SEISMIC SAFETY OF NUCLEAR PLANTS

PERFORMANCE BASED APPROACH

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SEISMIC DESIGN IN GENERAL

The NPP has to be designed, and built, in such a way that the three main safety functions

- **safe reactor shutdown,**
- **adequate reactor cooling,**
- **prevention of diffusion of radioactive substances towards the public and the environment**

are ensured against the DBE (design basis events) during its life (from beginning of operation until the end of life).

One of the important DBE is the earthquake (SSE).

SSE : DEFINITION

Conceptually, we want that, if one of the worst possible earthquakes that can occur at the site hits the plant, the plant will remain able to face the event reaching a final safe condition: major damages are accepted provided that the final safe conditions (and functions) are ensured.

The set of these "worst" earthquakes are the SSE (Safe Shut Down Earthquakes): the earthquakes against which the plant is designed in order to remain capable of being ''safely shut down''. They are established on the basis of seismicity and geological studies.

The set of the SSE is normally characterized by one Design Response Spectrum (DRS). In the past the DRS was mainly determined as the envelope of the Response Spectra of the earthquakes of the set.

The outlined approach introduces large conservatism in the design.

SSE: PRESENT PROPOSAL UNDER DISCUSSION

It is because of this conservatism that in many years of reactor operation only minor damages occurred to nuclear plants in the case of earthquakes.

However this conservatism is not always well balanced: different items in the plant may have different margins.

This emerges when seismic PRA (probabilistic risk assessment) are performed. Moreover the need of an hazard curve arises.

To get a DRS consistent with the hazard curve an approach based on fragilities and hazard curves of SSC has been proposed (DOE, ASCE) in the recent past and is still under discussion.

BASIC IDEA OF THE PROPOSED APPROACH

The proposed approach is based on the following idea:

Define the DRS directly in such a way that the *target maximum average annual frequency* for a given damage (e.g. Core Damage) is assured.

The *target maximum average annual frequency* is what is called (e.g. by ASCE) Performance Probability. The whole approach is named:

Performance Based Approach

Instead of verifying by PRA ''a posteriori'' that the design achieves the desired target, perform the design in a way ensuring ''a priori'' that the goal is reached

CONSIDERATION ON THE PROPOSED APPROACH

Being (notation from ASCE/SEI 43-05) :

H(a)	**the hazard (events per year)**
F(A,a)	**the fragility of a component designed for acceleration A**
Pf	**the target performance probability (events per year)**

it is

$$Pf = -\int_0^{\infty} (dH/da)\, F(A, a)\, da$$

The proposed approach means: find A given Pf

DIFFICULTIES IN THE PROPOSED APPROACH

To find A starting from Pf is not easy. Not only one parameter but a set of parameters has to be determined. Moreover:

Seismic design is a complicate process affecting structures, components, systems, active components, electrical and electronic equipment and devices and many kinds of required functions (i.e. performances) are defined : functional and structural integrity, tightness, fail safe, geometry preservation, mechanical actions, etc.

Seismic design requires linear and non linear analyses and calculations, calculations of floor response spectra, performance of dynamic testing,..

To apply the proposed approach it is necessary to take into account the whole complexity of the seismic design.

FINAL REMARKS

The practical feasibility and the implications of the proposed approach have to be verified.

The proposed approach could produce a more balanced distribution of safety margins in the design.

International cooperation and discussion on the above issues as well as all the information coming from real earthquakes affecting NPP (e.g. Kashiwazaki Kariwa) are essential to achieve a common understanding of the issues and to achieve effective advancements in seismic design.