Translation

Provision against earthquakes affecting nuclear facilities

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1 Introduction

Design of nuclear facilities aims at prevention of events hazardous to safety and at mitigation of their consequences. Accident risk i.e. the product of the probability of an event which leads to an accident situation and the hazard arising from the event should be sufficiently small.

Strong motion earthquakes have a very low occurrence rate in Finland but their worst impact on nuclear facilities may be so significant that making provision against earthquakes is necessary. This guide defines general guidelines for the design and demonstration of nuclear facilities' earthquake resistance and for the monitoring of earthquakes during operation.

The requirements of this guide mainly apply to new facilities. Modifications of nuclear facilities constructed before the issuance of the guide or modifications concerning their monitoring during operation will be reviewed on a case by case basis. The Finnish Centre for Radiation and Nuclear Safety will impose detailed requirements upon every nuclear facility separately.

2 Design earthquake

In the design of a nuclear facility, loads induced by the design earthquake shall be taken into account. The design earthquake is a maximum impact earthquake which, with great certainty, can be expected in the site area not more than once in ten thousand years on average. In the occurrence rate estimate, in addition to the area's seismic history, also regional and local geology and tectonic considerations are to be taken into account as basic information.

The dynamic effects imposed upon a nuclear facility by the design earthquake are expressed by means of a Response Spectrum. The Spectrum is selected so that it corresponds to the Maximum(peak) Ground Acceleration of the bedrock surface on a site. Dynamic effects constitute the loads to be taken into account in the design of components and structures. In the design, also an acceleration time-history constructed from the Response Spectrum can be employed to define loads.

If there is not sufficient site-specific information availabe for defining the response spectra reliably, the required spectra are to be formed in conformity with the practice presented in Ref./6/. If none of the above mentioned procedures can be applied, the figure 1.0 m/s^2 shall be used as the value of the maximum acceleration resultant or as the value of its horizontal perpendicular components, and 0.67 m/s^2 as the value of the vertical component when determining loadings.

The value chosen for the design earthquake including substantiation shall be presented in conjunction with a PSAR.

3 Seismic classification of components and structures

Components and structures at nuclear facilities are classified into three categories according to the earthquake-resistance requirements set for them.

Components and structures in seismic category 1A are such as

- are needed during the safe shutdown of a nuclear facility or during residual heat removal
- restrict the escape of radioactive materials in the nuclear fuel outside the nuclear facility or
- contain significant amounts of radioactive materials in an easily released form.

These components and structures with their potential restraints and supports shall maintain their integrity, tightness, operability and proper location during any loading situation induced by the design earthquake.

Components which would be otherwise classified as seismic category 1A but which need not maintain active functional capability in order to fulfill the mentioned safety functions, belong to seismic category 1P. With the exception of maintaining functional capability, the same requirements apply to them as apply to seismic category 1A components.

All other structures and components are in seismic category N. No requirements are placed on their earthquake resistance but any damage to them shall not endanger structures and components in seismic categories 1A and 1P.

Seismic classification shall be presented in conjunction with safety classification which is attached to a licence application and which is in conformity with the guide YVL 2.1 /2/.

4 Demonstration of earthquake resistance

Before the commissioning of a nuclear facility the licencee shall demonstrate that the nuclear facility's systems and structures resist design earthquake induced loads in conformity with the requirements of their seismic categories.

A system's or a component's earthquake resistance is demonstrated in connection with its strength calculations. In case of e.g. an electrical or instrumentation equipment for which no strength calculations are required, a special report of earthquake resistance shall be provided.

When demonstrating a nuclear facility's earthquake resistance, changes in acceleration components induced by the design earthquake shall be taken into consideration when motion is transferred from bedrock along structures to the base of the component or structure examined. The horizontal component of the base's Maximum Accelerations is chosen for each item in conformity with its most delicate direction whenever this can be established. In other cases, components are selected for two mutually perpendicular horizontal directions (the item's main directions).

Static or dynamic analyses, tests or experimental assessments can be employed when demonstrating earthquake resistance.

4.1 Analytical demonstration

The earthquake resistance of a component or a structure can be demonstrated by static or dynamic calculation methods. In static calculations, the product of mass distribution and the highest base acceleration is used as the load. If the horizontal or vertical acceleration of a base is equal to or greater than 1.0 m/s^2, however, a dynamic analysis is required for a component or a structure the lowest natural frequency of which is below 33 Hz or unknown. An acceptable dynamic analysis method is the Response Spectrum Method based on the dynamics of a single-degree-of-freedom vibrator the relative damping coefficient of which is chosen conservatively e.g. from Ref. /6/. If the natural vibration frequency is unkown, the vibration frequency will be chosen which imposes the greatest loads, and these stresses are multiplied by a factor of 1.5 to allow for the potential impacts of other natural frequencies.

The items on which the design earthquake will impose nonlinear vibrations due to gaps etc shall be analysed, if necessary, by time-history analysis in accordance with Ref. /6/. The time-history analysis is also suited for earthquake resistance demonstration in all cases of linear vibratory motion.

A base's maximum accelerations are derived from the bedrock maximum accelerations either by time-history or response spectrum analysis. Instead of a base's maximum accelerations, bedrock maximum accelerations multiplied by a factor of 1.5 can be applied for bases the maximum distance of which from a building's foundation does not exceed 10 m.

Natural frequencies are defined by the known structural dynamics methods or by measurement.

4.2 Tests

The earthquake resistance of components and structures which are difficult to analyse can be demonstrated by shake table tests. Components to be examined in this way include i.a. active components such as electrical equipment and regulating components in pipings. Shake table tests suited for these components are addressed in Ref. /9/.

4.3 Empirical assessment

Earthquake resistance of a component or a structure can be assessed on the basis of an earlier report prepared for a corresponding item in conformity with sub-sections 4.1 or 4.2. Also commensurate experiences of occurred earthquakes can be utilised.

Therefore, analytical demonstration is not required for a piping if

- the piping can be compared with other piping which has been analysed in sufficient detail
- the piping is identical to and functional under the same operational conditions as other piping which has performed satisfactorily and the earthquake-resistance of which has been assessed either by tests or empirically.

4.4 Allowable stresses

In stress calculations, loads induced by the design earthquake shall be added to other loads encountered at the same time. Loads and load combinations induced by the design earthquake and other accident conditions such as a LOCA generally need not be taken into account simultaneously. As regards mechanical components, the design earthquake is classified by accident conditions according to Ref. /3/ and allowable stresses are determined accordingly.

5 Monitoring during operation

Strong motion recorders which register earthquake acceleration data shall be installed at a nuclear facility.

A minimum of two strong motion recorders shall be installed in a nuclear facility's reactor building. One recorder shall be installed on the base mat and the other above the level of components and structures important to safety. Furthermore, strong motion recorders shall be placed in the vicinity of a nuclear facility to evaluate the soil-structure dynamic interaction effects postulated by analyses. These devices shall record acceleration data for vertical and two mutually perpendicular horizontal directions.

Own strong motion recorders are not required for other nuclear facilities in the immediate vicinity of a nuclear power plant.

After a noteworthy earthquake, the seismic input signal obtained from strong motion recorders will be utilised in the assessment of the degree of necessity of the inspection of components and structures important to safety and the prerequisites for the continuation of operation.

6 Literature

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2 YVL 2.1 Safety classification of nuclear power plant systems, structures and components, Rev. 1, 14 Dec. 1982
3 YVL 3.5 Nuclear power plant pressure vessels. Stress analysis, draft May 5, 1978
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No. 50-SG-S1 Earthquakes and Associated Topics in Relation to Nuclear Power Plant Siting
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5 International Organization for Standardization ISO 8258 Nuclear Power Plants - Design against Seismic Hazards
ISO/TC 85/SC3/GT7 Draft 1980 Seismic Design Criteria in Zones I < 7 MSK
6 US.NRC. Regulatory Guides
1.29 Seismic Design Classification
1.48 Design Limits and Loading Combinations for Seismic Category I Fluid System Components
1.60 Design Response Spectra for Seismic Design of Nuclear Power Plants
1.61 Damping Values for Seismic Design of Nuclear Power Plants (+ Code Case N-411, NUREG 1061 vol 5)
1.70.9 Additional Information: Design of Seismic Category I Structures
1.92 Combining Modal Responses and Spectral Components in Seismic Response Analysis
1.122 Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment of Components (+ Code Case-397 App N)
7 Statens Kärnkraftinspektion, godkänd FSAR för Forsmark 3
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KTA 2201.2 Teil 2 Baugrund
KTA 2201.4 Teil 4 Auslegung der maschinen- und elektrotechnischen Anlagenteile
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This guide is a translation of the guide YVL 2.6 issued on 19 Dec. 1988.

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