (or not) as a design basis;
- The provisions which exist or can be envisaged to prevent the loss of control by the operator of the plant.

Cyber attacks

An Electrabel cyber attack security program has been in place for several years. This program's purpose is to identify vulnerabilities and improve information security.

The method to determine the cyber attack scenarios relevant for safety-related computer based controls and systems was established by analyzing the vulnerability of critical systems based on the ongoing effort from the cyber attack security program. The identification of the selected scenarios was established through an analysis of how cyber attacks are carried out.

Vulnerability and criticality are defined as follows:

- The vulnerability of a system is measured by the possible negative impact on its integrity and availability;
- Critical systems are identified by their importance in maintaining control over reactors and safety functions.

The final report will

- identify, for concerned safety related controls and systems, the events and combination of events as well as the reasons for the selection (or not) as a design basis;
- detail the provisions which exist or can be envisaged to prevent system alteration, or loss of control by the operator of the plant.

2.4.2.6 Loss of electrical power supply and loss of ultimate heat sink

The lines of defence in terms of redundancy, capacity and diversity as foreseen by design will be described.

The progressive loss of these lines of defence will be considered, and for each line of defence, the time to have the equipments operating as well as their autonomy[26] will be given. This will be done for both design capacity and best-estimate capacity.

Based on the knowledge of the plants and engineering judgment the assessment will identify the weak points if any. In addition possible provisions for improvements that could be envisaged will be indicated.

2.4.2.7 Severe Accident Issues

Regarding Severe Accident Management (SAM), the Final Report will address all the topics and questions detailed in the specifications in relation with

[26] Battery capacity, fuel capacity, water supply,....

- accident management measures currently in place at the various stages of a scenario of loss of cooling function of reactor core and spent fuel pools;
- accident management measures and plant design features for protecting containment integrity after occurrence of damage;
- accident management measures currently in place to mitigate the consequences of loss of containment integrity and to reduce releases to the environment.

Regarding evaluation of potential non-conventional means, the following will be taken into account:

- To detect possible cliff edge effects and to determine potential complementary lines of defence in terms of non-conventional means, as well as the time frames in which those means have to be operational, a time-line approach based on a abrupt total station black out for each unit will be used. The time-line will be drawn up, based on a supposed long-lasting station blackout, for the initial operating states considered according to paragraph 2.2.3;
- It will be verified that the potential non-conventional complementary means, in response to the above considered scenario, remain effective when only one unit is affected, as well as when the whole site is affected. The way to integrate these means in the emergency preparedness and planning procedures in order to have them available when required will be proposed.

3 Electrabel Organization

3.1 Introduction

In the following paragraphs, the organization set up by Electrabel to carry out the complementary safety evaluation as requested by the FANC and to establish the Final Reports will be briefly outlined.

Within the Electrabel organization, the development of these Final Reports is known as "Project BEST" (where BEST is the acronym for "BElgian Stress Tests")

3.2 Electrabel / Tractebel Engineering Organization

3.2.1 Project Steering Committee

It was decided to organize periodically a Project Steering Committee to assure a high level steering and follow-up of the BEST project, as well as a timely and adequate decision making and approval process. Participants in this Project Steering Committee are representatives of the management of the different entities contributing to the BEST project, as detailed in § 3.2.2., under the leadership of the Corporate Department Assets & Nuclear Projects (A&NP) of Electrabel Generation.

3.2.2 Project Group BEST

The day-to-day management of the project BEST is taken up by a project group of five experienced project managers, representing the different entities of GDF Suez contributing to the BEST Project:

- Three entities of Electrabel Business Entity Generation : both nuclear sites (Kerncentrale Doel (KCD) and Centrale Nucléaire de Tihange (CNT)), and the Corporate Department Assets & Nuclear Projects (A&NP);
- The Corporate Department ECNSD (Electrabel Corporate Nuclear Safety Dept.);
- Tractebel Engineering.

The representative of the department A&NP is the project leader of the Project BEST.
By means of weekly meetings, project progress is tracked, bottlenecks are identified, and remedial actions are defined, if necessary.

3.2.3 Working Groups BEST

To address the different themes of the FANC specifications, six workgroups have been defined:

1. WG 1 : Triggering event "Earthquake"
2. WG 2 : Triggering events "Flooding" and "Other extreme natural events"
3. WG 3 : Loss of safety functions "Loss of electrical power" and "Loss of the ultimate heat sink"
4. WG 4 : Severe accident management
5. WG 5a : Triggering events "Terrorist attacks" (aircraft crash, ...) and "Other man-made events" (partim toxic and explosive gases and blast waves)
6. WG 5b : Triggering event "External attacks on computer-based controls and systems" ("Cyber-attacks")

These working groups are also composed of experts from the same Electrabel/Tractebel-departments as mentioned above. Moreover, a representative of the Project Group is present in the working groups 1 to 5a, in order to ensure coherence and an unimpeded flow of information.

The working groups meet weekly as well, and back up-participants are assigned to guarantee continuity. Approximatively 40 experts are active in the Project BEST.

3.2.4 Follow up-meetings with the FANC and Bel V

On a monthly to two-monthly basis, Electrabel presents its progress to the FANC and to Bel V in follow up-meetings. At these occasions, Electrabel questions regarding the FANC "Belgian Stress tests" specifications can also be clarified by the FANC / Bel V.

3.3 Translation of the FANC "Belgian Stress tests" specifications into separate deliverables

To facilitate workload distribution among the different workgroups, as well as subsequent follow-up, the FANC "Belgian Stress tests" specifications have been divided in a number of "deliverables". Each deliverable consists of a specific answer to a specific FANC question issued from the specifications.

> *Example : ref. [1], p. 7/10, § a). "Loss of Offsite Power (LOOP) : Describe how this situation is taken into account in the design and describe which internal backup power sources are designed to cope with this situation."*

The development of these deliverables is the main task of the different working groups.

3.4 Realization of the Stress tests Final Reports

3.4.1 General remarks

Electrabel will develop two Stress tests Final Reports : one for the Doel Nuclear Power Plant (NPP), and one for the Tihange NPP. Each Final Report will consist of two different parts.

Both parts will be based on the FANC "Belgian Stress tests" specifications. One part will refer to the "ENSREG" part of these specifications[28], and another one will refer to the specific "Belgian" part of these specifications. In this second part, some aspects (e.g. related to aircraft crash, cyber attack, or any other security-related issue) will remain confidential.

The language of the Reports will be Dutch for the KCD report and French for the CNT report.

It should also be noted that, in order to elaborate the Stress tests Final Reports, Electrabel has invoked the assistance of several (national and international) experts and organizations to contribute to the technical content of the reports (e.g. R.O.B., IATA, SG&H[29]).

In order to develop the required Stress tests Final Reports, Electrabel has defined three project phases:

1. Phase 1 : development of the deliverables (as described above in § 3.3). Within the FANC specifications, a distinction can be made between a part related to the design basis of the Nuclear Power Plants, a part related to the robustness of the NPPs beyond their design basis (evaluation of the margins), and a part related to the Severe Accident Management (SAM) strategies.
   At the end of phase 1, the technical information to be included in the Final Report should be available in written form (for all three parts), but not necessarily with the correct level of detail.
2. Phase 2 : concatenation of the individual deliverables, to arrive at a "draft 0" of the final report, collection of comments of different stakeholders (sites, A&NP, ECNSD, Tractebel Engineering), and integration of these comments in the report texts. At the end of phase 2, the full report text should be internally coherent, but not necessarily already in a suitable format.
3. Phase 3 : editing of the report in its final form, with attention to readability and ease of understanding (e.g. use of abbreviations, use of specific technical terms, ...).

[28] This is the part of the FANC specifications which is similar to the ENSREG specifications, and will be subjected to a Peer Review exercise in 2012.
[29] SG&H : Simpson, Gumpertz & Heger

3.4.2 Phase 1

In this phase, the experts participating in the working groups develop all the individual deliverables. For each individual deliverable, a thorough independent "2-level" review has been organized within the working groups. Each deliverable is reviewed by another expert in the field. Once approved by author and reviewer, the deliverable is validated by the working group. In this step of the process, emphasis is more on coherence (between units, between plants, etc ...) for the considered theme.

In their analysis of the FANC "Belgian Stress tests specifications", all working groups also list possible improvements that might be valuable in the management of Fukushima-type severe accident scenarios.

These possible improvements are categorized according to their benefit, implementation complexity and (possible) realization schedule as short-term, medium term or long-term improvement actions (for further evaluation, after delivery of the Stress tests Final Reports).

Each Working Group pilot is responsible for the complete listing and categorization of all these relevant actions. Results of this (ongoing, continuous) exercise are regularly communicated to the Project Group for further analysis and validation. Some of the short term-improvements have already been implemented. Examples have been given in § 2.1.4.

Planning phase 1 : May/June/July/August 2011.

3.4.3 Phase 2

In phase 2, the individual deliverables are concatenated to a complete text (draft 0 of the Stress tests Final Report). These texts are reviewed by independent experts from Tractebel Engineering, ECNSD and the site organizations. After this review, these texts are ready for final edition.

Planning phase 2 : August/September 2011.

3.4.4 Phase 3

Finally, it is planned to edit both reports, with attention to following specific points (in order to increase readability of the report) :

- Timely introduction of new concepts
- Timely explanation of new abbreviations
- Addition of relevant footnotes where needed
- Introduction of flow schemes or technical drawings to clarify particular points

Planning phase 3 : September / October 2011.

4 Progress

4.1 Introduction

Since the start of the project BEST (late March, early April 2011) substantial progress has been made within the Electrabel / Tractebel Engineering-organization to develop the required Final Reports for KCD and CNT.

At the same time, several improvements to further strengthen the robustness of our plants with respect to extreme Fukushima-like scenarios have been implemented. (More details were already given in § 2.1.4.).

In the following paragraph, the main stages of this progress are documented.

4.2 Actual status of the project

To give a broad overview of the project progress, following important milestones are worth mentioning (approximately in chronological order):

March 2011

- From the start and in all subsequent months, Electrabel has actively collaborated with ENISS[30], and has interacted (through ENISS) on a regular basis with other European utilities impacted by the Stress tests.
- March 31 : Electrabel participated in an initial meeting with the FANC, in which the Stress tests initiative was introduced.

April 2011

- The WENRA specifications (version of April 21, 2011) were thoroughly analyzed.
- Attention was given to the development of a suitable methodology to tackle the issue of earthquake margin evaluation. In this regard, contacts were established with the Royal Observatory of Belgium (R.O.B.) in order to discuss the reevaluation of the seismic hazard at the Doel and Tihange sites.
- Initial ideas were developed regarding internal organization, resources, interfaces, ... to organize the BEST project.
- In response to the WENRA specifications (version of April 21, 2011), a project group and several working groups were defined. Experts were assigned, and precautions were taken within the respective organizations to ensure that personnel was freed from other, less urgent ongoing projects.

May 2011

- May 5 : within the Electrabel / Tractebel organization, an official "Kick off-meeting" launching the project BEST was organized. Soon thereafter, initial working group meetings were held.
- May 12 : the Electrabel response to the WANO SOER 2011-02 questionnaire was sent to WANO.
- May 17 : Publication of the FANC specifications. In addition to the WENRA / ENSREG document (see below), the FANC also requires an assessment of several additional triggering events. To take these into account in the Stress Test Reports, additional working groups were defined.
- May 19 : Follow up-Committee with the FANC, Bel V, Electrabel and Tractebel Engineering.
- A preliminary analysis was made of the different scenarios that have to be studied to cope with the "Belgian Stress tests" specifications.
- May 24 : Letter by European Commissioner Oettinger to the chairman of ENSREG, in which the ENSREG specifications proposal (in itself based on the WENRA specifications of May 12-13) was accepted.
Since the FANC specifications were based on the ENSREG specifications, the FANC specifications can be divided in two parts, an "ENSREG" part and a "Belgian" part, covering the additional triggering events mentioned above. This distinction was taken into account, e.g. in the development of a (Draft) Final Report table of contents.
- Following the contacts established in the month of April, the Royal Observatory of Belgium (R.O.B.) performed a preliminary evaluation of the seismic hazard of the Doel and Tihange sites.

30 ENISS : "European Nuclear Industry Safety Standards". ENISS currently represents the nuclear utilities and operating companies from 17 European countries with nuclear power programme

June 2011 :

- June 1 : in a meeting with Bel V, the different scenarios to be studied as part of the project BEST were presented and discussed.
- In the weeks of June 14 and June 20, American experts from the Engineering firm Simpson Gumpertz & Heger (SG&H) performed extensive inspections in several Doel and Tihange buildings, as part of the assessment of earthquakes as a triggering event.
- June 20 : the result of the scenario discussions was presented to the FANC.
- June 22 : Follow up-Committee with the FANC, Bel V, Electrabel and Tractebel Engineering.

July 2011 :

- July 5 : the project BEST was presented to the Scientific Council. Attention was given to the Electrabel organization to tackle the challenge posed by the "Belgian Stress tests" specifications.
- July 11 : the methodology developed by Electrabel to perform its stress tests was presented to the FANC and to Bel V, to make sure that this methodology corresponds to the FANC expectations.
- July 13 : contacts were established with INPO[31] and the U.S. Department of Commerce (via the U.S. Mission to the European Union, Brussels) to gain information on matters related to aircraft crash issues.
- In the months of June and July, international contacts were established to gain information from other utilities regarding their approach to the (ENSREG) stress tests specifications. Exchange visits with some other utilities were organized.
- July 27 : Follow up-Committee with the FANC, Bel V, Electrabel and Tractebel Engineering.
- A preliminary version of the deliverables related to the "Design" part of the specifications was established (end of phase 1 for the design basis-document). Reading committees were established to review the resulting draft text.

August 2011 :

- August 12 : a presentation was given to representatives of the non-power reactor Class 1 installations in Belgium[32], as part of a "Stakeholder meeting" organized by the FANC. These installations will also be subjected to stress test assessments, although with a different schedule, shifted in time.
- August 12 : following the July 13 action, contacts were established with Sargent & Lundy, to gain information on matters related to aircraft crash issues.
- August 15 : the Electrabel Progress Report was transmitted to the FANC, in agreement with the official deadline requested by the FANC.
- In parallel, the working groups continue their activities, to develop detailed answers to the parts of the specifications related to the evaluation of the margins with respect to beyond-design scenarios, and to the management of severe accidents.

[31] INPO : Institute of Nuclear Power Operations, based in Atlanta, U.S.A.
[32] Belgoprocess, IRE, SCK, ...

5 Electrabel Stress tests Reports TOC Proposal

5.1 Introduction

In the following paragraphs, a (draft) Electrabel proposal for the Final Reports Table Of Content ("TOC") is given. Two parts can be distinguished:

- A first paragraph (§ 5.2.1.) pertaining to the "ENSREG" specifications. The contents of this paragraph are based, with some modifications, on the TOC-proposal developed by ENISS (as requested by WENRA and ENSREG, in order to facilitate the peer reviews of the national reports starting in 2012).
- A second paragraph (§ 5.2.2.) pertaining to that part of the specifications which is specific to the FANC document, and is not found in the ENSREG text. In particular, it concerns the aspects of terrorist attacks and some other man-made events.

The detail displayed in the following plan is given by way of indication. It is liable to be adjusted during the writing and integration of the report (e.g. to summarize aspects to improve comprehensibility of the given explanations).

Regarding the ENSREG part : this proposal can be used by other European Nuclear Licensees as well, so that these Licensees' Stress tests Final Reports are as homogeneous as possible. However, it is obvious that each licensee will follow the specifications given by his national regulator. For this reason, an additional paragraph § 5.2.2. has been added.

5.2 Draft Electrabel Stress tests Report Table of Contents

5.2.1 Answer to ENSREG specifications

NOTE : The following TOC should be considered as *preliminary*, since the detailed definitive ENSREG requirements with regard to the table of contents to be used in the Stress tests reports are not yet finalized.

0. Executive summary

The licensee will:

- *Remind briefly the main hypothesis taken into account (e.g. all operational states considered in the plant technical specifications, realistic assessments in case of severe accidents...)*
- *Point out for the different topics (earthquake, flooding, loss of electrical supply and heat sink, Severe Accident Management) the main results about design basis, margin analyses, robustness, adequacy of provisions, management measures and the main proposed improvements.*

1. General data about site/plant

1.1. Brief description of the site characteristic

- *location (sea, river)*
- *number of units*
- *license holder*

1.2. Main characteristics of the units/nuclear installations

- *reactor type*
- *thermal power*
- *date of first criticality*
- *existing spent fuel storage (or shared storage)*

1.3. Significant differences between units

1.4. Scope and main results of Probabilistic Safety Assessments

2. Earthquake

2.1 Design basis

2.1.1 Earthquake against which the plant is designed

2.1.1.1 Characteristics of the design basis earthquake (DBE)
2.1.1.2 Methodology used to evaluate the design basis earthquake
2.1.1.3 Conclusion on the adequacy of the design basis for the earthquake

2.1.2 Provisions to protect the plant against the design basis earthquake

2.1.2.1 Key structures, systems and components (SSC) including main associated design/construction provisions required for achieving safe shutdown state and supposed to remain available after the earthquake
2.1.2.2 Main operating provisions
2.1.2.3 Indirect effects of the earthquake taken into account

2.1.3 Compliance of the plant with its current licensing basis

2.1.3.1 Licensee's general organisation / process to ensure compliance
2.1.3.2 Licensee's organisation for mobile equipment and supplies
2.1.3.3 Potential deviations from licensing basis and remedial actions in progress
2.1.3.4 Specific compliance check already initiated by the licensee

2.2 Evaluation of margins

2.2.1 Range of earthquake leading to severe fuel damage

2.2.1.1 Weak points and cliff edge effects
2.2.1.2 Measures which can be envisaged to increase robustness of the plant

2.2.2 Range of earthquake leading to loss of containment integrity

2.2.3 Earthquake exceeding the design basis earthquake for the plant and consequent flooding exceeding design basis flood

2.2.3.1 Physically possible situations and potential impacts on the safety of the plant
2.2.3.2 Weak points and cliff edge effects
2.2.3.3 Measures which can be envisaged to increase robustness of the plant

3. Flooding

3.1 Design basis

3.1.1 Flooding against which the plant is designed

3.1.1.1 Characteristics of the design basis flood (DBF) flooding
3.1.1.2 Methodology used to evaluate the design basis flood
3.1.1.3 Conclusion on the adequacy of the design basis for flooding

3.1.2 Provisions to protect the plant against the design basis flood

3.1.2.1 Key structures, systems and components (SSC) required for achieving safe shutdown state and supposed to remain available after the flooding
3.1.2.2 Main associated design/construction provisions
3.1.2.3 Main operating provision

3.1.2.4 *Other effects of the flooding taken into account*

3.1.3 *Plant compliance with its current licensing basis*

3.1.3.1 *Licensee's general organisation to ensure conformity*
3.1.3.2 *Licensee's organisation for mobile equipment and supplies*
3.1.3.3 *Potential deviations from licensing basis and remedial actions in progress*
3.1.3.4 *Specific compliance check already initiated by the licensee*

3.2 *Evaluation of margins*

3.2.1 *Additional protective measures which can be envisaged in the context of the design, based on the warning lead time*
3.2.2 *Weak points and cliff edge effects*
3.2.3 *Measures which can be envisaged to increase robustness of the installation*

4. *Extreme natural events*

4.1 *Very bad weather conditions (storm, heavy rainfalls…)*

4.1.1 *Events and any combination of events – reasons for a selection (or not) as a design basis event*
4.1.2 *Weak points and cliff edge effects*
4.1.3 *Measures which can be envisaged to increase robustness of the plant*

5. *Loss of electrical power and loss of ultimate heat sink*

5.1 *For nuclear power reactors*

5.1.1 *Loss of off-site power*

5.1.1.1 *Design provisions taking into account this situation, back-up power sources provided, capacity and how to implement them*
5.1.1.2 *Autonomy of the on-site power sources*
5.1.1.3 *Provisions taken to prolong the time of on-site power supply*
5.1.1.4 *Measures which can be envisaged to increase robustness of the plant*

5.1.2 *Loss of off-site power and of on-site back-up power sources*

5.1.2.1 *Design provisions*
5.1.2.2 *Battery capacity and duration*
5.1.2.3 *Autonomy of the site before fuel degradation*
5.1.2.4 *(External) actions foreseen to prevent fuel degradation*
5.1.2.5 *Measures which can be envisaged to increase robustness of the plant*

5.1.3 *Loss of off-site power and loss of the ordinary back up source, and loss of any other diverse back up source*

5.1.3.1 *Design provisions*
5.1.3.2 *Battery capacity and duration*
5.1.3.3 *Autonomy of the site before fuel degradation*
5.1.3.4 *(External) actions foreseen to prevent fuel degradation*
5.1.3.5 *Measures which can be envisaged to increase robustness of the plant*

5.1.4 *Loss of primary ultimate heat sink (access to water from the river or the sea)*

5.1.4.1 *Design provisional autonomy of the site before fuel degradation*
5.1.4.2 *(External) actions foreseen to prevent fuel degradation*
5.1.4.3 *Measures which can be envisaged to increase robustness of the plant*

5.1.5 Loss of the primary ultimate heat sink and "alternate heat sink"

5.1.5.1 Design provisional autonomy of the site before fuel degradation
5.1.5.2 (External) actions foreseen to prevent fuel degradation
5.1.5.3 Measures which can be envisaged to increase robustness of the plant

5.1.6 Loss of the primary ultimate heat sink, combined with station black out

5.1.6.1 Design provisional autonomy of the site before fuel degradation
5.1.6.2 (External) actions foreseen to prevent fuel degradation
5.1.6.3 Measures which can be envisaged to increase robustness of the plant

5.2 For the spent fuel pits of the fuel building

5.2.1 Loss of offsite power

5.2.1.1 Design provisions taking into account this situation, back-up power sources provided, capacity and how to implement them
5.2.1.2 Autonomy of the on-site power sources
5.2.1.3 Provisions taken to prolong the time of on-site power supply
5.2.1.4 Measures which can be envisaged to increase robustness of the plant

5.2.2 Loss of off-site power and loss of the ordinary back-up source

5.2.2.1 Design provisions
5.2.2.2 Battery capacity and duration
5.2.2.3 Autonomy of the site before fuel degradation
5.2.2.4 (External) actions foreseen to prevent fuel degradation
5.2.2.5 Measures which can be envisaged to increase robustness of the plant

5.2.3 Loss of off-site power and loss of the ordinary back-up source, and loss of any other diverse back up source

5.2.3.1 Design provisions
5.2.3.2 Battery capacity and duration
5.2.3.3 Autonomy of the site before fuel degradation
5.2.3.4 (External) actions foreseen to prevent fuel degradation
5.2.3.5 Measures which can be envisaged to increase robustness of the plant

5.2.4 Loss of the primary ultimate heat sink

5.2.4.1 Design provisional autonomy of the site before severe accident
5.2.4.2 (External) actions foreseen to prevent fuel degradation
5.2.4.3 Measures which can be envisaged to increase robustness of the plant

5.2.5 Loss of the primary ultimate heat sink and loss of the alternative ultimate heat sink

5.2.5.1 Design provisional autonomy of the site before severe accident
5.2.5.2 (External) actions foreseen to prevent fuel degradation
5.2.5.3 Measures which can be envisaged to increase robustness of the plant

5.2.6 Loss of the primary ultimate heat sink, combined with station black out

5.2.6.1 Design provisional autonomy of the site before severe accident
5.2.6.2 (External) actions foreseen to prevent fuel degradation
5.2.6.3 Measures which can be envisaged to increase robustness of the plant

5.3 Dependence of one unit on the functions of other units

6. Severe accident management

6.1 Organisation of the licensee to manage the accident and the possible disturbances

6.1.1 Organisation planned

6.1.1.1 Organisation of the licensee to manage the accident
6.1.1.2 Possibility to use existing equipment
6.1.1.3 Provisions to use mobile devices (availability of such devices, time to bring them on site and put them in operation)
6.1.1.4 Provisions for and management of supplies (fuel for diesel generators, water, etc.)
6.1.1.5 Management of radioactive releases, provisions to limit them
6.1.1.6 Communication and information systems (internal and external)

6.1.2 Possible disruption with regard to the measures envisaged to manage accidents and associated management

6.1.2.1 Extensive destruction of infrastructure around the installation including the communication facilities
6.1.2.2 Impairment of work performance due to high local dose rates, radioactive contamination and destruction of some facilities on site
6.1.2.3 Feasibility and effectiveness of accident management measures under the conditions of external hazards (earthquakes, floods)
6.1.2.4 Unavailability of power supply
6.1.2.5 Potential failure of instrumentation
6.1.2.6 Potential effects from the other neighbouring unit(s) at site

6.2 For nuclear power reactors

6.2.1 Loss of core cooling: Accident management measures currently in place before occurrence of fuel damage in the reactor pressure vessel

6.2.1.1 Preventive actions to prevent fuel damage and to eliminate high pressure fuel damage
6.2.1.2 Risks of cliff edge effects and deadlines
6.2.1.3 Adequacy of the existing management measures and possible additional provisions

6.2.2 Loss of cooling: Accident management measures currently in place after occurrence of fuel damage in the reactor pressure vessel

6.2.2.1 Mitigative measures
6.2.2.2 Risks of cliff edge effects and deadlines
6.2.2.3 Adequacy of the existing management measures and possible additional provisions

6.2.3 Accident management measures and installation design features for protecting containment integrity after occurrence of fuel damage

6.2.3.1 Management of hydrogen risks (inside and outside the containment)
6.2.3.2 Prevention of overpressure of the containment
6.2.3.3 Prevention of re-criticality
6.2.3.4 Prevention of basemat melt through: retention of the corium in the pressure vessel
6.2.3.5 Need for and supply of electrical AC and DC power and compressed air to equipment used for protecting containment integrity
6.2.3.6 Risks of cliff edge effects and deadlines
6.2.3.7 Adequacy of the existing management measures and possible additional provisions

6.2.4 Accident management measures currently in place to mitigate the consequences of loss of containment integrity

6.2.4.1 Design, operation and organisation provisions
6.2.4.2 Risks of cliff edge effects and deadlines
6.2.4.3 Adequacy of the existing management measures and possible additional provisions

6.3 For the spent fuel storage

6.3.1 Measures for managing the consequences of a loss of cooling function for the pool water

6.3.1.1 Before and after losing adequate shielding against radiation
6.3.1.2 Before and after uncovering of the top of fuel in the fuel pool
6.3.1.3 Before and after occurrence of fuel degradation in the fuel storage facility
6.3.1.4 Risks of cliff edge effects and deadlines
6.3.1.5 Adequacy of the existing management measures and possible additional provisions

6.3.2 Specific points

6.3.2.1 Adequacy and availability of the instrumentation
6.3.2.2 Availability and habitability of the control room
6.3.2.3 Potential for hydrogen accumulation

5.2.2 Answer to FANC Specifications

This paragraph covers the (draft) Electrabel Stress Test Report Table of Contents, pertaining to the FANC "Belgian Stress tests specifications – Applicable to power reactors" of May 17, 2011, in particular the attachment with the List of Triggering events, paragraphs D and E, since these are in addition to the ENSREG specifications.

1. Terrorist attacks

1.1. Review of maintenance of vital functions in case of an aircraft crash or a direct hit by an object

1.1.1. Crash scenarios
1.1.2. Provisions to satisfy the defence in depth principle, keeping the plant away from a SBO or the loss of UHS

1.2. Weak points and cliff edge effects

1.3. Main provisions to protect the unit against fuel fire effects

2. Other man-made events

2.1. Site specific impacts caused by toxic and explosive gases and blast waves

2.1.1. Events and combination of events and reasons for the selection (or not) as a design basis
2.1.2. Provisions to prevent the loss of control by the operator of the plant

2.2. Site specific impacts caused by external attacks on computer-based controls and systems

2.2.1. Events and combination of events and reasons for the selection (or not) as a design basis
2.2.2. Provisions to prevent the loss of control by the operator of the plant

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6 References

[1] FANC letter "Specificaties voor stress test voor nucleaire inrichtingen van klasse I", 2011-06-30-FVW-5-1-13-NL/70859, with its annexes:
- Annexe 22 June 2011 (and its attachment): "Belgian Stress tests" specifications – Applicable to all nuclear plants, excluding power reactors
- Annexe 17 May 2011 (and its attachment) : "Belgian Stress tests" specifications – Applicable to power reactors

Appendix 1 Overview of the scenarios

Earthquake	Design Basis Earthquake
	Design Basis Earthquake + Loss of Off-Site Power + Internal Flooding
	Beyond Design Basis Earthquake
	Beyond Design Basis Earthquake inducing a Beyond Design Basis Flood (only if physically possible given the plant location)
Flooding	Design Basis Flood
	Design Basis Flood + Heavy Rainfall
	Design Basis flood + Strong Wind
	Beyond Design Basis Flood + Heavy Rainfall
	Beyond Design Basis Flood + Strong Wind
	Beyond Design Basis Flood + Heavy Rainfall + Strong Wind
Electrical/Heat Sink	Loss of Off-Site Power
	Station Black Out (no loss of alternate power)
	Total Station Black Out
	Loss of Main Ultimate Heat Sink
	Loss of Main and Back-up Ultimate Heat Sink
	Design Basis Earthquake + Loss of Off-Site Power + Loss of Main Ultimate Heat Sink
	Station Black Out (no loss of alternate power) + Loss of Main Ultimate Heat Sink
	Total Station Black Out + Loss of Main Ultimate Heat Sink

Appendix 2 List of abbreviations

AC/DC :	Alternating Current / Direct Current
A&NP :	Assets & Nuclear Projects
Bel V :	Technical Support Organization of the FANC
BEST :	Belgian Stress Tests
CNT :	Centrale Nucléaire de Tihange (Tihange NPP)
DBE :	Design Base Earthquake
DBF :	Design Base Flood
DE :	(Bâtiment de) Désactivation (Wet spent fuel storage building)
ECNSD :	Electrabel Corporate Nuclear Safety Department
ENSREG :	European Nuclear Safety Regulatory Group
ENISS :	European Nuclear Industry Safety Standards
FANC :	Federaal Agentschap voor Nucleaire Controle / Federal Agency for Nuclear Control
IAEA :	International Atomic Energy Agency
IATA :	International Air Transport Association
JCO :	Justification for Continued Operation
KCD :	Kerncentrale Doel (Doel NPP)
LCO :	Limiting Conditions for Operation
LOOP :	Loss of Offsite Power
LUHS :	Loss of Ultimate Heat Sink
NCM :	Non-Conventional Means
NPP :	Nuclear Power Plant
NRC :	Nuclear Regulatory Commission
PSR :	Periodic Safety Review
PWR :	Pressurized Water Reactor
RLE :	Review Level Earthquake
R.O.B. :	Royal Observatory of Belgium
SAM :	Severe Accident Management
SBO :	Station Blackout
SCG :	Splijtstofcontainergebouw (Dry spent fuel storage building)
SFP :	Spent Fuel Pool
SG :	Stoomgenerator
SG&H :	Simpson, Gumpertz & Heger
SMA :	Seismic Margin Assessment
SMR :	Seismic Margin Review
SOER :	Significant Operating Experience Report
SQUG :	Seismic Qualification Utility Group
SSC :	Systems, Structures and Components
TE :	Tractebel Engineering
TOC :	Table of Content
UHS :	Ultimate Heat Sink
WAB :	Water- en Afvalbehandeling (Water and waste treatment)
WANO :	World Association of Nuclear Operators
WENRA :	Western European Nuclear Regulators' Association