IAEA SAFETY STANDARDS

Seismic Hazards in Site Evaluation of Nuclear Installations

Regional Workshop on Volcanic, Seismic, and Tsunami Hazard Assessment Related to NPP Siting Activities and Requirements
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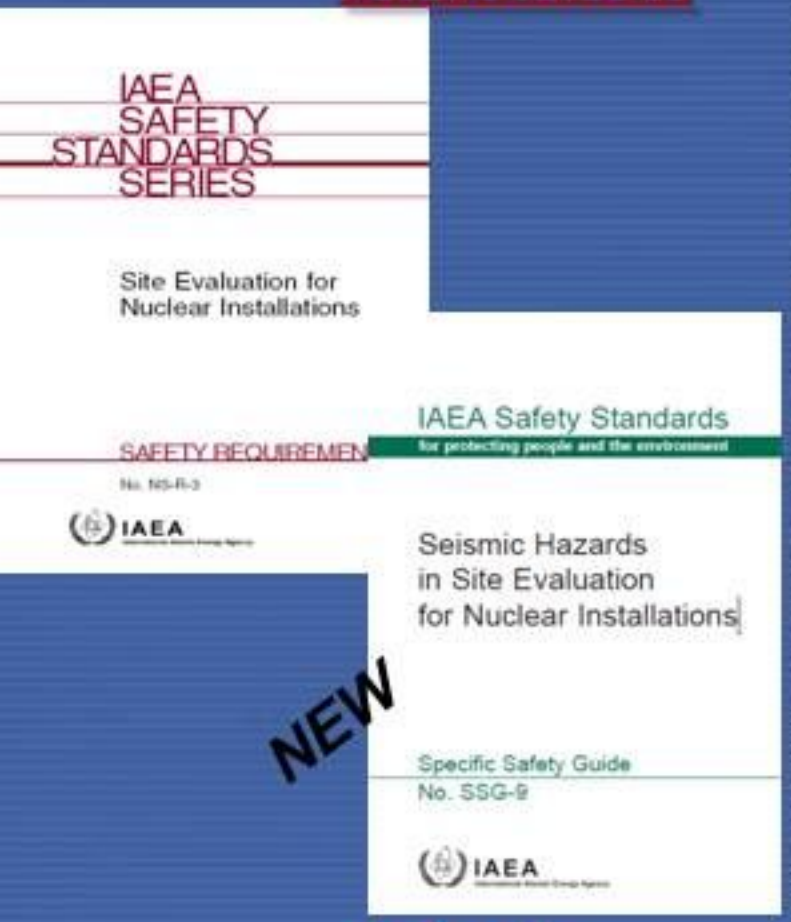
International Atomic Energy Agency

IAEA Safety Standards – Seismic Safety

SITE EVALUATION



Seismic Hazards SSG-9

DESIGN

new installations

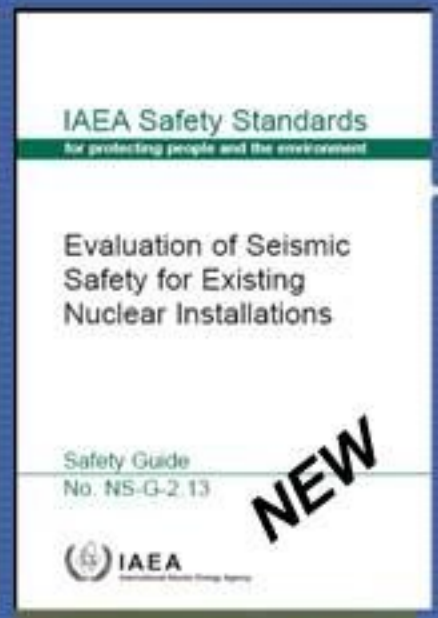
Seismic Design and Qualification NS-G-1.6

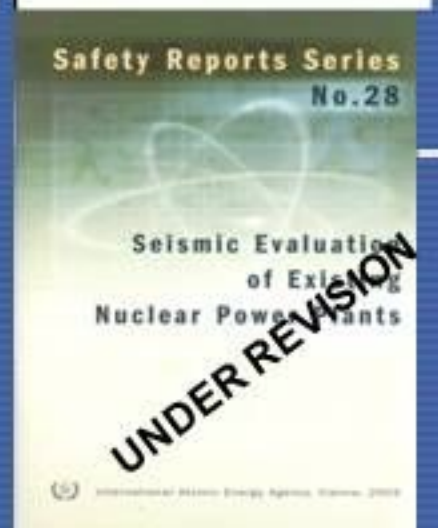
OPERATION

operating/existing installations

Evaluation of Seismic Safety - Existing NI NS-G-2.13

Periodic Safety Review





The complete lifetime of the installation *(t)*

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Background

Generation I – 50-SG-S1 (1979)

- Distinction between low and high seismicity countries (the Guide was valid for high seismicity countries)
- Confusion between probabilistic and statistical approaches
- Collection of varied and sometimes inconsistent national approaches
- Recommendation for generic response spectra (USNRC RG 1.60)

Background

Generation II – 50-SG-S1 (Rev. 1, 1991)

- Seismotectonic modelling using a four-scale approach; regional, near regional, site vicinity, site area
- Applicable to all countries (no distinction between low/high seismicity)
- Seismogenic structures and zones of diffuse seismicity
- Deterministic with an option for probabilistic
- Minimum requirement for 0.1g design
- Clear definition of a “capable fault”
- Site specific response spectra

Background

Generation III – NS-G-3.3 (2002)

- More emphasis on uncertainties
- More guidance on new topics of data generation such as paleoseismology
- More guidance on probabilistic seismic hazard analysis
- Decoupling of design response spectra and the hazard based response spectra (site specific)

Background

Why Safety Guide on Seismic Hazard revised?

- Feedback from seismic safety reviews between 2002-2010 (about 20 missions) some involving PSHA
- Need to include other nuclear installations
- International experience on PSHA such as Pegasos
- Need of a better treatment of uncertainties in both deterministic and probabilistic analyses.
- Distinction between uncertainties that can be reduced through site specific investigations and those that are "imported".

Background

Why Safety Guide on Seismic Hazard revised?

- Latest PSHA studies have used approaches with significant human and financial resources. This is not always possible and alternative methodologies are needed to properly account for uncertainties. More attention is needed on organizational and management aspects.
- Evaluation of the potential for fault displacement in the site area or vicinity for existing nuclear installations using a probabilistic approach.

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Objective

The objective of Safety Guide SSG-9 is to provide recommendations and guidance on evaluating seismic hazards at a nuclear installation site and, in particular, on how to determine:

(a) the vibratory ground motion hazards, in order to establish the design basis ground motions and other relevant parameters for both new and existing nuclear installations; and

(b) the potential for fault displacement and the rate of fault displacement that could affect the feasibility of the site or the safe operation of the installation at that site.

This Safety Guide is intended for use by regulatory bodies responsible for establishing regulatory requirements, and for operating organizations directly responsible for the assessment of seismic hazards at a nuclear installation site.

Scope

The guidance and procedures recommended in this Safety Guide can appropriately be used in site evaluations and in evaluations of seismic hazards for nuclear installations in any seismotectonic environment.

Other seismic hazard phenomena involving permanent ground displacement (e.g. liquefaction, slope instability, subsidence, ground collapse, seismically induced soil settlements) as well as seismically induced floods are treated in detail in the Safety Guides relating to geotechnical aspects of site evaluation and foundations and to external floods.

Scope

SSG-9 addresses an extended range of nuclear installations as defined: land based stationary nuclear power plants, research reactors, nuclear fuel fabrication facilities, enrichment facilities, reprocessing facilities and independent spent fuel storage facilities. The methodologies recommended for nuclear power plants are applicable to other nuclear installations by means of a graded approach, whereby these recommendations can be customized to suit the needs of nuclear installations of different types in accordance with the potential radiological consequences of their failure when subjected to seismic loads.

Scope

The recommended direction of grading is to start with attributes relating to nuclear power plants and eventually to grade down to installations with which lesser radiological consequences are associated. If no grading is performed, the recommendations relating to nuclear power plants are applicable to other types of nuclear installations.

Scope

For the purpose of this Safety Guide, existing nuclear installations are those installations that are:

(a) at the operational stage (including long term operation and extended temporary shutdown periods);

(b) at a pre-operational stage for which the construction of structures, the manufacturing, installation and/or assembly of components and systems, and commissioning activities are significantly advanced or fully completed; or

(c) at temporary or permanent shutdown stage while nuclear fuel is still within the facility (in the core or the pool).

Scope

In existing nuclear installations that are at the operational and preoperational stages, a change of the original design bases may lead to a significant impact on the design and, consequently, to important hardware modifications. Such a change in the original design bases may be made for a new seismic hazard at the site or a change in the regulatory requirements regarding the consideration of seismic hazards and/or seismic design of the installation.

The probabilistic seismic hazard analysis recommended in this Safety Guide also addresses what is needed for probabilistic safety assessments (PSAs) conducted for nuclear installations. In accordance with NS-R-1, seismic PSAs are required for seismic evaluation of nuclear power plants.

Content of SSG-9

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Content of SSG-9

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- DSHA vs PSHA
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- Site Specific vs Regional PSHA
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- Probabilistic Fault Displacement Analysis
- Conclusions

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Objectives of a SHA

- Derivation of the Design Basis Ground Motion Values for New NPPs
- Considerations for fault displacement hazards
- Seismic Evaluation for NPPs
  - Seismic PSA
  - Seismic Margin Analysis
- Considerations for Nuclear Installations other than NPPs (including Waste Repositories)
- This presentation will only consider NPPs

Building up of a Database

Introduction of 4 scales of investigation

- Regional (R~150 km) 1 : 500 000
- Near regional (R~25 km) 1 : 50000
- Site vicinity (R~5 km) 1 : 5000
- Site area (fenced area) 1: 500

This recommendation has been in the IAEA SG since 1991.
The USNRC RG 1.165 has similar requirements (1996)

Seismic Hazard Evaluation – Scales of investigations

Geological, geophysical and geotechnical databases

Site vicinity

Objectives:

- **Neotectonic fault history**
- **Potential for surface faulting**

Near regional scale

Objectives:

- Detailed seismotectonic characterization
- Latest faults movements

Regional scale

Objectives:

- General geodynamic setting
- Characterization of geological features
- Delineation of seismogenic sources

Site area (~1 km^2)

5 km (maps scale 1:5 000)

25 km (maps scale 1:50 000)

>150 km (maps scale 1:500 000)

Objectives:

- **Permanent ground displacement**
- **Dynamic properties of foundation materials**

A need for application of increased efforts

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The 'Near Field' Issue

The site for the NPP is generally chosen at a relatively 'aseismic' part of the country. This generally means that well known seismogenic sources are more than at least 50 km from the site. Consequently the seismic source that contains the site is a 'zone of diffuse seismicity' (to use the terminology of the IAEA Safety Guide). Because there are few dispersed epicentres and that these are not well correlated with tectonic structures, these areas generally do not attract the interest of researchers and therefore contain the least amount of both geological and seismicity data that is available prior to the selection of the site.

Dealing with Uncertainties

- Random (aleatory) uncertainties – inherent in the variable
- Modelling (epistemic) uncertainties (Uncertainty attributable to incomplete knowledge about a phenomenon, which affects the ability to model it. Epistemic uncertainty is reflected in a range of viable models, multiple expert interpretations and statistical confidence.)
- Balance between data generation and coping with uncertainties
- Only some part of the uncertainty can be reduced by additional data – imported uncertainties cannot be reduced.

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DSHA vs PSHA

- Both methods need to transform the 'seismic event' to 'ground motion'. This transformation is the major source of variability
- In PSHA the rate of earthquake recurrence is an important parameter
- In DSHA it is not a parameter but it may be used to distinguish between seismic sources

DSHA vs PSHA

- It is difficult to say which method is more conservative – depends on the safety factors (in the DSHA) and the probability of exceedance considered
- The treatment of uncertainties (both aleatory and epistemic) should be similar in PSHA and DSHA
- In general, the differences in earlier and more recent studies are due to the fact that uncertainties have not been accounted for in the earlier studies (not because one is DSHA and the other is PSHA)

Using PSHA in S-PSA

A plant PSA is a requirement of IAEA Safety Standard NS-R-1 (including external initiators)

PSHA for a SPSA (for an operating NPP) needs to conform to overall project constraints:

- Generally no new data – therefore need to cope with greater uncertainties
- Consistency in the treatment of epistemic uncertainties throughout the PSA (e.g. PSHA and fragilities)
- Requirements originating from the plant CDF

Site Specific vs Regional PSHA

- Site specific PSHA (and of course DSHA) should be performed using the 4 scale approach (region, near region, site vicinity and site area).
- Regional PSHA can take into consideration only the regional database (maybe also near regional to a limited extent).
- Differences between the two may be attributable to the difference in the database
- For single site the attenuation relationships may have different σ values (one site variability)

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Use of CAV as filter in SHA

- There is a need to use a lower bound filter in SHA because of the cut-off imposed by attenuation relationships (M~4.5 – 5.0)
- In practice this also serves as a filter for earthquakes the occurrence of which will be of no consequence to the NPP (even if they occur very close)
- As the hazard metric is ground motion and not earthquake magnitude, a filter using a ground motion based parameter (such as CAV) will be more consistent with the aims of a SHA
- Eventually, it is possible to use a CAV distribution (instead of one number) and integrate this filter explicitly into PSHA.

Probabilistic Fault Displacement Analysis

- SSG S9 recommends a probabilistic approach to the fault displacement issue for existing NPPs
- There are a number of NPPs with such issues.

Project Management System

A project work plan should be prepared prior to, and as a basis for, the execution of the seismic hazard analysis project. The work plan should convey the complete set of general requirements for the project, including applicable regulatory requirements. It is advisable that this set of requirements be reviewed by the regulatory body prior to conducting the seismic hazard analysis. In addition to general requirements, the work plan should delineate the following specific elements: personnel and their responsibilities; work breakdown and project tasks; schedule and milestones; and deliverables and reports.

Conclusions

- SHA (for a NPP) is always part of a larger project (e.g. SPSA or design basis derivation) and needs to be considered within that context, i.e.
  - Safety approach
  - Performance and safety goals
  - Treatment of uncertainties
- Preferably both PSHA and DSHA should be used.
- The database requirements, the uncertainty treatment and expert involvement should be similar in a PSHA and DSHA to the extent possible.

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Thank you for your attention

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