Technical notice

Earthquake resistance of the Donzère-Mondragon canal embankment

1. Geographical situation of the Tricastin NPP

Le Tricastin nuclear site is located on the right bank of the Donzère-Mondragon canal. Most of the platform of the Tricastin site is set approximately six metres below the normal operating level of the Donzère-Mondragon canal. It is protected from the flooding risk by an embankment.

The Tricastin NPP, operated by EDF, is located right on the edge of the Donzère-Mondragon canal.

The Areva platform on the Tricastin site comprises nine basic nuclear installations (BNI), several installations classified on environmental protection grounds (ICPE) and a secret basic nuclear installation (SBNI), under the authority of the Authority for Defence-related facilities and activities (ASND).

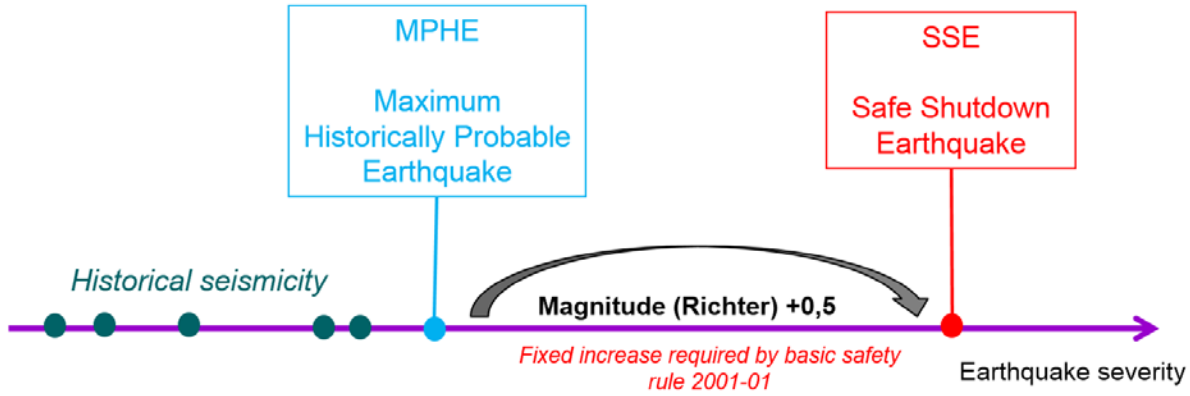
2. Earthquake resistance in the BNI safety case

The earthquake considered in the nuclear safety case for basic nuclear installations (BNI) is called the safe shutdown earthquake (SSE). It is calculated using a deterministic approach detailed in basic safety rule 2001/01 of 31 May 2001.

2.1. Principle

The SSE is determined from the maximum historically probable earthquake (MHPE). The MHPE is conventionally associated with a return period of 1,000 years. This seismic level can be considered

as being the most severe "in human memory" identified in the region concerned. The MHPE is defined by repositioning the historical earthquake in the immediate vicinity of the site.
The SSE specific to the site is established by applying a specific increase to the magnitude of the MHPE. This increase can more specifically cover any uncertainties regarding the historical data.



2.2. Earthquakes to be taken into account in the safety case for the Tricastin BNIs

The MHPE considered for defining the SMS to be taken into account in the safety case for the Tricastin BNIs has the characteristics of the *Chateauneuf du Rhône* earthquake which occurred on 8 August 1873 at a distance of 13 km from the site. This earthquake had an epicentre intensity of VII-VIII on the MSK[1] scale and a magnitude of 4.7 on the Richter scale.

Earthquakes with the same intensity on the MSK scale occurred on 23 January 1773 and 19 July 1873.

The magnitude of the SSE considered for the Tricastin installations is 5.2 on the Richter scale.

[1] It should be recalled that the Medvedev, Sponheuer and Karnik scale, referred to as the MSK scale, is the intensity scale currently used in France and in most European countries. It was developed in 1964. The degrees of intensity characterising the level of the seismic shock and the associated effects are numbered from I to XII. This extremely useful qualitative evaluation in no case represents a measurement of a physical parameter of the ground vibrations. Given the difficulty involved in precise calculation, the intensity is sometimes given to the nearest degree.

I	imperceptible shock, but recorded by the instruments
II	shock partly felt, especially on upper floors
III	weak felt, hanging objects swing
IV	largely observed shock indoors; objects tremble
V	fairly strong shock; sleeping people woken up; objects fall; sometimes minor cracks in plasterwork
VI	strong shock with slight damage; sometime cracks in walls; many people frightened
VII	very strong shock with damage; major cracks in the walls of numerous dwellings; chimneys collapse
VIII	extensive damage; the most vulnerable dwellings are destroyed; nearly all suffer major damage
IX	destruction of numerous constructions; monuments and columns collapse
X	devastating shock with general destruction of constructions, even the least vulnerable
XI	catastrophic shock; all constructions are destroyed
XII	very catastrophic shock with landscape change; enormous crevasses in the ground, valleys blocked, rivers change paths, etc.

3. History of embankment resistance studies

In the wake of the Fukushima-Daiichi accident, ASN ordered EDF to take a number of measures to reinforce the ability of the NPPs to withstand extreme events. It thus asked EDF to implement a "hardened safety core" on its installations, for dealing with these extreme situations. With regard to the extreme flooding risk, it asked the licensee of the Tricastin NPP in June 2012 to provide it with the following before 30th June 2013 ([ECS-11]) "*a study indicating the level of seismic robustness of the embankments and other structures protecting the installations against flooding and, according to this level of robustness, presenting:*

- *the consequences of failure of these structures,*
- *the technical solutions envisaged for protecting the Hardened Safety Core equipment […].*

For the embankments, this analysis must specify the actual composition (stratigraphy and characteristics of the materials) of the embankments and its possible variability, local singularities and their potential role in embankment degradation mechanisms, as well as the stability of the safety gates in the event of a major drop in the water level in the Donzère-Mondragon canal following a failure of the embankment on the left bank".

In December 2012, AREVA also sent ASN the updated flooding risk studies for the Tricastin platform. This study presented the consequences of partial failure of the Donzère-Mondragon canal embankment, without an earthquake, in the embankment area referred to as "gravel".

In 2013, EDF sent its first studies on the ability of the embankment to withstand a "hardened safety core" earthquake (SND). EDF needed however to conduct geotechnical surveys on a portion of about 400 m of the "gravel" embankment - the composition of which differs from the rest of the embankment - and adapt its seismic strength studies to the results of the surveys conducted.

After performing seismic resistance calculations for the embankment and as a result of these investigations, EDF notified ASN on 18th August 2017 of a significant event linked to the inability of this portion of the embankment to withstand the safe shutdown earthquake (SSE)

AREVA notified ASN of this same event on 22nd August 2017, in the light of the risks to its own installations.

4. Consequences for the EDF NPP of this inability of the Donzère-Mondragon canal embankment to withstand an earthquake

4.1. Feared accident situation

EDF states that the ability of the embankment to withstand a SSE level earthquake is not guaranteed, with the risk of leaks and partial collapse of the embankment. It does however confirm the correct behaviour of the embankment for an "MHPE" earthquake. The occurrence of an earthquake of an intensity greater than recent historical earthquakes would therefore be liable to lead to flooding of the nuclear platform, although it is not possible to precisely identify the seismic level at which this phenomenon would occur.

Flooding of the NPP platform following an earthquake would lead to loss of off-site and on-site electrical power supply and failure of the cooling systems for the EDF reactors. Flooding could also lead to the loss of numerous items of equipment not raised inside the installation, such as certain equipment associated with reactor instrumentation and certain back-up systems. Access to the site would also be made difficult, thus hampering the emergency response.

A situation such as this with total loss of reactor cooling systems would lead to core melt in the four reactors in just a few hours and would have an unacceptable large-scale health impact.

4.2. ASN position regarding the Tricastin NPP

In the absence of proof that the Donzère-Mondragon canal embankment can withstand the safe shutdown earthquake, ASN considered that this situation constitutes a serious risk and prescribed the temporary shutdown of the Tricastin NPP reactors.

The shutdown of the reactors enables the power produced by the nuclear fuel to be reduced (residual power after shutdown of the chain reaction), thus limiting the amount of water needed to remove this heat. In consequence, the reactor shutdown makes it easier for the emergency response to take place in the eventually of a flood further to an earthquake.

Shutdown of a reactor in normal operation takes several days, with the licensee gradually lowering the temperature and the pressure in the various systems. A number of configurations are possible during the shutdown period; the fuel can be kept in the reactor vessel or stored in the pool. ASN thus asks EDF to determine the best status for the installations after reactor shutdown and the compensatory measures providing the best safety guarantees in the light of the risk of failure of the embankment in case of earthquake.

Restart of the reactors would require prior authorisation from ASN. EDF will therefore have to conduct additional geotechnical investigations, carry out reinforcement works and demonstrate that the entire embankment can withstand an SSE earthquake.

5. Consequences for Areva's civil nuclear installations of this deviation regarding the inability of the Donzère-Mondragon embankment to withstand an earthquake

5.1 Feared accident situations

At the request of ASN, Areva produced an initial, concise study of the consequences for the safety of its installations of an earthquake leading to flooding.

The Areva installations on the Tricastin site vary widely and entail a variety of risks. The main ones are gaseous releases of chemical substances, more specifically hydrofluoric acid (HF), and uranium pollution.

An SSE level earthquake could lead to HF releases from:

- the uranium hexafluoride production unit (known as "structure 400") in the Comurhex 1 conversion plants,

- the building called the "emission zone" of the W plant.

For this reason, ASN requested the installation of water spray systems offering a good level of seismic resistance to limit the scale of the chemical releases that would result in such a case. Furthermore, the shutdown of these structures was prescribed and set at 31st December 2017 for structure 400 and 30th June 2018 for the "emission zone" of the W plant. The correct operation of these spray systems cannot however be guaranteed in the event of flooding following failure of the embankment.

Flooding could also create disorder in the storage of radioactive substances contained in drums located in "area 61" of BNI 105 and lead to a criticality risk if the drums were to be brought closer together. A system of racks offering improved support and guaranteeing the physical separation of the drums is being studied. Areva will need to check whether the risk of flooding as a result of the inadequate seismic resistance of the embankment makes it necessary to design a new system of racks, for example the storage at a greater height.

5.2 ASN Position

The "structure 400" of the Comurhex 1 conversion plants is at present temporarily shut down, following a significant event. In its resolution, ASN stipulates that the plant activities can only be resumed if Areva can rapidly implement means to mitigate the consequences of a gaseous HF release in the event of flooding following a breach in the "gravel" embankment along the Donzère-Mondragon canal in the case of safe shutdown earthquake.

The W plant is used to convert uranium in UF_6 form into a safer chemical state (U_3O_8). It would thus be preferable for the installation to continue to function. ASN therefore ordered Areva to take measures before 31st October 2017 to ensure the operability of the means to mitigate the consequences of a gaseous HF release in the "emission zone" of the W plant in the event of flooding following a breach in the "gravel" embankment along the Donzère-Mondragon canal in the case of a safe shutdown earthquake.

ASN also requires that Areva update its BNI 105 modification application with the aim of reinforcing the safety of the storage of drums in area 61 of BNI 105, in the event of flooding following a breach in the "gravel" embankment along the Donzère-Mondragon canal in the case of a safe shutdown earthquake.