Belgian stress tests

National report on nuclear power plants

Man-made events

This national report is issued by the Belgian regulatory body as part of the the programme of stress tests carried out on Belgian nuclear power plants following the accident at Fukushima-Daiichi.

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Introduction

Belgium has seven nuclear reactors intended for the production of electricity situated on two distinct sites:

- The site at Doel, situated on the banks of the Scheldt near Antwerp (Flanders), comprises four reactors:
    - Doel 1/2: twin units, each of 433 MWe, commissioned in 1975,
    - Doel 3: unit of 1 006 MWe, commissioned in 1982,
    - Doel 4: unit of 1 039 MWe, commissioned in 1985,
- The site at Tihange, situated on the banks of the Meuse near Liège (Wallonia), comprises three reactors:
    - Tihange 1: unit of 962 MWe, commissioned in 1975,
    - Tihange 2: unit of 1 008 MWe, commissioned in 1983,
    - Tihange 3: unit of 1 054 MWe, commissioned in 1985,

These installations are operated by ELECTRABEL, a subsidiary of the GDF-SUEZ Group.

Following the accident that occurred on 11 March 2011 at the nuclear power plant at Fukushima-Daiichi, the member states of the European Union set up a comprehensive reassessment programme on the safety of nuclear power plants situated on its territory.

This programme of stress tests is intended to reassess the safety margins of European nuclear power plants in the event of extreme natural events (earthquakes, flooding, etc.), in order to draw the appropriate lessons.

In addition, the Belgium regulatory body extended the scope of the assessments to other potential threats related to human activities (toxic or explosive gases, shock waves) and malicious acts (computer hacking, aircraft crash), in order to draw up a comprehensive review of the safety of the installations.

As these man-made events are not part of the European programme of stress tests, they are reported in this separate national report, which will not be subject to peer review at an international level.

The Belgian programme of stress tests covers ELECTRABEL's seven nuclear reactors, (including the spent fuel storage pool for each), as well as two mutualised spent fuel storage facilities on each site:

- the SCG building at Doel (dry storage in containers),
- and the DE building at Tihange (wet storage pool).

According to the specifications of the Belgian stress tests relating to "man-made events", the programme of stress tests in Belgium consists of two consecutive phases:

- Phase 1: Execution of stress tests (deadline: 31.10.2011).
  The licensee carries out the stress test within their installations and records the results in the technical reports which are submitted to the Federal Agency of Nuclear Control (FANC).
- Phase 2: Analysis of the results at a national level (deadline: 31.12.2011).
  In partnership with its technical subsidiary Bel V, the FANC studies the reports, evaluates the approach adopted and analyses the results obtained. The FANC shall draw up a national report on this basis.

Phase 1 of the programme of stress tests ended on 31 October 2011 and the licensee fulfilled its obligations within the time frame. The final reports drawn up by the licensee on the sites of Doel and Tihange include a (public) component on "man-made events". Some aspects of this analysis of man-made events however remain secret on security grounds (act of 11 December 1998).

Phase 2 of the programme was realised by experts from the FANC and Bel V. They assessed in detail the reports in order to judge the quality of the argument and the validity of the results given by the licensee. Technical meetings and targeted site inspections were scheduled as needed to confirm the validity, relevance and robustness of some data and hypotheses considered by the licensee in its studies. The process culminated in the drafting of this national report on "man-made events".

In line with Belgian specifications for stress tests, the Belgian national report on man-made events covers the following risks:

- Accidental or intentional aircraft crash;
- Toxic and explosive gases and shock waves;
- Cyber attack

To provide a self-supporting national report, the relevant data provided by the licensee in its reports on stress tests have been summarised. The assessment made by the Belgian regulatory body (FANC and Bel V) is provided at the end of each chapter.

The actions proposed by the licensee and the additional improvements requested by the regulatory body shall be implemented within the shortest possible period, given the complexity of the works to be carried out and their importance to the safety of the installations. To this end, the licensee will update a consolidated action plan and will propose a schedule which will be discussed with the regulatory body.

Subsequently, the regulatory body will establish a specific follow-up of the implementation of this action plan. This will notably include:

- Regular updates from the licensee regarding the progress of the action plan;
- Periodic information meetings between the regulatory body and the licensee in order to discuss the progress of the action plan and any difficulties/delays;
- Site inspections carried out by the regulatory body on a periodic basis also after the completion of the main achievements, in order to verify the progress on the works on site and compliance with the expectations.

Thanks to this follow-up, the regulatory body monitors the proper execution of the action plan by the licensee and the fulfilment of its commitments within the deadlines.

In the framework of the policy of transparency of the regulatory body, this national report will be made available to the public and media on its website (http://www.fanc.fgov.be).

1. Aircraft crash (accidental or intentional)

1.1. Reassessment carried out by the licensee in the framework of the stress tests

A comprehensive reassessment of the risk of aircraft crashes due to terroristic origins on the units of the sites at Doel and Tihange had already been carried out by the licensee in 2002-2004, in response to the events of 11 September 2001 in the United States.

In the framework of the programme of stress tests, the licensee has reviewed the available studies and extended their scope, notably with regard to the loss of electrical power sources and the loss of heat sink for the units, as well as the simultaneous loss of various installations if an aircraft would slide over a certain distance.

Additional measures intended to improve safety in the event of an aircraft crash were then proposed.

1.2. Main results presented by the licensee

Generally speaking, the results presented by the licensee are common to the two sites at Doel and Tihange.

Analogous to the approach provided in the European programme for stress tests, special attention was paid to the risk of the loss of safety functions in the nuclear power plants (electrical power sources and heat sink) as a result of an aircraft crash (and not due to extreme natural events as in the European stress tests programme).

Based on the information included in the licensee's reports and additional information provided by it at the technical meetings and site inspections, the main results regarding "aircraft crashes" are as follows:

- The potential consequences of an aircraft crash on the safety functions of the nuclear power plant (maintaining the sources of cooling and power) have been analysed. For the different scenarios considered (glide path and angle of the attack or crash), the potential impact of the aircraft on important installations (e.g. electrical buildings, high voltage substations, auxiliary cooling towers, etc.) was studied. The reactors each have two levels of safety systems that ensure the safety functions: the first level safety systems protects the unit from incidents and accidents of internal origin and the second level provides protection from external events. The second level emergency systems are located in bunkered buildings that are geographically separate from the first level safety systems. Consequently, it is almost impossible for an aircraft crash to cause the simultaneous loss of the systems of both levels.

- The reactor buildings of the most recent units (Doel 3 and 4, Tihange 2 and 3), are equipped with a double concrete containment and can therefore withstand the impact of an aircraft without damage to the primary circuit.

- For the reactor buildings of the oldest units (Doel 1/2, Tihange 1), significant damage to the external concrete structure, with the possibility of projectiles penetrating into the containment, cannot be excluded. However, damage to the containment, does not necessarily imply damage to the primary circuit, or to the cooling and back-up systems, given

the additional protection provided by the numerous concrete structures present within the reactor building.

- The spent fuel storage pools have a low vulnerabitily to aircraft crashes, given the thickness of the concrete walls of the spent fuel pools and their location very near to the ground. A way to replenish the pools with water in the event of cracks in the foundation of the spent fuel pools is being studied for the Doel 1/2 and Tihange 1 units.

- The implementation of additional physical obstacles of sufficient height (pylons...) around the sites is being studied to intercept an aircraft at low altitude, which would both avoid a direct impact on sensitive installations and result in the loss of kerosene fuel outside the buildings.

- Fire-extinguishing equipment is available at each site to combat a kerosene fire. Evaluations are currently in progress to optimise the capacity of the equipment for extinguishing a kerosene fire.

- For the Tihange 1 unit a study is undertaken for the construction of a new "bunkered" building resistant to an aircraft crash and which would house the second level emergency systems.

1.3. Results of the evaluation of the licensee's reports

The approach taken by the licensee to review the aircraft crash risk corresponds to the methodology previously approved by the regulatory body.

It is very unlikely for an aircraft to accidentally crash into a nuclear power plant.

However, in Belgium a high level of protection against aircraft crashes was provided for recent nuclear installations and measures improving the safety in the older nuclear power plants were realised, particularly during the periodic safety reviews. Nevertheless it is not possible to realise technical improvements in the plants to guarantee total resistance against terrorist attacks as seen at the World Trade Center. In accordance with international practice, terrorist aircraft crashes are part of a certain residual risk.

If one of the Belgian nuclear power plants should suffer an attack similar to that of 11 September 2001, the "emergency plan for nuclear risks on the Belgian territory" would be initiated.
Given the construction of the Belgian nuclear power plants on the one hand, the design of which incorporates the concept of defence in-depth, and, on the other hand, the measures provided in the framework of a nuclear emergency plan, the regulatory body consider that in the event of a terrorist attack, it would be very unlikely for the aircraft to damage the critical parts of the plant and that the radiological consequences for the population and the environment, if that should occur despite everything, would remain within acceptable limits.

Several factors are important to limit the probability of the occurrence and potential consequences of the direct impact of an aircraft on the critical parts of a nuclear power plant:

- All the reactors have two levels of safety systems: The first level provides protection against internal incidents and accidents and the second level protects against external risks. The second level emergency systems are located in bunkered buildings that are geographically separate from the first level safety systems. Therefore it is almost impossible for an aircraft crash to cause the simultaneous loss of both protection levels.

- Buildings that house potentially critical targets are relatively small in size, notably when compared to the targets of the 11 September 2001 attacks.

- To penetrate the reactor building, the impact must occur at high speed. However, the higher the speed, the more difficult or even impossible it is to hit a relatively small target (like the reactor building) at a critical point such that serious damage is caused.

- Multiple structures within the building (concrete structures) and around it (high voltage pylons, adjoining buildings) mean that it is practically impossible to damage a potentially critical system.

Detailed analysis of the reports of the licensee and subsequent technical meetings and site inspections by the regulatory body result in the conclusion that the approach presented and the resulting action plan for improvement are adequate.

In general it is important to provide, on the one hand, additional measures to prevent potentially critical targets from being reached by optimally placing obstacles as already proposed by the licensee and, on the other hand, by reinforcing corrective and mitigating measures in the event of an aircraft crash, whether deliberate or accidental.

The regulatory body has identified additional requirements to further strengthen the robustness of the units and the site against the risk of an aircraft crash:

1. The **emergency plans and procedures** for each unit shall be extended with the specific measures required to respond effectively to an aircraft crash at the site. For example, the "Response strategy in the case of an aircraft threat" directive shall be entirely integrated in the emergency plan procedures. Special emergency plan drills shall be organised to simulate an aircraft crash.

2. The licensee shall consider the **means** for the management of an aircraft crash (kerosene fire extinguishing equipment, obstacles, water supply to the spent fuel pools) as safety relevant equipment when they serve to mitigate the consequences of an aircraft crash. In this context, the licensee shall determine the specific provisions applicable to this type of equipment (inspections and tests, preventive maintenance, etc).

3. The "**Extensive damage mitigation guidelines**" of the US Nuclear Regulatory Commission, formulated in response to the events of 11 September 2001 and which also provide for the use of non-conventional emergency means in the event of an aircraft crash or major fire, shall be viewed as a basic reference for implementation in Belgian NPPs. Based on a comparison of the existing non-conventional emergency means and these EDMG guidelines, necessary improvements shall be made.

2. Toxic or explosive gases, shock waves

2.1. Reassessment carried out by the licensee in the framework of the stress tests

The reassessment of risks related to toxic or explosive gases, as well as the formation of a shock wave, is essentially based on the studies that were carried out in the framework of the periodic safety reviews of each unit .

Events and combinations of events that may result in dangerous situations were reassessed during the most recent periodic safety reviews, by considering the different hazard sources present within an 8 km radius around the nuclear power plants:

- toxic or explosive products transported or stored in the vicinity of the sites: industrial installations, tubes and pipelines, transport on waterways, railways and roads;
- toxic or explosive products stored on site.

Subsequently, the robustness of the installations against the considered hazards is analysed and the appropriate actions for improvement were proposed, in so far as necessary, to guarantee control of the units.

2.2. Main results presented by the licensee

Based on the information included in the licensee's reports and additional information provided by it at the technical meetings and site inspections, the main results regarding "toxic and explosive gases and shock waves" are as follows:

- Arrangements are in place to protect control personnel of the units in the event of a release of toxic gas on the site. These means include notably gas detectors in the ventilation ducts, isolation systems of the supply of external air or personal protective equipment (filtration or isolation masks) in sufficient numbers;

- "Bunkered" buildings (reactor buildings, buildings containing the spent fuel storage pools, emergency buildings) are designed to withstand the 'reference explosion outside the building', as well as the associated projectiles;

- Some of the bunkered and non-bunkered buildings are equipped with gas detectors in the ventilation ducts that make it possible to give protection from the intake of explosive gases into the building.

In addition, the licensee indicates to have the intention to install additional toxic gas detectors at the site in Doel.

2.3. Results of the evaluation of the licensee's reports

The approach adopted by the licensee for review of the risk of toxic or explosive gases and shock waves responds to the methodology proposed and approved beforehand by the regulatory body.

Detailed analysis of the reports of the licensee and the subsequent technical meetings and site inspections carried out by the regulatory body resulted in the conclusion that the approach adopted and the action plan for improvement that resulted from the review are adequate.

The regulatory body has however identified additional requirements aimed at further strengthening the robustness of the units and the site against the risks of the spread of toxic or explosive gases and shock waves:

1. The **habitability of the control rooms** (main and emergency control room): the personnel in the control room shall be able to remain at their post, especially in an emergency, while being sufficiently protected particularly against the intake of a toxic, explosive or radioactive gas cloud. To this end, the control room area of each unit shall be guaranteed to be airtight (to external air); this provision shall be accompanied by the implementation of adapted and effective measures to detect the presence of external atmospheric pollution and isolation systems for the ventilation in the rooms concerned if so far necessary to realise their air-tightness. To this end, the regulatory body demands an improvement of the following specific aspects:
    - Emergency control room at Doel 1/2: protection from toxic gases;
    - Main control room at Tihange 1: automatic isolation of the ventilation in the event of the detection of toxic gases;
    - Main control room at Doel 1/2: reinforcement of the air-tightness.

2. The regulatory body also demands that the licensee performs a more extensive assessment of the long-term habitability of the **rooms** that will be occupied according to the **emergency plan**. For this purpose, it shall take sufficient account of situations in which the emergency plan shall cover multiple or all installations at a site. The assessment of the habitability of the rooms shall address all aspects (in particular the radiological risk and the toxic gases). This requirement applies to all units.

3. In addition to the analyses carried out, the regulatory body demands that the licensee examines the consequences of serious events (such as an earthquake) for which it is impossible to exclude a release into the environment of multiple toxic or explosive gases resulting from a **multiple failure of the storage vessels** of industrial installations near the sites and that may threaten the habitability of the vital rooms or seriously complicate the implementation of the measures in the emergency plan. The licensee is asked to propose a methodology to evaluate the risk in this regard.

4. **Monitoring the evolution of the industrial environment around the sites:** the licensee shall carry out active monitoring of new industrial applications and of transport developing around the sites, it shall review the risks as appropriate and provide for adequate responses if necessary or bring it to the attention of the regional or federal authorities. Restrictions on land use around the sites shall also be proactively discussed between the licensees, the regulatory body and the regional public authorities in order to prevent increasing the risks in the vicinity of the installations.

5. The ventilation systems of the buildings at Doel 1/2 and Tihange 1, as well as the buildings housing the first level safety systems at Doel 3 and 4 and Tihange 2 and 3 are not equipped with **explosive gas** detectors. The licensee shall carry out an evaluation and, if necessary, a feasibility study for the installation of explosive gas detectors that serve to isolate the ventilation and thereby to prevent any intake of explosive gas into the building.

3. Cyber attack

3.1. Reassessment carried out by the licensee in the framework of the stress tests

The licensee has analysed the risks relating to four types of cyber attack:

- external attack, from outside the company office network,
- off-site attack, via the company office network,
- on-site attack, via the units's company office network,
- on-site attack, through direct physical access to the computers and systems on the unit's networks.

The licensee then studied the possibilities of the loss of control of the plant by the licensee, given existing safety provisions.

3.2. Main results presented by the licensee

Based on the information included in the licensee's reports and additional information provided by it at the technical meetings and site inspections, the main results regarding "cyber-attacks" are given in the following paragraph.

The licensee indicates that the loss of safety functions of the nuclear power plants resulting from cyber attack is impossible, because:

- the reactor control and reactor protection systems are not connected either to the units's office network, or the company network;
- almost all the reactor control and reactor protection systems use an analogue technology via wires that is not vulnerable to cyber attack;
- provisions are in place (including physical protection) to protect IT systems that support safety functions;
- a programme of improvements has been implemented to increase the level of security.

3.3. Results of the evaluation of the licensee's reports

The approach adopted by the licensee for reviewing the risk of the loss of safety functions at the nuclear power plants of Doel or Tihange following a cyber-attack responds to the methodology proposed by the licensee and approved by the regulatory body.

Detailed analysis of the licensee's reports resulted in the conclusion that the approach presented is satisfactory as its conclusion, according to which a cyber-attack could not cause the loss of safety functions at Belgian nuclear power plants, is consistent with engineering judgment.

The licensee has an IT security strategy comparable to that of other companies aware of the habitual risks of sensitive systems (segmentation of networks based on access via firewalls, monitoring, hardening of systems, prevention of malwares, procedures, training, etc.).
Nevertheless, cyber-security aspects are continuously developing and the technologies related to it are constantly evolving, which implies that the security aspects shall be verified regularly. In the specific case of the nuclear industry, IT and ICS (Industrial Control Systems) are less available than in other industries and hence less subject to change.

More specifically, the risks of cyber-security shall be checked carefully:

- Vulnerability/the risk increases more as the IT of the installations is modernised.
- Vulnerability/the risk increases with the increase of subcontracting. This risk is partly managed by the development of internal regulations for external contractors.
- The vulnerability of industrial systems of the SCADA type (Supervisory Control and Data Acquisition) type increases as new malware appears that is developed to attack these systems.

However, the regulatory body has identified an additional aspect by which it would be desirable to strengthen the robustness of the plant and the site against cyber-attacks.

The majority of the safety functions rely on analogue technology and only a small part of the equipment uses digital and computer-based technology. As new digital and computer-based technologies are increasingly used, the regulatory body recommends to perform, with the assistance of IT experts, a security evaluation on the premises of the licensee. The purpose of this **independent external audit** shall consist of verifying the measures that in order to decrease the risks against cyber-attacks, are applied by the licensee to computer-based safety functions. Independent IT security standards (ISO, COBIT or others) shall make it possible to measure the security against objective criteria that are verified by third parties (external audit) as is the practise for industrial processes other than IT.