International Technical Meeting
on
Seismic Safety of NPPs

Tivoli (Italy) – March 25-26, 2010

Outcomes

An International Technical Meeting with focus on ''Seismic Safety of Nuclear Power Plants'' has been held in Tivoli (Italy) on March 25-26, 2010 with the objective to exchange views and discuss the topic of seismic safety of NPPs based on international in-progress studies, research activity, lessons learned from experience, current design and regulatory practices.
It was organized by ITER-Consult, CIRTEN, ENEA, ''La Sapienza'' and AIN with the support of IAEA and under the auspices of the Ministry of Economical Development of Italy. The participating organization included IAEA, ISPRA, ITER, ENEA, Ansaldo, Areva, JNES, IRSN, CIRTEN, ''La Sapienza''.

The presentations and the discussion covered the following topics:

- **Seismic hazard and site specificity**
- **Seismic design approach and methodology**
- **Design Margins**
- **Seismic safety requirements and regulatory guidance**
- **Lessons learned from the experience**

It was recognized that significant steps forward have been made in the last years on each of the topics in terms of advanced technical and scientific knowledge, new achievements and new approaches. The discussion gave the opportunity to consolidate some relevant outcomes.

Seismic hazard and site specificity

1. The improved capability to monitor earthquakes that has been reached in the last years and the higher sensitivity of modern seismic instruments have given evidence, in general, of stronger ground motion values than those considered or estimated in the past.

2. Seismogenic structures (active faults) are now better defined in age and location which implies an improved capability to effectively localize NPPs (siting) and to estimate ground motion hazards.

3. It is now clearly recognized the need and the importance to better ensure the treatment of uncertainties in both Deterministic Seismic Hazard Assessment (DSHA) and Probabilistic Seismic Hazard Assessment (PSHA). It is also accepted

that both methods should be used in a complementary way for a more effective and reliable assessment of the seismic hazard.

4. The site selection and site evaluation process shall be performed with clear safety objectives considering all the potential external events. The presence of capable faults (the potential for fault displacements) on the site represents the only exclusion criterion related to seismic hazard (i.e. for which it is considered that an engineering solution is not possible). IAEA Safety Guides provide a comprehensive approach for this topic.

5. It is confirmed the importance to investigate and identify, as deeply as possible, the site specific characteristics which may affect the vibratory ground motion and may induce ground failures. Site specific investigations can contribute to substantially reduce random and epistemic uncertainties inherent to the seismic hazard. It is also recognized that some uncertainties (imported) will still remain and therefore there is a need for a minimum level of ground motion hazard (e.g., >0.1g).

Seismic design approach and methodology

6. The seismic design of a NPP is generally performed according to two levels of ground motion hazard: seismic level 2 (SL-2) associated with safety requirements (also referred as SSE) and seismic level 1 (SL-1) usually related to operational requirements (also referred as OBE). The assessment of ground motion hazard can be based on probabilistic and deterministic methods or a combination of both. Up to now the regulatory and industrial standards for seismic design of NPP and nuclear facilities are mainly based on a deterministic approach, even if probabilistic concepts are used in the definition of the design earthquake(s).

7. Recent trends are toward the development of risk consistent and risk informed approach; different agencies and professional societies are working in these area. DOE 1024 Guidelines, ASCE standard 43-05, and ANS 2.26, 2.27, 2.29 from American Nuclear Society aim to establish a consistent framework for this approach. The US REG 1. 208 of 2007 provides guidance on the development of the site specific ground motion using a performance based approach.

8. Seismic Categorization of Structures, Systems and Components (SSC) is a key aspect in the definition of methodologies and design criteria. Evolution has been observed in the definition of seismic classification (more categories), and requirements associated to the seismic classes (categories). It has been underlined the importance to ensure the requirements all over the life time of the NPP.

9. Seismic qualification of NPP safety equipment, considering aging (qualified life), is a key aspect of seismic design proving the capability of NPP equipment to perform the required safety functions during and after a seismic event.

10. The seismic event represents a strong common cause failure for the SSC of a NPP. This implies the need to analyse and verify in a systematic way, giving

evidence, that the required safety functions are ensured keeping into account all possible interactions (functional and physical) with the potential distributed damages of non-safety SSC.

11. It is recognized that probabilistic methodology, being capable to make comparison and reveal weakness, could effectively complement the design process, and related design provisions, in order to have more balanced design. The Performance Based Approach (PBA) can be a way to use probabilistic approach. Its effectiveness need to be further assessed.

12. Innovative approaches such as seismic isolation of the buildings needs further investigation for a more proven effectiveness of their use also depending from the site seismicity level.

Design Margins

13. It is confirmed the importance to guarantee appropriate margins in the design process. The actual margin of a structure with respect to a defined event depends from many combining factors. These margins have allowed operating NPP to withstand seismic forces to structures and components much over the pre-defined design input (DBE). They are granted also by the use of clear design rules and parametric analysis to cover the uncertainties involved in such a complex process.

14. How the margin can be associated to BDBE is the subject of analysis and investigation (see Karisma Benchmark). The development of new standards and design rules can benefit from a better understanding of design margins of SSC's in NPP seismic safety design.

Seismic safety requirements and regulatory guidance

15. The role of IAEA in promoting nuclear safety is well recognized and strongly supported. The recent establishment of the International Seismic Safety Centre (ISSC) to serve as global focal point of seismic safety of nuclear installations represents an important initiative in response to the rising expectations of Member State's.

16. The national nuclear regulatory authority should give clear indication (guidance) on the safety objectives and requirements (criteria and methodology) to be applied by the applicant while performing seismic analysis, developing seismic design and submit safety assessment to the Regulatory Authority for approval.

17. The licensing process for NPP needs to have clear and well defined references in terms of requirements and criteria to be applied in the analysis and in the design. Their implementation shall be shown in the safety analysis. In this purpose a comprehensive set of guides should be issued or reference to international best practices should be made.

18. The assessment of the remained risk for exceedance of the Design Basis Earthquake is present as requirements in some regulatory guidance.

19. It has been confirmed the important role of the International cooperation and networking as substantial tool to exchange information, to update knowledge, to benefit from joint efforts in studies and analyses, to share experiences.

20. Transparency and public communication are fundamental tools in achieving the public acceptance of a nuclear site. Attention has to be given to these tools in the process to gain credibility from the public in particular for the Nuclear Regulatory Authority.

Lessons Learned from experience

Significant technical and scientific learning has been achieved from the Niigataken-chuetsu-oki earthquake (NCOE) of July 16, 2007, which affected the Tokyo Electric Power Company (TEPCO) Kashiwazaki-Kariwa (KK) Nuclear Power Station (NPS) with a magnitude of 6.6, The following major aspects can be summarized

a. A significant exceedance of the design base earthquake was experienced
b. Amplifications due to deep sediments and 3D effects were recorded
c. Limited damages not safety related have been observed
d. Integrity of safety important system and equipment was ensured
e. Emergency D/G did not start as it was available the external power supply
f. Some main shock records disappeared due to overfill of memory capacity by many aftershocks
g. Automatic shutdown worked well
h. NPP restart has needed almost 2 years
i. Fault lengths were re-evaluated to be consistent with the modeled source rupture process.
j. Observed response of the buildings were well predicted by 3D FEM and soil structure interaction
k. Fault model simulation was adopted by revised safety guide in Japan and reflected to the update of NS-G-3.3 (DS422, 2009)
l. Deformation were negligible at reactors and turbine buildings
m. KK experience was reflected to the re/evaluation of seismic safety of existing nuclear facilities.
n. For public acceptance IAEA missions were very valuable

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