Document Preparation Profile (DPP)
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1. IDENTIFICATION

Document Category: **Safety Guides**

Working ID: **DS490**

Proposed Title: **Seismic Design and Qualification for Nuclear Power Plants**

Proposed Action: **Revision of a document**

Published Title	Seismic Design and Qualification for Nuclear Power Plants
Publication Date	2003
Series No.	NS-G-1.6

Review Committee(s) or Group: **NUSSC**

Technical Officer(s): **Sujit SAMADDAR and Francisco BELTRAN, NSNI/ISSC**

2. BACKGROUND

The IAEA Safety Guide for seismic design and qualification (NS-G-1.6, Ref. 1) is intended to be applied to the design and construction of new nuclear power plants. It is based on the general practices in Member States. The Safety Guide introduces general seismic safety concepts, such as the design basis earthquake and the seismic categorization of components. Then, it provides guidance on seismic design, seismic qualification and seismic instrumentation. The Safety Guide includes recommendations for plant layout, for the required geotechnical parameters and for the seismic design of civil structures, piping and equipment. Additionally, the Safety Guide describes qualification by means of analysis, testing, earthquake experience or similarity, and it gives the range of application for each method.

It is recognized that there are steady advances in technology, scientific knowledge, regulations and events that prompt the update and revision of IAEA Safety Standards. The following are some of the issues that occurred after publication of the current Safety Guide in 2003 and prompt for an update:

- Two earthquakes with far reaching consequences for the nuclear seismic engineering have occurred:
  - The Chūetsu offshore earthquake, which affected the Kashiwazaki-Kariwa nuclear station (July 2007).
  - The Tohoku earthquake, which caused strong seismic motions at four nuclear sites (Fukushima Dai-ichi, Fukushima Dai-ini, Tokai and Onagawa) and produced the tsunami causing the Fukushima Dai-ichi nuclear power plant accident (March 2011).

  The effects of these two earthquakes on the nuclear plants have been, and still are, the subject of international research programs targeted to improve design practices and seismic safety evaluations. Basically, no safety significant seismic damage (i.e., due to shaking) occurred in these plants. Lessons include how site effects can produce significantly different building responses, even in closely located buildings; the importance of displacement controlled effects (seismic anchor motion); the potential for damage from sloshing in pools, and the confirmation of good-practice seismic design rules (e.g., absence of damage in well anchored equipment, even for motions well above the design motions).

- Significant changes in seismic design and qualification philosophy have taken place in some Member States, including risk informed seismic design (Ref. 4, 10 and 15); broader bases for qualification of equipment based on seismic experience of similar equipment in actual earthquakes (Ref. 11 and 13); and requirements for seismic safety margin over design basis earthquake for new plants (Ref. 14 and 8). Particularly, the performance based approach of Ref. 15 provides a quantifiable goal and a systematic method to achieve that goal for the seismic design of nuclear facilities.

- In the recent years, an effort has been made to improve the consistency between the output of Probabilistic Seismic Hazard Assessments (PSHA) and the seismic motion used as input for the design (Foundation Input Response Spectra – FIRS). Local site effects are analysed over very significant depths affecting soft rock and soil layers, in order to obtain the FIRS (Ref. 16).
- Recent results of PSHA for rock sites in some Member States have shown a significant increase in the high frequency contents (above 10-15 Hz) for the uniform hazard spectra (UHS) relevant for the design of nuclear facilities. This has fuelled the interest for introducing incoherence effects into the site response analysis. For large footprint structures and for the high frequencies in the seismic motion, a significant reduction of average input motion can be achieved if the spatial incoherence of the seismic waves is taken into account. Theoretical incoherence patterns have been developed from records taken at dense arrays of accelerometers deployed in Taiwan, Japan and the United States, for different ground conditions. Consequently, these patterns have now a firm experimental background, which allows application to nuclear projects.
- Recent design tendencies favour seismic isolation of structures in high seismicity sites. See for example the JNES standard (Ref. 11), not to mention the construction of large base isolated nuclear facilities, such as the Jules Horowitz European boiling water research reactor (RJH) and the Tokamak Complex building in the site of the International Thermonuclear Experimental Reactor (ITER), both in Cadarache (France).
- Results of applied research oriented to the application of displacement based methods for the design of nuclear structures, especially for near field earthquakes, have been published. Displacement based methods are well introduced in the practice for seismic design of conventional structures and are now acceptable in the context of performance based design of nuclear structures (IAEA-TECDOC-1655, Ref. 7).

3. JUSTIFICATION FOR THE PRODUCTION OF THE DOCUMENT

The current version of the IAEA Safety Guide for seismic design and qualification was published in 2003 (NS-G-1.6, Ref. 1). A revision of the current Safety Guide is desirable in order to introduce the progress in the state of practice and the results of international research on the effects of the significant seismic events that have taken place after the publication of the guide in 2003. Particularly, the following topics will be introduced or expanded:

- The use of the seismic experience of performance of structures, systems and components in nuclear power plants during the Chūetsu offshore earthquake and the Tohoku earthquake. Seismic experience underlines the importance of following specific seismic design conceptual rules;
- The broader bases and generalized use of seismic experience as a basis for seismic qualification of equipment;
- The definition of seismic performance goals in probabilistic terms (risk informed performance based seismic design);
- The concept of “plant seismic margin” to be addressed during the design process, in order to achieve a minimum (realistically computed) seismic safety margin over the design basis earthquake;
- The advances in soil/rock local response calculation and the introduction of incoherence of seismic waves into the definition of the seismic design input motion;
- New rules for the design of seismically isolated structures in nuclear facilities, based on recent research and experience during strong motion earthquakes;

- Introduction of displacement based methods in the seismic design, in the context of performance based design of nuclear structures.

The Safety Guide should address the requirements in the next higher rank document, the IAEA Safety Requirements for design, which have been revised very recently (SSR-2/1, DS426/465, Ref. 3). Even though the basic requirements for seismic design have not changed, SSR-2/1 now requires the definition of design specifications for safety features necessary to address design extension conditions. This requirement has an effect on the seismic categorization of structures, systems and components defined in Safety Guide NS-G-1.6.

Additionally, SSR-2/1 places now more emphasis on avoiding cliff edge effects and on the simultaneous impact of the earthquake on several units at the same site. These topics are both related with the achievement of a minimum (realistically computed) seismic margin over the design basis earthquake pointed out above and the revised Safety Guide NS-G-1.6 will address this point.

4. OBJECTIVE AND SCOPE

The objective and scope of the current Safety Guide will be maintained. The objective is to provide recommendations on a generally accepted way to design a nuclear power plant so that the design earthquake motion at the site will not jeopardize the safety of the plant. The scope will cover the design of land based stationary nuclear power plants with water cooled reactors.

5. PLACE IN THE OVERALL STRUCTURE OF THE RELEVANT SERIES AND INTERFACES WITH EXISTING AND/OR PLANNED PUBLICATIONS

The revised Safety Guide will maintain its place within the Safety Standards series of the Agency. Particularly, the Safety Guide interfaces with the following documents of the series:

- SSR-2/1. “Safety of Nuclear Power Plants: Design”. Specific Safety Requirements. (DS426/465, expected to be endorsed by CSS in November, 2014). (This document gives the requirements for design, including seismic design).
- SSG-9. “Seismic Hazards in Site Evaluation for Nuclear Installations”. Specific Safety Guide. 2010. (This document provides guidance for definition of design basis earthquakes and for assessing site specific seismic hazards different from ground motion).
- NS-G-2.13. “Evaluation of Seismic Safety for Existing Nuclear Installations”. Safety Guide. IAEA. 2009. (Methods used for evaluation of seismic safety of existing installations are now used at the design stage to show adequate margin over the design basis earthquake in new designs).
- NS-G-3.6. “Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants”. Safety Guide. IAEA. 2004. (This document provides guidance on the required geotechnical data for seismic design and on methods for the design of earth structures and foundations).
- SSG-30. “Safety Classification of Structures, Systems and Components in Nuclear Power Plants”. Specific Safety Guide. 2014. (This document provides recommendations and guidance on how to meet the requirements established for the identification of SSCs important to safety and for their classification on the basis of their function and safety significance).

6. OVERVIEW

The current contents of the Safety Guide will be reorganized and updated according to the new developments and trends in the Member States. The table of contents of the revised Safety Guide will be as shown in the next page and described in the following pages.

Chapter 1 is basically maintained from the current version, except for some updating of background and references.

Chapter 2 is new. It includes most of the information given in chapter 2 of the current version, but it also gathers all the input data required for design that are now disperse in other sections of the current version. A new section on “Input from Site Characterization” has been added, which includes the required geotechnical parameters. Guidance on the seismic categorization of structures, systems and components required to mitigate/control beyond design basis conditions (DEC) will be given in this chapter.

Chapter 3 is completely reorganized and updated. The idea is to follow the standard workflow of a design project. First, the general concept of the seismic design is given, and the requirements for computing the site free-field response and obtaining foundation ground properties for seismic soil-structure interaction are discussed. Adequacy of soil investigations and guidance to capture the variation of ground response due to sub surface strata are included. Then, the rules for selecting a seismically adequate plant layout are given. Seismic analysis of civil structures is introduced afterwards, together with the requirements for computing the seismic demand on structures, systems and components. Combination rules with loads other than earthquake are given and, finally, the guidelines for assessing seismic capacity (to be compared with the demand) are given. Displacement based approaches are briefly introduced and their range of application is given (IAEA TECDOC-1655, Ref. 7).

After giving these general design rules, specific design rules are given in Chapter 3 for a number of component categories: building structures, earth structures, seismic base isolation, mechanical equipment, electrical equipment, piping, cable trays and HVAC ducts. Each of these sections identifies the key seismic design issues and it gives what is considered now seismic good practice for each category of component.

Chapter 4 gathers former chapters 4 (generalities on seismic qualification), 5 (qualification by analysis) and 6 (seismic qualification by testing and earthquake experience). It provides a unified view over seismic qualification, consistent with current practice and updated according to the new developments.

Chapter 5 corresponds to the former chapter 7 (seismic instrumentation). The content is basically maintained. However, the section on “Post-earthquake actions” is updated according to recent developments (IAEA Safety Report No. 66, Ref. 6), and the instrumentation good practices learnt in Chūetsu offshore earthquake, which affected the Kashiwazaki-Kariwa nuclear station, are presented.

A new chapter, Chapter 6, is introduced to deal with the seismic margin to be achieved by the design. According to current practice, seismic design is performed for the design basis earthquake using criteria established in the design standards. Afterwards, the seismic safety margin over the design basis earthquake is assessed using best-estimate methodologies, such as those described in IAEA NS-G-2.13 (Ref. 3). The computed margin is then compared with the target margin established by the Regulation or other design specifications (Ref. 14 and 8). Chapter 6 will introduce these concepts and it will refer to IAEA NS-G-2.13 (Ref. 3) for the best-estimate methodologies that can be used to show the required margins.

Finally, another new chapter, Chapter 7, is introduced. This chapter gathers the requirements for safety analyses, quality assurance and periodic safety reviews, which are somewhat disperse in the current version of the Safety Guide.

The Appendix to the current version (“Samples of Seismic Categorization”) is maintained.

The publication is not expected to be co-sponsored by any other organization.

7. PRODUCTION SCHEDULE

Provisional schedule for preparation of the document is as follows:

STEP 1: Preparing a DPP	DONE
STEP 2: Approval of DPP by the Coordination Committee	October 2014
STEP 3: Approval of DPP by the relevant review committees	January 2015
STEP 4: Approval of DPP by the CSS	April 2015
STEP 5: Preparing and submitting a draft	October 2015
STEP 6: Approval of draft by the Coordination Committee	November 2015
STEP 7: Approval by the relevant review Committees for submission to Member States for comments	June 2016
STEP 8: Soliciting comments by Member States	June-Oct. 2016
STEP 9: Addressing comments by Member States	November 2016
STEP 10: Approval of the revised draft by the Coordination Committee Review in NS-SSCS	December 2016
STEP 11: Approval by the relevant review committees for submission to the CSS	June 2017
STEP 12: Endorsement by the CSS	October 2017
STEP 13: Establishment by the Publications Committee and/or Board of Governors (for SF and SR only)	Not applicable
STEP 14: Target publication date	January 2018

8. RESOURCES

Estimated resources are as follows:

Secretariat:

Professional staff	25 person-weeks
General staff	8 person-weeks

One technical meeting (TM):

Non-staff personnel	6 person-weeks

Two consultancy meetings (CS):

Non-staff personnel	6 person-weeks

Two contracts for consultant services (CSA):

Non-staff personnel	8 person-weeks

9. REFERENCES

1. SSR-2/1. “Safety of Nuclear Power Plants: Design”. Specific Safety Requirements. IAEA. (New revision DS426/465, expected to be endorsed by CSS in November, 2014).
2. NS-G-1.6. “Seismic Design and Qualification for Nuclear Power Plants”. Safety Guide. IAEA. 2003.
3. NS-G-2.13. “Evaluation of Seismic Safety for Existing Nuclear Installations”. Safety Guide. IAEA. 2009.
4. SSG-30. “Safety Classification of Structures, Systems and Components in Nuclear Power Plants”. Specific Safety Guide. IAEA. 2014.
5. SSG-9. “Seismic Hazards in Site Evaluation for Nuclear Installations”. Specific Safety Guide. IAEA. 2010.
6. Safety Report No. 66. “Earthquake Preparedness and Response for Nuclear Power Plants”. Safety Report. IAEA. 2011.
7. TECDOC-1655. “Non-linear Response to a Type of Seismic Input Motion”. IAEA. 2011.
8. WENRA. “Report - Safety of New NPP Designs”. Study by the Reactor Harmonization Working Group

(RHWG) of the Western European Nuclear Regulators Association (WENRA). March 2013.

9. RG 1.208. “A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion”. Regulatory Guide. U.S. Nuclear Regulatory Commission. March 2007.
10. NUREG-0800. “Standard Review Plan”. Chapter 3, revision 3. U.S. Nuclear Regulatory Commission. March 2007.
11. JNES-RC-2013-1002. “Proposal of Technical Review Guidelines for Structures with Seismic Isolation”. Seismic Safety Division. Japan Nuclear Energy Safety Organization. 2013.
12. IEEE 344-2004. “IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations”. Institute of Electrical and Electronics Engineers. June 2005.
13. RG 1.100. “Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants”. Revision 3. U.S. Nuclear Regulatory Commission. September 2009.
14. DC/COL-ISG-020. “Interim Staff Guidance on Implementation of a Probabilistic Risk Assessment-Based Seismic Margin Analysis for New Reactors”. U.S. Nuclear Regulatory Commission. March 2010.
15. ASCE 43-05. “Seismic Design Criteria for Structures, Systems and Components in Nuclear Facilities”. American Society of Civil Engineers. 2005.
16. EPRI 1025287. “Seismic Evaluation Guidance – Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic”. Electric Power Research Institute. November 2012.