



CIRIAF

Centro Interuniversitario di Ricerca sull'Inquinamento da Agenti Fisici - "Mauro Felli"

**Dodicesimo
Congresso
Nazionale**

Ciriaf

Tavola Rotonda



Energia, Economia e Ambiente

SITUAZIONE DELL'ENERGIA NUCLEARE



Università degli Studi
di Perugia

Perugia 30-31 marzo 2012

Facoltà di Ingegneria - Aula Magna

Il commissario UE all'Energia, Oettinger, aveva annunciato l'effettuazione per i 143 reattori nucleari dell'Unione Europea, sulla base di criteri concordati da tutti gli Stati membri, di cosiddetti "stress tests" per verificare la loro capacità di resistenza ad eventi eccezionali. Sono stati così elaborati criteri che includono eventi calamitosi non solo naturali, ma anche provocati dall'uomo (attacchi terroristici, impatto di aeroplani etc.), che erano stati i punti di maggiore attrito con alcuni membri UE. Gli aspetti strettamente legati alla sicurezza nazionale, come la prevenzione degli atti terroristici, saranno trattati separatamente con i singoli Paesi e in modo confidenziale.

Ciò introdurrà standard di sicurezza più stringenti negli impianti all'interno e ai confini dell'Unione Europea. Il processo di valutazione sarà diviso in 3 fasi: la prima ("pre-assessment") sarà effettuata dagli stessi operatori degli impianti che dovranno rispondere a un questionario e fornire la documentazione di supporto; nella seconda le autorità nazionali verificheranno la rispondenza delle indicazioni trasmesse dagli operatori; nella terza ("peer review") team composti da esperti di varie nazionalità effettueranno la revisione conclusiva dei rapporti nazionali.

Ciascun team sarà composto da 7 esperti (1 in rappresentanza della Commissione e 6 delle 27 autorità nazionali), che avranno la facoltà di effettuare ispezioni a sorpresa. Gli stress tests, che dovranno essere completati entro l'aprile 2012, saranno effettuati sui reattori dei 27 Paesi UE e, sulla base di specifiche intese bilaterali, anche di Svizzera, Russia, Ucraina e Armenia.

On the basis of the proposals made by WENRA at their plenary meeting on the 12-13 of May, the European Commission and ENSREG members decided to agree upon "an initial independent regulatory technical definition of a "stress test" and how it should be applied to nuclear facilities across Europe".

Definition of the "stress tests"

For now we define a "stress test" 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. This reassessment will consist:

- in an evaluation of the response of a nuclear power plant when facing a set of following section "technical scope" and**
- in a verification of the preventive and mitigative measures chosen following a defence-in-depth logic: initiating events, consequential of loss safety functions, severe accident management.**

In these extreme situations, sequential loss of the lines of defence is assumed, in a deterministic approach, irrespective of the probability of this loss. In particular, it has to be kept in mind that loss of safety functions and severe accident situations can occur only when several design provisions have failed. In addition, measures to manage these situations will be supposed to be progressively defeated.

For a given plant, the reassessment will 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.

A cliff-edge effect could be, for instance, exceeding a point where significant flooding of plant area starts after water overtopping a protection dike or exhaustion of the capacity of the batteries in the event of a station blackout.

This is to evaluate the robustness of the defence-in-depth approach, the adequacy of current accident management measures and to identify the potential for safety improvements, both technical and organisational (such as procedures, human resources, emergency response organisation or use of external resources).

By their nature, the stress tests will tend to focus on measures that could be taken after a postulated loss of the safety systems that are installed to provide protection against accidents considered in the design. Adequate performance of those systems has been assessed in connection with plant licensing. Assumptions concerning their performance are re-assessed in the stress tests and they should be shown as provisions in place.

It is recognised that all measures taken to protect reactor core or spent fuel integrity or to protect the reactor containment integrity constitute an essential part of the defence-in depth, as it is always better to prevent accidents from happening than to deal with the consequences of an occurred accident.

Technical scope of the "stress tests"

The existing safety analysis for nuclear power plants in European Countries covers a large variety of situations. The technical scope of the stress tests has been defined considering the issues that have been highlighted by the events that occurred at Fukushima, including combination of initiating events and failures. The focus will be placed on the following issues:

Initiating events

- Earthquake**
- Flooding**

Consequence of loss of safety functions from any initiating event conceivable at the plant site

- **Loss of electrical power, including Station Black Out (SBO)**
- **Loss of the Ultimate Heat Sink (UHS)**
- **Combination of both**

Severe accident management issues

- **Means to protect from and to manage loss of cooling function**
- **Means to protect from and to manage loss of cooling function in the fuel storage pool**
- **Means to protect from and to manage loss of containment integrity.**

The former consequences are not limited to earthquake and tsunami as in Fukushima: flooding will be included regardless of its origin. Furthermore, bad weather conditions will be added.

Furthermore, the assessment of consequences of loss of safety functions is relevant also if the situation is provoked by indirect initiating events, for instance large disturbance from the electrical power grid impacting AC power distribution systems or forest fire, airplane crash.

The review of the severe accident management issues focuses on the licensee's provisions but it may also comprise relevant planned off-site support for maintaining the safety functions of the plant. Although the experience feedback from the Fukushima accident may include the emergency preparedness measures managed by the relevant off-site services for public protection (fire-fighters, police, health services), this topic is out of the scope of these stress tests. All reactors and spent fuel storages shall be supposed to be affected at the same time. Possibility of degraded conditions of the site surrounding area shall be taken into account.

Consideration should be given to:

- **automatic actions;**
- **operators actions specified in emergency operating procedures**
- **any other plant measures of prevention, recovery and mitigation of accidents.**

Three main aspects need to be reported:

1. **Provisions taken in the design basis of the plant and plant conformance to its design requirements;**

2. Robustness of the plant beyond its design basis. For this purpose, the robustness (available design margins, diversity, redundancy, structural protection, physical separation, etc) of the safety-relevant systems, structures and components and the effectiveness of the defence-in-depth concept have to be assessed.

Regarding the robustness of the installations and measures, one focus of the review is on identification of a step change in the event sequence (cliff edge effect) and, if necessary, consideration of measures for its avoidance.

3. Any potential for modifications likely to improve the considered level of defence-in-depth, in terms of improving the resistance of components or of strengthening the independence with other levels of defence.

In addition, the licensee may wish to describe protective measures aimed at avoiding the extreme scenarios that are envisaged in the stress tests in order to provide context for the stress tests. The analysis should be complemented, where necessary, by results of dedicated plant walk down.

To this aim, the licensee shall identify:

- **the means to maintain the three fundamental safety functions (control of reactivity, fuel cooling, confinement of radioactivity) and support functions (power supply, cooling through ultimate heat sink), taking into account the probable damage done by the initiating event and any means not credited in the safety demonstration for plant licensing**
- **possibility of mobile external means and the conditions of their use**
- **any existing procedure to use means from one reactor to help another reactor**
- **dependence of one reactor on the functions of other reactors of the same site.**

Earthquake design basis

- **Earthquake against which the plant is designed : level of the design basis earthquake (DBE) expressed in terms of peak ground acceleration (PGA) and reasons for the choice.**

Also indicate the DBE taken into account in the original licensing basis if different

- **Methodology to evaluate the DBE (return period, past events considered and reasons for choice, margins added ...), validity of data in time**
- **Conclusion on the adequacy of the design basis.**

Provisions to protect the plant against the DBE

- **Identification of the key structures, systems and components (SSCs) which are needed for achieving safe shutdown state and are supposed to remain available after the earthquake**
- **Main operating provisions (including emergency operating procedure, mobile equipment. ..) to prevent reactor core or spent fuel damage after the earthquake**

Indirect effects of the earthquake to be taken into account are:

- **failure of SSCs that are not designed to withstand the DBE and that, in loosing their integrity could cause a consequential damage of SSCs that need to remain available (e.g. leaks or ruptures of non seismic pipework on the site or in the buildings as sources of flooding and their potential consequences)**
- **loss of external power supply**
- **situation outside the plant, including preventing or delaying access of personnel and equipment to the site.**

Evaluation of the margins

Based on available information (including engineering studies to support engineering judgement), what is the level of flooding that the plant can withstand without severe damage to the fuel (core or fuel storage)?

Depending on the time between warning and flooding, indicate whether additional protective measures can be envisaged/implemented.

- **Indicate which are the weak points and specify any cliff edge effects. Identify which buildings and which equipment will be flooded first**
- **indicate if any provisions can be envisaged to prevent these cliff edge effects or to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions ...).**

Loss of electrical power and loss of the ultimate heat sink

Electrical AC power sources are:

- off-site power sources (electrical grid)**
- plant generator**
- ordinary back-up generators (diesel generator, gas turbine ...)**
- in some cases other diverse back-up sources.**

Sequential loss of these sources has to be considered.

The ultimate heat sink (UHS) is a medium to which the residual heat from the reactor is transferred. In some cases, the plant has the primary UHS, such as the sea or a river, which is supplemented by an alternate UHS, for example a lake, a water table or the atmosphere.

Sequential loss of these sinks has to be considered.

Loss of off-site 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**
 - **Indicate for how long the on-site power sources can operate without any external support**
 - **Specify which provisions are needed to prolong the time of on-site power supply (refueling of diesel generators...)**
 - **Indicate any envisaged provisions to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions...).**

For clarity, systems such as steam driven pumps, systems with stored energy in gas tanks etc. are considered to function as long as they are not dependent of the electric power sources assumed to be lost and if they are designed to withstand the initiating event (e.g. earthquake).

Loss of off-site power and of on-site backup power sources (SB0).

Two situations have to be considered:

- **LOOP + Loss of the ordinary back-up source**
- **LOOP + Loss of the ordinary back-up sources + loss of any other diverse back- up sources.**

For each of these situations:

- **provide information on the battery capacity and duration**
- **provide information on design provisions for these situations**
- **indicate for how long the site can withstand a SB0 without any external support before severe damage to the fuel becomes unavoidable**
- **specify which (external) actions are foreseen to prevent fuel degradation:**

- **equipment already present on site, e.g. equipment from another reactor**
- **assuming that all reactors on the same site are equally damaged**
- **equipment available off-site**
- **near-by power stations (e.g. hydropower, gas turbine) that can be aligned to provide power via a dedicated direct connection**
- **time necessary to have each of the above systems operating**
- **availability of competent human resources to make the exceptional connections**
- **identification of cliff edge effects and when they occur.**
- **Indicate if any provisions can be envisaged to prevent these cliff edge effects or to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions ...)**

Loss of primary ultimate heat sink (UHS)

- Provide a description of design provisions to prevent the loss of the UHS (e.g. various water intakes for primary UHS at different locations, use of alternative UHS, ...).

Two situations have to be considered:

- Loss of primary ultimate heat sink (UHS), i.e. access to water from the river or the sea
- Loss of primary ultimate heat sink (UHS) and the alternate UHS.

For each of these situations:

- Indicate for how long the site can withstand the situation without any external support before damage to the fuel becomes unavoidable
- Provide information on design provisions for these situations
- Specify which external actions are foreseen to prevent fuel degradation

- **equipment already present on site, e.g. equipment from another reactor**
- **assuming that all reactors on the same site are equally damaged**
- **equipment available off-site**
- **time necessary to have these systems operating**
- **availability of competent human resources**
- **identification of cliff edge effects and when they occur**
- **indicate if any provisions can be envisaged to prevent these cliff edge effects or to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions ...).**

Loss of the primary UHS with SBO

- Indicate for how long the site can withstand a loss of "main" UHS + SBO without any external support before severe damage to the fuel becomes unavoidable
- Specify which external actions are foreseen to prevent fuel degradation:
 - equipment already present on site, e.g. equipment from another reactor
 - assuming that all reactors on the same site are equally damaged
 - equipment available off site
 - availability of human resources
 - time necessary to have these systems operating;
identification of when the main cliff edge effects occur.
- Indicate if any provisions can be envisaged to prevent these cliff edge effects or to increase robustness of the plant (modifications of hardware, modification of procedures, organisational provisions ...)

Severe accident management

This chapter deals mostly with mitigation issues. Even if the probability of the event is very low, the means to protect containment from loads that could threaten its integrity should be assessed. Severe accident management, as forming the last line of defense-in-depth for the operator, should be consistent with the measures used for preventing the core damage and with the overall safety approach of the plant.

Describe the accident management measures currently in place at the various stages of a scenario of loss of the core cooling function:

- before occurrence of fuel damage in the reactor pressure vessel/a number of pressure tubes**
- last resorts to prevent fuel damage**
- elimination of possibility for fuel damage in high pressure**
- after occurrence of fuel damage in the reactor pressure vessel /a number of pressure tubes**
- after failure of the reactor pressure vessel/a number of pressure tubes**

Describe the accident management measures and plant design features for protecting integrity of the containment function after occurrence of fuel damage

- **prevention of H₂ deflagration or H₂ detonation (inerting, recombiners, or igniters), also taking into account venting processes**
- **prevention of over-pressurization of the containment; if for the protection of the containment a release to the environment is needed, it should be assessed whether this release needs to be filtered. In this case, availability of the means for estimation of the amount of radioactive material released into the environment should also be described**
- **prevention of re-criticality**
- **prevention of basemat melt through**
- **need for and supply of electrical AC and DC power and compressed air to equipment used for protecting containment integrity.**

Describe the accident management measures currently in place at the various stages of a scenario of loss of cooling function in the fuel storage (the following indications relate to a fuel pool):

- **before/after losing adequate shielding against radiation**
- **before/after occurrence of fuel degradation (fast cladding oxidation with hydrogen production) in the fuel pool.**

At each stage:

- **identify any cliff edge effect and evaluate the time before damages**
- **assess the adequacy of the existing management measures, including the procedural guidance to cope with a severe accident, and evaluate the potential for additional measures. In particular, the licensee is asked to consider:**
 - **the suitability and availability of the required instrumentation**
 - **the habitability and accessibility of the vital areas of the plant (the control room, emergency response facilities, local control and sampling points, repair possibilities)**
 - **potential H₂ accumulations in other buildings than containment**

The following aspects have to be addressed:

-organisation of the licensee to manage the situation, including:

- staffing, resources and shift management**
- use of off-site technical support for accident and protection management (and contingencies if this becomes unavailable)**
- procedures, training and exercises**
- Possibility to use existing equipment**
- Provisions to use mobile devices (availability of such devices, time to bring them on site and put them in operation, accessibility to site)**
- Provisions for and management of supplies (fuel for diesel generators, water ...)**
- Management of radioactive releases, provisions to limit them**
- Management of workers' doses, provisions to limit them**
- Communication and information systems (internal, external).**
- Long-term post-accident activities.**

The envisaged accident management measures shall be evaluated considering what the situation could be on a site:

- Extensive destruction of infrastructure around the plant including the communication**
- Facilities (making technical and personnel support from outside more difficult)**
- Impairment of work performance (including impact on the accessibility and habitability of the main and secondary control rooms, and the plant emergency/crisis centre) due to high local dose rates, radioactive contamination and destruction of some facilities on site**
- Feasibility and effectiveness of accident management measures under the conditions of external hazards (earthquakes, floods)**
- Unavailability of power supply**
- Potential failure of instrumentation**
- Potential effects from the other neighbouring plants at site.**

The licensee shall identify which conditions would prevent staff from working in the main or secondary control room as well as in the plant emergency/crisis centre and what measures could avoid such conditions to occur.