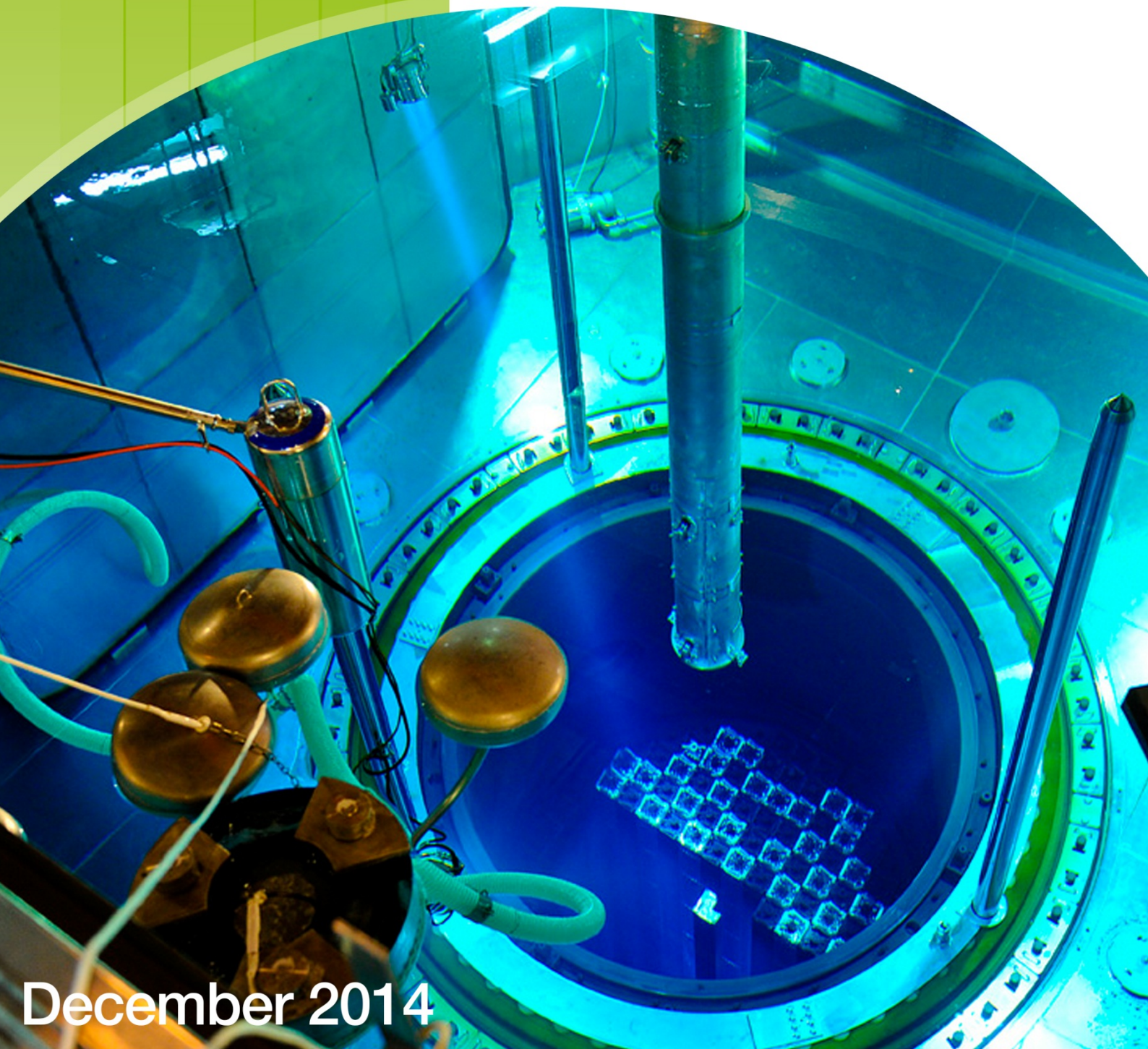
BELGIAN STRESS TESTS

FANC

federal agency for nuclear control

National progress report on the stress tests of nuclear power plants



December 2014

For the sake of transparency, the Federal Agency for Nuclear Control will publish an annual report on the progress of the stress test action plans. This report provides an overview of the actions undertaken by the licensee in 2014 to enhance the protection of the Belgian nuclear power plants following the Belgian stress tests, and their follow-up by the regulatory body.

This progress report is an update of the previous progress report which was published in early 2014.

1. Introduction

Belgium has seven pressurized water reactors operating on two different sites:

- Four reactors on the Doel site, close to Antwerp (Flanders), located on the Scheldt river:
  - Doel 1/2: twin units of 433 MWe each, commissioned in 1975,
  - Doel 3: single unit of 1 006 MWe, commissioned in 1982,
  - Doel 4: single unit of 1 039 MWe, commissioned in 1985.

- Three reactors on the Tihange site, close to Liège (Wallonia), located on the Meuse river:
  - Tihange 1: single unit of 962 MWe, commissioned in 1975,
  - Tihange 2: single unit of 1 008 MWe, commissioned in 1983,
  - Tihange 3: single unit of 1 054 MWe, commissioned in 1985.

Both sites are operated by the same licensee, Electrabel, a company of the GDF-SUEZ energy and services Group.

For all matters related to nuclear safety, the licensee's activities are under the control of the Belgian regulatory body[1], which consists of:

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

As a consequence of the accident that occurred on 11 March 2011 at the Japanese Fukushima-Daiichi nuclear power plant, a wide-scale targeted safety reassessment program was set up among the member states of the European Union operating nuclear power plants.

This "stress tests" program is designed to re-evaluate the safety margins of the European nuclear power plants when faced with extreme natural events (earthquake, flooding and extreme weather conditions) and their potential consequences (loss of electrical power and loss of ultimate heat sink), and to take relevant action wherever needed. The approach is meant to be essentially deterministic, focusing on preventive as well as mitigative measures (severe accident management).

The scope of the Belgian NPP stress tests covers all seven reactor units, including the associated spent fuel pools, the dedicated spent fuel storage and the waste management facilities at both sites, namely:

[1] Additional information about the Belgian regulatory body and nuclear facilities is available in the 2014 report for the Convention on Nuclear Safety, which was published on the FANC website (http://www.fanc.fgov.be).

- "SCG" building at Doel (dry cask spent fuel storage facility),
- "DE" building at Tihange (wet spent fuel storage facility),
- "WAB" building at Doel (Water and Waste treatment building).

Similar stress tests have been performed in Belgium for the non-NPP nuclear facilities. The results of these tests are presented in other reports from the regulatory body, available here and here. The Water and Waste treatment building (WAB) at Doel, which includes equipment for the processing, storage and handling of liquid effluents and solid radioactive waste, is featured in this report, even though it was originally part of the stress test for the other Belgian nuclear facilities. But since Electrabel, the operator and license holder of the WAB, has integrated the action plan for the WAB into the global action plan for nuclear power plants, the regulatory body has chosen to include the WAB building in this report.

In accordance with the European methodology, the stress tests of the nuclear power plants are performed in three phases:

1. The licensee performs stress tests in its facilities and submits a final report to the Belgian regulatory body (in the present case, one final report per site). In these reports, the licensee describes the reaction of the facilities when facing the different extreme scenarios, and indicates, where appropriate, the improvements that could be implemented to reinforce safety. The licensee completed this phase on 31 October 2011.

2. The regulatory body reviews the licensee's final reports and evaluates the approach and the results. Based on these data, the regulatory body writes its own national report and communicates it to the European Commission. This phase was completed by the regulatory body on 30 December 2011.

3. The report of all national regulatory bodies participating in the stress tests program is subject to an international peer review. The national reports are reviewed by other regulatory bodies representing 27 European independent national Authorities responsible for the nuclear safety in their country. This phase was completed by ENSREG on 26 April 2012. A follow-up meeting is to be organized in 2015 to present the developments of the stress test action plans.

The resulting national action plan synthetizes all actions undertaken by the licensee as a result of the stress tests program. Until full implementation, this action plan is updated regularly.

Some of these actions have been amended or cancelled because the remaining operating lifetime of the units made them irrelevant. This was the case for the actions planned for the Doel 1 and Doel 2 units. In 2012-2013, the Belgian government decided to cease the operation of these two reactors in 2015. As a consequence, the Stress Test action plan was amended for these two reactors so that it no longer included those actions that had become unnecessary in the light of the shut-down and decommissioning plans. However, on December 18th 2014, the Belgian government decided to no longer oppose a 10-year life extension for these two reactors. Since the licensee Electrabel had still not officially requested this Long Term Operation (LTO) by the end of 2014, the Belgian Federal Agency for Nuclear Control (FANC) did not take a stance on the possibility of an authorization for this life extension. As a resutl, at the end of 2014, the official reference scenario for these two reactors remains a permanent shut down by 2015, and the Stress Test action plan has not yet been modified.

The target dates mentioned in the action plan must be considered “indicative”, given the fact that some actions might face time constraints due to interactions with other projects (LTO Tihange 1, PSR, etc.) and depend on internal or external resources for their on-site supply and implementation.

Upon demand of the Belgian Federal Government, terrorist attacks (aircraft crash) and other man-made events (cyber-attack, toxic and explosive gases, blast waves) were also included as possible triggering events in the stress tests program for the nuclear power plants, even though the assessment of these man-made events does not fall under the scope of the European stress tests programs. For security reasons, the progress on specific actions related to man-made events is not included in this report.

2. Development of the national stress test action plan

The national action plan was drafted and updated progressively in accordance with the stress tests program, and is still liable to modifications.

The licensee's action plan was amended several times to take into account the requirements and recommendations resulting from the on-going stress tests and from consultation with several interested parties on a national and international level.

a) Licensee's initial action plan

A self-assessment led the licensee to identify a set of safety improvements, which were presented in the licensee's final reports released in October 2011. The proposed actions pursued the following main objectives:

- Topic 1 (extreme natural events):
    - enhanced protection against external hazards (earthquake, flooding, extreme weather conditions).
- Topic 2 (loss of electrical power and loss of ultimate heat sink):
    - enhanced power supply,
    - enhanced water supply,
    - enhanced operation management (procedures),
    - enhanced emergency management (on-site),
    - non-conventional means (NCM).
- Topic 3 (severe accident management) :
    - enhanced protection against severe accidents (SAM).

Overall, the indicative deadlines proposed by the licensee for the implementation of the actions were in line with the importance of the issues. They also took into account the complexity of the actions, the dependence on internal or external resources for supply and implementation, and the potential interactions with other projects (especially the "LTO" project for the oldest units).

By the end of year 2011, a number of short-term actions had been implemented already. The majority of the remaining actions was to be implemented in 2013 and 2014. By the end of 2014, however, 113 out of 366 actions are still not completed, while 253 out of 366 actions have been completed by the licensee and are at various levels of review by the Belgian Regulatory Body.

b) Regulatory body review

The regulatory body reviewed the licensee's final reports and approved the proposals made by the licensee, but also identified some opportunities for additional improvement, for which it expected relevant actions. These were detailed in the national report, released in December 2011.

Furthermore, the regulatory body asked the licensee to complete a few specific actions earlier than planned, because of their importance for the improvement process. The licensee's action plan was updated accordingly.

On 15 March 2012, the licensee submitted a detailed stress tests action plan, including the additional requirements of the regulatory body mentioned in the national stress tests report. This plan identified a total of 350 individual actions.

c) International peer review

The subsequent international peer review of the national stress tests reports, supervised by ENSREG, provided further improvements, not only on a national level but also on the European level. One of the objectives of the peer review was to share relevant findings and to benefit from the best practices and insights found in other countries, in order to further improve safety. ENSREG issued a number of suggestions in a peer review report and a peer review country report released in April 2012, followed by a compilation of recommendations and suggestions released in July 2012.

Analysis of these documents led to addition of several actions to the licensee's action plan. Most of the recommendations based on practices in other countries were already being implemented in the Belgian units or were already featured in the action plan.

After the integration of the additional actions resulting from the ENSREG peer review, the FANC formally approved the consolidated version of the licensee's action plan on 25 June 2012.

d) Current national action plan

The content of the current national action plan (updated in December 2014) is the result of the various inputs described above.

3. Status of the stress test actions

For the purpose of readability, this report does not list the status of all actions. In the followings paragraphs, only the major actions are highlighted. The present 2014 Progress Report is primarily an update of the 2013 Progress Report.

3.1. Enhancement of the protection against external hazards

The stress tests of the Belgian nuclear power plants comprised an extensive reassessment of the protection of the nuclear reactors against seismic and external-flooding hazards as well as extreme meteorological conditions. In its final stress test report, ENSREG recommends that the return frequencies of the dimensioning hazards be decreased to 10E-4 per annum. The nuclear reactor protections need to be improved in order to resist a 10,000-year beyond-design flood or a 10,000-year seismic hazard.

An analysis of the stress test results revealed that several actions were necessary to enhance the protection against external hazards.

3.1.1. Earthquake

In order to assess the **adequacy of the design basis earthquake** (DBE), the Royal Observatory of Belgium (ROB) performed a first seismic risk assessment in 2011.

For the NPP Doel 3 and Doel 4, the obtained results still conformed with the values used in the design basis. Because of their imminent shutdown, Doel 1 and Doel 2 were not assessed for this aspect.

For the Tihange NPP, the assessment resulted in the finding of a greater peak ground acceleration ("PGA") than was presumed when designing the facilities. The assessment is currently being completed and consolidated, so there is no definitive conclusion on the adequacy of the DBE yet. Nevertheless, the safety margin assessment performed during the stress tests has demonstrated that the equipment is more robust than required by the **design basis earthquake**.

Due to the stringent timeframe of the European stress tests, the PSHA study of the ROB had to be conducted in quite a short time. As suggested by the Royal Observatory of Belgium, the Regulatory Body requested the licensee **to carry out a more elaborate study** with due consideration of:

(1) other elements such as the use of a more recent ground-motion prediction equation or such as a cumulative absolute velocity ("CAV") filtering,
(2) external reviews by international experts and
(3) results from other international studies.

This reevaluation of the seismic hazard is currently still in progress and on schedule. The licensee Electrabel plans to have the final report ready by early 2015.

The **safety margin assessment** for the Doel and Tihange units was performed on the basis of a review level earthquake ("RLE") as high as 1.7 time the peak ground acceleration (PGA) of the current design basis earthquake. It showed that the Systems, Structures and Components ("SSC") required for achieving and maintaining a safe shutdown state are robust enough, except for a few mechanical and electrical elements that have a low or moderate probability to resist a RLE. More information on the definition of the probability levels can be found in the Belgian Stress Tests - National Report for the Nuclear power Plants on the FANC website. Further justifications or improvements of these SSC through easy-to-implement modifications were realized in 2011 and 2012.

Other actions to enhance the protection of the NPPs against seismic hazards are still ongoing:

- The stress tests have highlighted that 28 **Structure, Systems and Components** (SSC) of Doel and Tihange have a low probability of resisting an earthquake exceeding the "Review Level Earthquake" (RLE). 22 SSCs were identified at Tihange 1, 3 at Tihange 2, 1 at Doel 1/2, 1 at Doel 3 and 1 at Doel 4. Following the stress tests, the licensee has committed to either confirming that the current margins are sufficient by means of more precise calculations, or raising these SSCs to a high probability of resisting an RLE by means of corrective actions. The licensee completed most modifications in 2013; the final modifications in Doel and Tihange were completed in 2014.
  In 2013, the regulatory body has begun their review process of the action reports submitted by the licensee. This review is finished now

  At Tihange 1, the licensee classified the **Electrical Auxiliary Building** (BAE) as having a medium probability to resist a RLE. Although a medium probability is acceptable in the context of the stress tests, the licensee committed to evaluating the feasibility of raising the BAE to a high probability of resistance. This feasibility study showed that the actions necessary to do this are technically difficult or impossible. Nevertheless, there remain some specific and feasible improvements that could be considered. Since the BAE is specific to Tihange 1, its improvement has been incorporated in the action plan for the Long Term Operation of this reactor. The improvement works are being carried out within the framework of the extension of the Emergency System Building ("Système d'Ultime Repli Eténdu"), aiming at extending the plant capability to go to safe shutdown in case of common-cause-failure scenarios affecting either instrumentation and control, or electrical sources (such common-cause failures can result from a fire in the BAE building, possibly induced by an earthquake).

- In Doel, the licensee planned to check the seismic qualification of the Refueling Water Storage Tank (RWST) of Doel 1/2 and its piping to establish whether it complied with the RLE level. However, when the Belgian government decided in 2013 to permanently shut down these two nuclear reactors in 2015, the Regulatory Body deemed it unreasonable to still demand the implementation of this action. At the end of 2014, debates on the permanent shut-down of Doel 1 and 2 were re-opened again, so it is possible that the regulatory body will demand implementation of this action after all, as part of the Long Term Operation requirements.
- Similarly, most actions that had to be implemented at Doel 1 and Doel 2 in the context of the stress test action plans (e.g. improving the reliability of the water supply to the steam

generators) were originally scheduled to be integrated into the Long Term Operation of these reactors. Following the governmental decision to shut down these two reactors, the licensee was granted permission not to implement these actions. However, if the licensee decides to apply for a Long Term Operation of these two reactors, the regulatory body will need to reconsider its former decision in the upcoming months.

In summary, the main progress made in 2014 for the protection against earthquakes consists of the revaluation of the PSHA study in detail and the completion of the SSC upgrade. The action plan is still on par with the schedule, except for one of the actions for the upgrade of the SSCs against earthquakes, which is slightly delayed.

Figure 1 summarizes the ongoing action plan of the licensee at Doel and Tihange for the enhancement of the sites' protection against seismic hazards. It shows the evolution of the implementation of the action plan between the end of 2013 and the end of 2014. Most of the actions carried out at Tihange concerned an upgrade of the SSCs to a high probability level of resisting to an RLE. The licensee completed most of these actions in 2014. The results have been analyzed by the regulatory body. The remaining actions mostly concern an update of the internal procedures and are almost completed.

In this and all following graphs, the number of actions has slightly increased. This has different reasons. First, and most importantly, the actions performed at the corporate level (Electrabel Brussels) have been added to the graphs. The actions relevant to the two NPPs are shown in both columns. Second, the action plan was slightly adapted in 2014, with a regrouping, restructuring or redefining of some actions. It's important to remind that these graphs have an indicative value as every action is considered to have similar relevance.

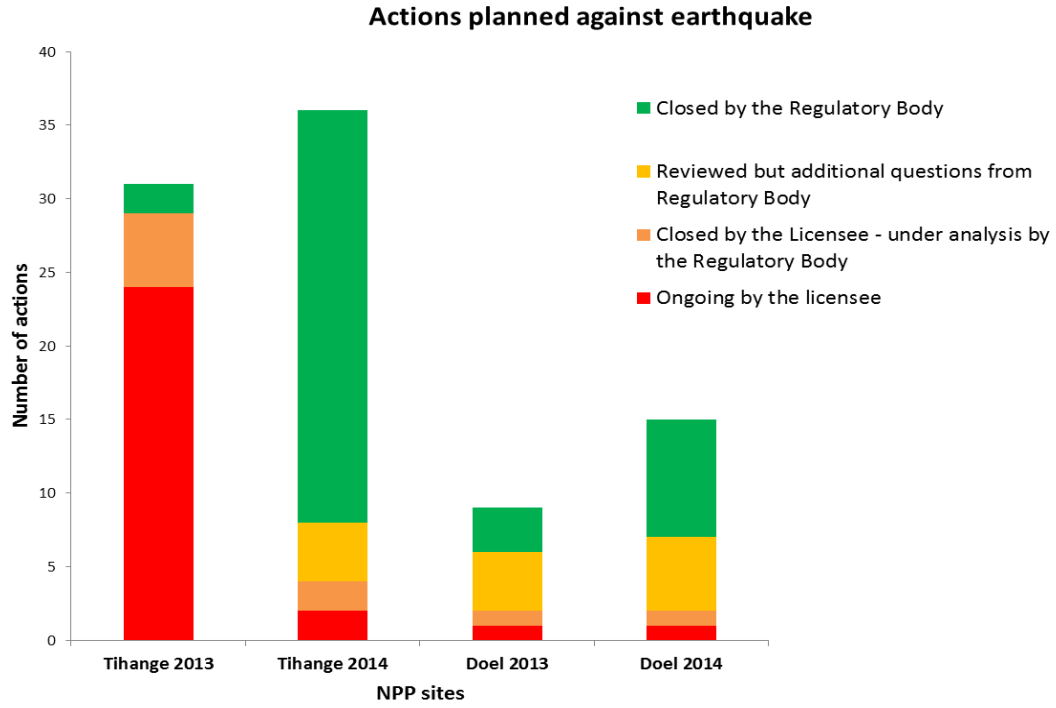


Figure 1: Evolution of the implementation of the actions concerning the protection against earthquakes between 2013 and 2014.

3.1.2. Flooding

Tihange

- During the previous Periodic Safety Review (PSR) in Tihange, a probabilistic methodology was used to determine the flood level of the Meuse as a function of return frequency. One of the conclusions reached shortly before the Fukushima event was that the Tihange site is currently protected by its design against a Reference Flood with a statistical return frequency between 10E-2 and 10E-3 per annum. Nevertheless, so as to comply with the new international standards, it was decided in 2011 to use a more conservative flood corresponding to a 10,000-year flood as the new design basis for the Tihange site. It turned out that the Tihange site could not be considered fully protected against this new Reference Flood. As a result, several actions were proposed in the National Report in December 2011 to enhance the protection against flooding by means of the following additional provisions:

    i. A peripheral protection of the site,
    ii. Some local volumetric protections,
    iii. The mobilization of non-conventional means on site.

  However, further analysis has shown that the implementation of the second level (local volumetric protections) would not provide an infallible protection and would decrease the reliability of the protection strategy against flooding due to the complexity of the interactions with the other levels of protection. The licensee and the Regulatory Body have therefore decided to abandon this second level.

  In 2013, the licensee Electrabel finalized the study phase of the first provision, the **peripheral protection** of the site. A wall, together with isolation devices of water intakes and solutions for discharging cooling and sewer water into the Meuse river, is currently being built to surround the lower areas of the site. As requested by the regulatory body, a safety margin for the wall height to adequately cover uncertainties associated with the new design basis flood was considered. The construction began in October 2013 and should be finalized by June 2015.

  Thus, the year 2014 witnessed some important progress in the construction of the peripheral protection against flooding. By the end of 2014, the peripheral protection (wall, pumping chambers, isolation of the release structures, etc.) was almost completed (see Figures 2 and 3). The licensee plans. According to the licensee's schedule, the civil works will be completed by the end of February 2015 and the mechanical and electrical devices will be ready by June 2015. The licensee expects that the peripheral protection will be ready for commissioning and final reception by September 2015.

Figure 2: Peripheral protection of the site of Tihange against beyond-design flooding

Figure 3: Construction of the water intakes (left) and the outlet pumping chambers (right) of Tihange 2

The last additional provision should protect the site either in case of a flood beyond-design, or when the peripheral protection would fail in protecting the site of Tihange against a flood below or equal to its design value. The **non-conventional means** will be deployed during the flooding alert period. These non-conventional means are situated at least 1 m above the level corresponding to the design flood and consist, among other things, of:

- Additional diesel generators located in new specific buildings,
- Fixed pipes (with a few exceptions of flexible elements),
- Pumps for make-up of water from water tables to the primary circuit, the steam generators and the spent fuel pools.

In 2012, the licensee has decided to reinforce the third level of protection, the non-conventional means (redundant pumps for instance), to compensate for the delay in the

construction of the site's peripheral protection. All the corresponding actions to these non-conventional means were finalized by the licensee in 2013. At the end of 2014, the regulatory body carried out the assessment of the modifications and officially closed the actions linked to this level of protection. This level of protection is now considered fully operational.

- At Tihange, the robustness of the **emergency preparedness strategy** and organization had to be improved. The flooding alert system is based on a direct communication between the SETHY (the regional authority in charge of the protection against flooding) and the NPP. As a conclusion of the stress test analysis, the regulatory body recommended to further improve the robustness and the efficiency of this communication. A convention was signed in 2013 between the licensee and the SETHY to define a collaborative environment, including access to more flow measurements and water levels over the Meuse and an increase of the available instrumentation during a flooding period.
  Moreover, means for on-site transport of personnel and equipment while the site is flooded (amphibious vehicles) are available since June 2012 at Tihange. In 2013, the licensee finalized the implementation of the associated procedures and the organization of the training of the personnel. At the end of 2014, the communication protocols with the SETHY were tested during emergency exercises.

- At Tihange, the internal hazards potentially induced by the flooding were examined, as requested by the regulatory body. The possibility of internal fires and internal explosions was considered. The licensee proposed protective actions, which were judged acceptable by the regulatory body and were then completed.

Doel

The Doel site was already well protected against flooding; it is only under a few specific circumstances that water can intrude into the site. As a preventive measure, sandbags are available to protect the critical entrances. In the framework of the Belgian stress tests, these sandbags were planned to be replaced by permanent volumetric protections. These barriers (cofferdams, etc.) against the flooding were installed at Doel in 2013. In 2014, the regulatory body finalized the assessment and officially closed these actions.

In addition, to enhance the protection of the Doel site against flooding, some actions were carried out on the embankment. To prevent any possible weakening, the licensee reinforced the embankment with concrete tiles in 2013. The licensee also modified the internal procedures to perform embankment inspections more regularly. In 2014, the regulatory body finalized the assessment and closed these actions.

In summary, by the end of 2014, the physical protection against flooding at Tihange is almost finished, while at Doel all required actions to protect the site against flooding have already been completed.
At Tihange, many actions were directly linked to the construction of the peripheral wall (wall construction, PIU [Internal Emergency Plan] procedures, etc.). The rest mainly corresponds to the

implementation of the non-conventional means for beyond-design protection. At Doel, most actions were related to volumetric protection and to reinforcement of the embankment.

Figure 5 summarizes the evolution of the implementation of the actions planned in Doel and Tihange against the flooding hazard between the end of 2013 and the end of 2014. As the status of the big projects (peripheral wall, etc) has not changed in 2014, the status of the action plan has not significantly evolved in 2014.

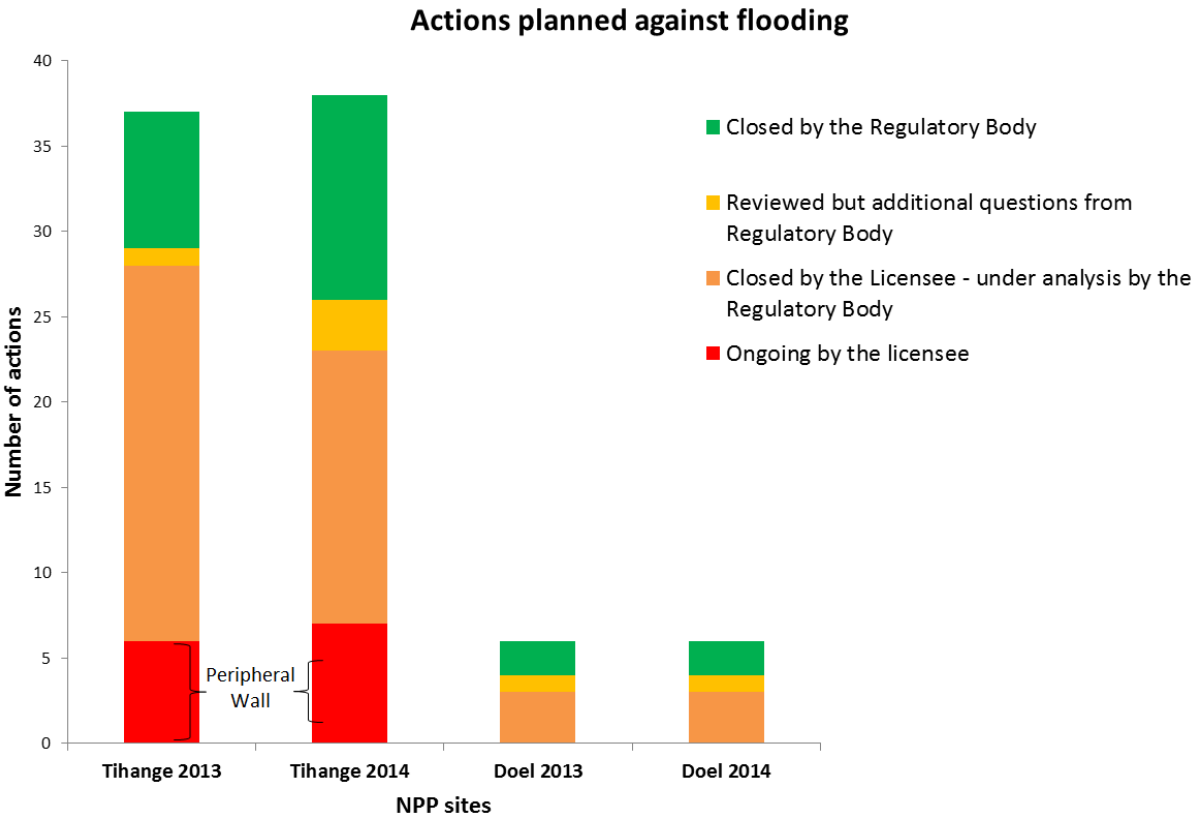


Figure 4 : Evolution of the resolution of the actions concerning the protection against flooding between 2013 and 2014.

3.1.3. Extreme weather conditions

In addition to the earthquake and flooding hazards, the resistance of the sites against extreme weather conditions was evaluated in the framework of the stress tests. Additional hazards like tornadoes, heavy raining, lightning, snowfall, etc. have also been taken into consideration. The stress tests have resulted in a list of actions to undertake in order to enhance the protection of the site.

- The regulatory body recommended reassessing of the capacity of the **drainage systems** (five separate networks at Doel, separate networks per unit at Tihange), using a detailed hydrodynamic model in order to cover both short-duration heavy rains and long-lasting rains. At Doel, the licensee finalized its revaluation of the impact of heavy rains in 2014. The regulatory body is currently assessing these studies for Doel.

At Tihange, important improvements of the sewer systems have to be realized by the licensee during 2015. The related project has been presented to the regulatory body.

- The robustness of the second-level system of Tihange 1 and Doel 1/2 against a beyond-design **tornado** has to be confirmed by the licensee, given the fact that high intensity tornadoes have been observed in the past years in neighboring countries. The licensee Electrabel finalized this action in 2014. The regulatory body is currently making an assessment of these actions.

- At Doel, the assessment of the protection against **lightning** is currently being carried out. Based on this analysis, an action plan will be drafted for the modification of the existing installation. This study is still ongoing in 2014 and will be completed by the end of 2015.

- In 2012-2013, the licensee improved its intervention procedures in case of **heavy snowfall** to remove snow layers of more than 30 cm from "non-bunkered" buildings.

In summary, at the end of 2014, the licensee faced a slight delay compared to the stress test planning for the finalization of the actions to protect the sites against extreme weather conditions. Figure 6 summarizes the ongoing action plan of the licensee at Doel and Tihange. The main progress in 2014 consists in the finalization of the reevaluation of the impact of heavy rains in Doel.

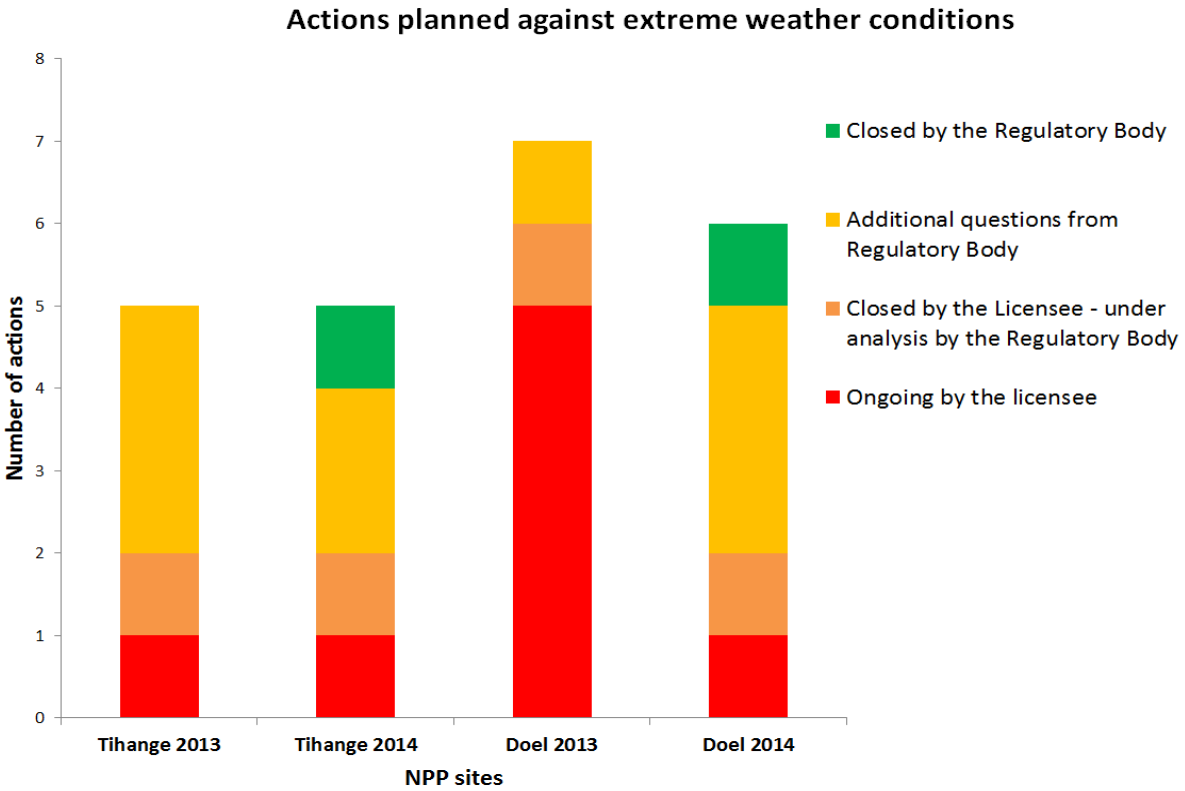


Figure 5 : Evolution of the resolution of the actions concerning the protection against extreme weather conditions between 2013 and 2014.

3.2. Enhancement of the power and the water supply

a) Initial situation on both sites

Tihange NPP

Considering the numerous and redundant power supply sources and heat sinks available, every reactor unit in Tihange has a high level of robustness in this respect. Indeed, every unit disposes of:

- three external power supply sources;
- two independent ultimate heat sinks (river water and alluvial groundwater), and additional access to limestone water that is independent of the alluvial groundwater;
- at least two levels of technically and geographically independent internal sources of power supply (in total, 16 diesel generators and a turbine-driven alternator), with a fuel autonomy of several weeks;
- a turbine-driven safety feedwater pump for each unit;
- and various cooling water capacities.

Furthermore, mobile devices (power generators, flexible hoses, pumps, valves, etc. - some of which are preinstalled) can also ensure power supply of the essential equipment and water supply of the steam generators and the primary system. Their capacity and deployment time have been designed according to the dynamics of the situations that were assessed.

Consequently, the cooling of reactor core and of the spent fuel pools are secured with a high degree of certainty even in very unlikely cases such as the loss of power supply sources or heat sinks. As a result, the risk of significant activity release should these extreme scenarios occur is negligible. In conclusion, the NPP has emergency equipment and sufficient autonomy to manage this kind of hazards for a long time. This time period is sufficient to restore off-site power supply or to bring in off-site resources.

Doel NPP

The Doel 1/2 units can use three independent heat sinks, which are all capable of independently keeping the units cooled:

- the Scheldt river;
- the atmospheric forced draught cooling towers;
- the heat exchangers cooled by the ambient air.

Likewise, the Doel 3 and Doel 4 units can use independent heat sinks which are all capable of independently keeping the units cooled:

- the atmospheric forced draught cooling towers, with supply from the Scheldt river and from cooling ponds;
- 3 cooling ponds of 30 000 m^3 each.

In every unit there are 2 internal electrical power supply levels. These 2 levels function independently from one another and are physically separated. For the power supply of the safety equipment, there are 19 diesel generators with – in total – a few weeks fuel supply. Moreover, most diesel generators are air-cooled, thus making them independent from an external heat sink.
Finally, every unit disposes of a pump, powered by a steam turbine, in order to be able to continue supplying cooling water to the steam generators. This cooling water is available in various tanks and in the cooling ponds.

b) Planned improvements

Nonetheless, some measures are considered to still enhance the robustness of the facilities. More than one hundred actions have been planned in the action plan for the enhancement of the power and the water supply in the Belgian NPPs. The licensee has currently finalized a little more than 50% of these actions. The following paragraphs summarize the progress of the major actions undertaken at Doel and Tihange:

3.2.1. Power and Water Supply

- **Complete Station Black Out (CSBO)**
  CSBO consists in a loss of off-site power supply and first-level and second-level internal power supplies. Compared to the design basis scenario of Station Black-out, this scenario adds the loss of the second-level internal power supplies. As this scenario is a beyond design basis scenario for all Belgian units, the licensee has proposed a set of additional measures to avoid the cliff edge effects.
  The licensee commits to use non-conventional means:
    - to refill the steam generators and the spent-fuel pools,
    - to ensure make-up for the primary circuit in open configuration,
    - to avoid the overpressure in the reactor building,
    - to restore the electrical power supply to instrumentation and control panels, and
    - to make operable the emergency compressed air circuit.

  Therefore, in the action plan, an alternative power supply for non-conventional means or safety equipment has to be implemented on both sites.

  At **Tihange**, the finalization of the installation of this emergency electrical grid is planned for 2016. Indeed in 2012-2013, the licensee Electrabel had to delay several actions related to the CSBO project in order to primarily focus the licensee attention on the flooding project at Tihange. Nevertheless, priority actions have already been executed in function of plant outages.
  The CSBO and the related operation management (see §3.8) are very complex issues. In consequence, the licensee has primarily focused his work on the development of a site global strategy against CSBO. This work has been presented to the Belgian regulatory body and a

design review of the CSBO improvements is planned for early 2015. By the end of 2014, most actions related to the CSBO topic in Tihange are therefore planned for 2016

- Some CSBO actions specific to Tihange 1 unit have been included in the action plan of the Long Term Operation of this reactor and are no more considered in the stress test action plan. Nevertheless, these actions are ongoing and have to be finalized before the second outage of the reactor following its lifetime extension (2016). This is specifically the case for the actions that will enhance the autonomy of the EAS auxiliary feedwater reservoir and will add an auxiliary feedwater pump to Tihange 1.

- To strengthen the power grid of Tihange, the licensee had to study the feasibility of a better geographical separation of the high-voltage lines (150 kV and 380 kV) to further improve the reliability of the external power supply to the NPPs, in collaboration with ELIA (the Belgian high-voltage network manager). In this framework, a request was sent to ELIA in 2013 to add new high-voltage lines from the other side of the Meuse, passing over the river. This solution was not judged realistic by ELIA.

  In addition, the licensee had to make sure, in agreement with ELIA, that in case of a loss of off-site power (black-out), the NPPs of Doel and Tihange have the highest priority for reconstruction of the external power supply to the NPPs. This agreement was finalized in 2013 by the licensee and ELIA.

  At **Doel**, the CSBO strategy is already being implemented. Several actions have been realized by the licensee. In this framework, the delivery of the requested mobile means has begun in 2014 and will finish in 2015. The mobile pumps have already been delivered and the mobile generators are ordered. Nevertheless, some other mobile equipment were temporarily available on the site to assume the needed safety functions since 2013.

Figure 6 : Mobile pumps training at the Doel NPP in the framework of the CSBO strategy

- A procedure to manage the autonomy of the electrical diesel generators was finalized in 2013 by the licensee. This procedure defines which equipment and facilities can be stopped to reduce the diesel and oil consumption of the electric diesel generators to increase their autonomy. Depending on the situation, 33 to 36 pieces of equipment can be stopped (mainly fans and pumps). By the end of 2014, the regulatory body had finalized the review and closed these actions.

- At Doel, the licensee provided a fuel tanker truck in 2013 for the on-site transport of diesel fuel as required in the stress test action plan. By the end of 2014, the regulatory body had finalized the review and closed these actions.

- At Doel, a new fire truck has been provided. This fire truck is multifunctional and can also play the role of a mobile pump. Some exercises have been carried-out in 2014.

Figure 7 : Training of the new multifunctional fire truck at Doel NPP.

At Doel 3 and Doel 4, in the framework of the **CSBO**, the installation of nozzles on the intake and discharge of the spray pumps (SP), and of connections to the emergency cooling (LU) and to the emergency feedwater (EF) systems, was planned in the stress test action plan. These actions include the purchase of mobile pumps in order to achieve alternative water make-ups. Initially planned for the end of 2014, these actions have been delayed to the end of 2015 due to delays in the equipment delivery. However, the installation of connections, which is possible only during the plant outages, is already executed, with the use of temporary taps.

3.2.2. Loss of primary and alternate ultimate heat sink (UHS)

"Loss of primary ultimate heat sink" has been studied in the original design basis of all the Belgian units when one unit is affected by this accident. "Loss of primary and alternate ultimate heat sink" is a beyond design basis accident. To avoid cliff edge effects, several measures have been proposed by the licensee. Some of them are similar to the CSBO measures like the use of non-conventional means to refill the steam generators and the spent fuel pools, to ensure make-up for the primary circuit in open configuration or to avoid the overpressure in the reactor building.

- In the framework of the UHS scenario, the regulatory body has requested for Tihange 2 and 3 to carry out alignment and operating tests of the emergency deep water intakes from the Meuse river and to justify the availability of the emergency intakes in accordance with the requirements of US NRC RG 1.27. The related actions have been finalized in 2013 by the licensee and analyzed by the regulatory body in 2014. The licensee conclusions and the consequent proposed actions are still not fully satisfying for the regulatory body and were being discussed at the end of 2014.

- In addition, the regulatory body has requested the licensee to justify that the water capacity of the second level of protection is sufficient when all the units of the site are affected by the loss of primary UHS. This justification has been presented by the licensee in 2013 for both sites and has been analyzed and confirmed by the regulatory body in 2014.

3.2.3. Spent Fuel Pools

- At Doel, the study of alternative water supply for the spent fuel pools (PL) using supplementary nozzles has been achieved by the licensee in 2013. The standpipes for water supply to the spent fuel pools are under construction at the end of 2014.

- Furthermore, for enhancing the monitoring of the spent fuel pools on both sites, improvements of level measurements are implemented or investigated by the licensee.

Moreover, the regulatory body has requested the evaluation of two configurations for the spent fuel pools: the configuration with a fuel assembly handled in the reactor pool during a CSBO and the configuration with the loss of water inventory in the spent fuel pools. The first evaluation will be finalized in 2015 while the second one has been finalized in early 2014.

In summary, at the end of 2014, the CSBO strategy was still in the process of being implemented by the licensee Electrabel. Most actions should be completed in 2016. The following figure summarizes the evolution of the implementation of the actions planned in Doel and Tihange to protect the nuclear power plants in case of a loss of power supply and a loss of water supply, between the end of 2013 and the end of 2014. The inclusion of beyond-design scenario for UHS and CSBO involves a lot of actions in the BEST action plan, as this topic includes one third of the total number of actions.

Figure 9 shows a small reduction of the number of actions planned by the licensee due to a reorganization of the action plan. The number of actions still ongoing is decreasing, as more than 50% of the actions have been completed by the licensee by the end of 2014.

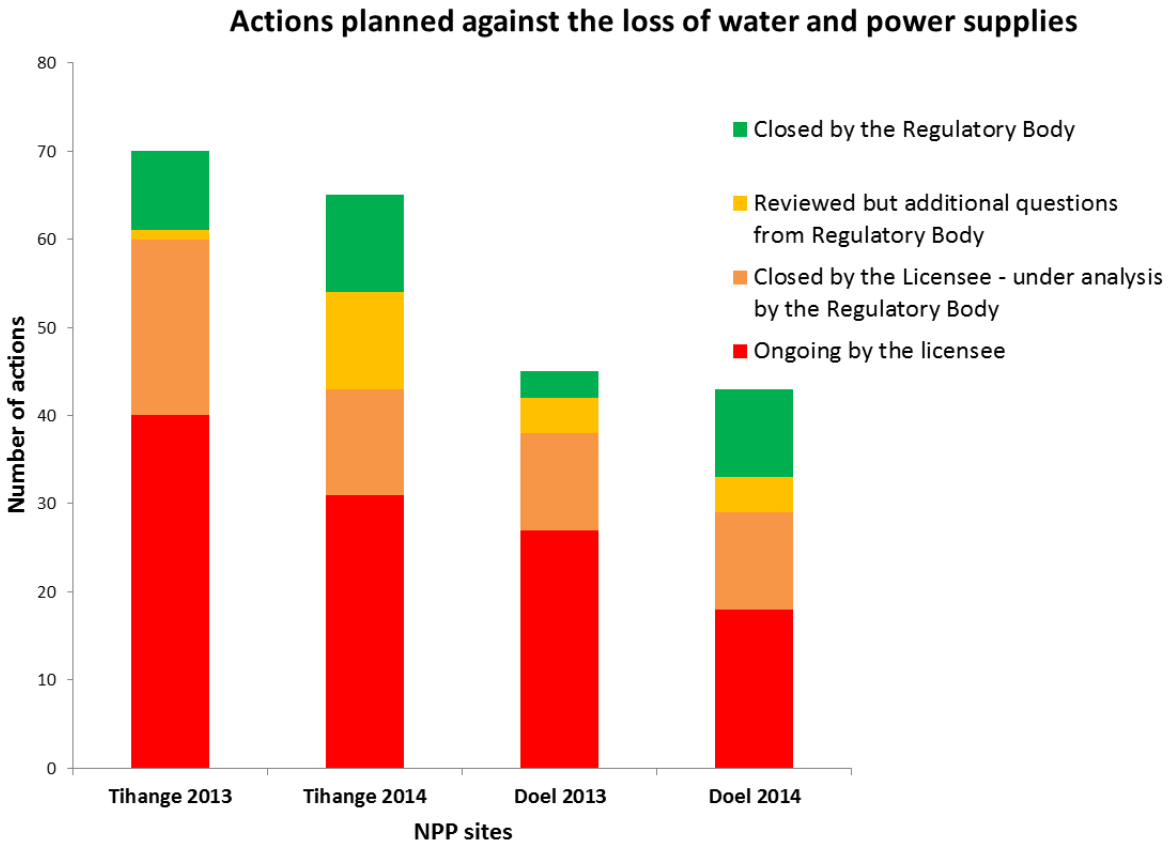


Figure 8 : Evolution of the resolution of the actions concerning the enhancement of power and water supply at Doel and Tihange between 2013 and 2014.

3.3. Severe Accident Management (SAM)

3.3.1. Enhancement of the operation management

As a result of the Fukushima accident, the licensee reassessed its organization so that it could face situations that are far beyond the design basis, which could affect several units simultaneously and could lead to the unavailability of some parts of the emergency management infrastructure or affect the access conditions and the environment.

The Belgian stress tests have highlighted that the operation management could be improved on the nuclear sites. In this respect, several actions have been undertaken to enhance procedures.

- At Tihange and Doel, the "earthquake procedures" have been modified in 2013 by the licensee to speed up the detection and mitigation of induced flooding on the site.

- The actions resulting from the periodic safety review concerning the flooding hazards at Tihange are described in section 3.1. The licensee is increasing the implementation of the related procedures. The procedures for the beyond-design protection are operational. The procedures related to the peripheral wall will be finalized after the construction of the wall is completed by the end of 2015.

- On both sites, the licensee will introduce procedures describing the actions to take in case of a total loss of heat sinks and in case of a total loss of internal or external power supplies. Many of these procedures have been finalized at Doel in 2014, except for the spent fuel pools. However, as these actions are directly linked to the CSBO project, described in section 3.2 and delayed to 2016, their finalization is not planned before 2016 in Tihange.

- Similarly, the introduction and the completion of the procedures for the connections and the commissioning of alternative power and water supplies have also been closed at Doel and delayed pending finalization of the CSBO project at Tihange.

3.3.2. Enhancement of the emergency management (PIU)

So far, the licensee's organization in emergency situations has been designed to overcome events affecting a single unit of the NPP and to manage design basis external events. This organization is periodically tested and improved through exercises.

As a result of the Belgian stress tests, the licensee reassessed this organization in order to be able to face far beyond design situations that could affect simultaneously several units.

In this respect, several actions have been decided in the framework of the stress tests:

- At **Tihange**, the site operation center "COS" was planned to move to an underground room in the new entrance building. However, this building has appeared to not be conveniently

located to resist to a beyond-design flood and to not be ideally protected against earthquakes. Consequently, the COS will be moved in term to a new building to be constructed and put into service in 2017. Considering the given commissioning schedule of the new COS, several actions have been undertaken in the present COS and other emergency rooms to improve their capacities (additional communication means, additional radioprotection equipment, an additional power generator - available in 2014, etc.).
In 2013, the licensee had defined the specifications of the new COS that were further discussed with regulatory body in 2014. The resulting design studies will be achieved and presented in 2015.

- At **Doel**, the construction of the new storage building for non-conventional means has been completed in 2014 (see Figure 10). The commissioning of this building is on pending.

Figure 9 : Construction completed of the new storage building at Doel NPP.

- A study on modifying and strengthening the emergency management organization has been launched to include “multi-unit” events at Doel and Tihange. The licensee has finalized the implementation of the new organization of the emergency plan and of the adapted logistics in 2013. The description of the new organization of the emergency plan has already been analyzed and questioned by the regulatory body. In 2014, the licensee has implemented the modifications and thus strongly adapted the emergency management organization as requested by the regulatory body which has closed this action.

- In addition, several additional actions have been or are carried out by the licensee in order to enhance the emergency management. These actions include the harmonization of site training programs, the construction of on-site resistant storage for mobile means, the setting-up of fallback bases, the improvement and diversification of communication means, additional means for managing work on a contaminated site, and so on. Most of these additional actions were finalized in 2013 and in 2014 by the licensee. The planning is on schedule.

3.3.3. Enhancement of the protection against severe accidents (SAM)

The scenarios involving severe accidents have been reassessed from a "defence-in-depth" perspective during the Belgian stress tests. Some actions that could further reduce the risk of potential releases into the environment resulting from an extreme situation were identified in the action plan. The main issue on this topic is the realization of filtered vent system for each nuclear reactor:

- The feasibility study for installing a filtered vent system on the containments of each unit was started in 2012 and has been finalized in 2013. Filtered vent systems will be installed on every NPP's in operation. The licensee has chosen a 'scrubber' design that does not require important work in the reactor building.
  The basic design has been completed in 2014. Therefore, the realization phase has finally begun in 2014. The filters and containment isolation valves have been ordered by the licensee. The licensee plans a final design for 2015 and a progressive installation from now depending on the NPP outages, up to end of 2017 for the latest unit (the planning does not yet consider the potential installation of filtered vent systems at Doel 1 and Doel 2).

- In addition, the assessment of the residual risk of hydrogen production and accumulation in spent fuel buildings have been carried out in 2013. At the end of 2014, the study that shows that there is no explosion risk due to the accumulation of hydrogen in the Spent Fuel Pool buildings of the NPP's, is still under assessment by the regulatory body.

- The follow-up of R&D activities related to the corium-concrete interaction issue is planned to be continuously carried out.

- A study aims at optimizing mobile means and their storing infrastructure, taking into account the analysis of the Extensive Damage Mitigating Guidelines (EMDG). This study was finalized in early 2014 and is presently assessed by the regulatory body.

- Concerning the estimation of the radiological release in case of a multiple-event, the upgrade of the emergency plan model is still ongoing within the SCK•CEN.

3.4. Water and waste treatment building - Doel (WAB)

In the National Report on the Belgian Stress Tests, the WAB at Doel was classified as a non-NPP facility. However, since the WAB building would be affected by events occurring at the Doel NPP and since the licensee Electrabel has included the WAB in its global action plan, the action plan for the WAB is included in this report.

Several actions were proposed by the licensee or requested by the regulatory body in order to enhance the protection of the WAB building. This resulted in a list of 15 actions to be performed in the WAB. Most of them were already implemented by the licensee and are currently being analysed by the regulatory body. The action plan for the WAB building should be completed in 2015.

- Concerning **earthquakes**, the licensee proposed to develop procedures in order to detect possible leaks in the WAB after earthquakes and to isolate them. This action has been officially closed by Electrabel and the Regulatory Body.

  The regulatory body also requested an upgrade of the four SSC graded at a low probability to resist a RLE to a high probability. These two actions have been finalized by the licensee and are still under review by the Regulatory Body.
- No actions had to be undertaken concerning the **flooding** hazards in the WAB building. However, the licensee had to enhance the protection against **heavy rains** for the WAB building. Indeed, the regulatory body has requested to limit the accumulation of water on the WAB roofs either by periodic inspections or by periodic maintenance of the necessary overflows. The licensee also has to evaluate the impact of rainfall of 10E-3 return frequency on the sewer system network. These two actions were realized by the licensee in 2014 and reviewed by the Regulatory Body.

  Finally, the regulatory body has requested to evaluate the possibility water entering into the WAB building and to define its potential impact on the safety functions. This action was finalized by the licensee in 2013.

3.4.1. Enhancement of power and water supply

The regulatory body has formulated several requests to enhance the protection of the WAB building against the loss of power and water supply.

In the framework of the CSBO and the UHS, the regulatory body has requested several actions (additional summary screen on the Digital Control System, additional control procedures, evaluation of the electric grid of the WAB, etc.). Most of these actions (5 out of 6) were finalized by the licensee in 2014. The Regulatory Body has already officially reviewed and closed 2 of these 5 actions.

3.4.2. Enhancement of emergency management

- The licensee had to conduct a limited study in order to define the necessary arrangements to pump the water contents of the basement to an intermediate storage place after extreme accidents. This action was finalized by the licensee in 2013 and is still being reviewed by the Regulatory Body.
- The regulatory body requested to make an inventory of the radioactive waste in various locations in the WAB available in the WAB and on the PC network on a permanent basis. The licensee presented its conclusions concerning this action in 2013. The Regulatory Body confirmed the completion of this action in 2014.

4. Conclusions

This report presents the status at the end of 2014 of the action plan defined by Electrabel following the stress tests on the Belgian nuclear power plants. The regulatory body considers the current progress of the licensee on the action plan satisfactory. Most actions follow the time schedule of the original action plan and the few delays have been duly justified by Electrabel.
By the end of 2014, 253 out of 366 actions were completed by the licensee Electrabel. Since most remaining actions are already ongoing, Electrabel consider the BEST project more than 80% completed.

In 2014, the licensee made significant progress on most large projects intended to enhance the robustness of the two Belgian nuclear power plants. At Tihange, the protection against flooding is almost ready, while at Doel all the actions have already been completed. The work on the Complete Station Black-Out is ongoing at both sites, as well as the actions concerning the loss of the Ultimate Heat Sink. The new emergency response center in Tihange is under construction. The design of the filtered venting systems is almost finished and the realization phase has now begun.

The regulatory body will continue to carefully follow the progress of the stress test actions implemented by the licensee in the future years. The collaboration between the licensee and the regulatory body appears to be successful and will be continued until the finalization of the stress test action plan.

The next update/follow-up of this report, describing the status of the action plan at the end of 2015, will be presented by FANC at the beginning of 2016.