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# Design of nuclear power plants against seismic events —

## Part 5: Seismic instrumentation

*Conception parasismique des installations nucléaires —*

*Partie 5: Instrumentation pour la détection et l'enregistrement des séismes*



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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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# Foreword

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A list of all parts in the ISO 4917 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

# Introduction

Objective of the seismic instrumentation is to ascertain whether a seismic event has occurred at the site of the nuclear power plant and to determine the size of this seismic event in relation to the one on which the design of the plant was based.

# Design of nuclear power plants against seismic events —

# Part 5:
# Seismic instrumentation

## 1 Scope

This document specifies the utilization and characteristics of instrumentation used to detect seismic events at nuclear power plants with water cooled reactors. The document can also be applied to other nuclear facilities after verifying its applicability.

The following types of electrical systems and equipment are not covered by this document:

— seismic instrumentation involved in the implementation of nuclear safety functions as defined by IEC 61226, for example automatic shutdown systems;

— seismic instrumentation not involved in the implementation of nuclear safety functions as defined by IEC 61226 but which due, for example, to close proximity to other safety classified systems, requires hardware qualification to be performed.

Such systems are specified, designed, manufactured, qualified, operated and dismantled according to the relevant requirements of IEC standards, in particular IEC 61513 and the lower level IEC standards according to the safety class and technologies used.

Seismic instrumentation used for the implementation of seismic reactor trip systems are developed according to the requirements of IEC 63186.

An automatic shutdown system is not covered by this document.

This document specifies the requirements to be fulfilled by the seismic instrumentation such that, firstly, it can be ascertained whether any of the design quantities on which the plant walk-down level and the inspection levels are based have been exceeded and that, secondly, the recording of the time history of the earthquake provides the necessary input values for a post-seismic analysis. The requirements are specified such that, independent of the detection and recording system, comparable results within tolerances are achieved in the time range as well as the frequency range.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4917-1, *Design of nuclear power plants against seismic events — Part 1: Principles*

ISO 4917-6, *Design of nuclear power plants against seismic events — Part 6: Post-seismic measures*

IEC 61226, *Nuclear power plants — Instrumentation, control and electrical power systems important to safety — Categorization of functions and classification of systems*

IEC/IEEE 60780-323, *Nuclear facilities — Electrical equipment important to safety — Qualification*

IEC/IEEE 60980-344, *Nuclear facilities — Equipment important to safety — Seismic qualification*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

**3.1**
**acceleration sensor**
sensor to detect the accelerations in three orthogonal directions and convert the accelerations into transferable signals

**3.2**
**acceleration acquisition system**
system of different components that measures and records the absolute acceleration components as a function of time

Note 1 to entry: The acceleration acquisition system essentially consists of several *acceleration sensors* (3.1), *recording devices* (3.5) and *seismic triggers* (3.6), not necessarily located in one device.

**3.3**
**aliasing effects**
errors that occur, if a sampled signal contains frequencies higher than half of the sampling rate (Nyquist-Frequency)

**3.4**
**amplitude frequency response**
frequency dependent relation between the real occurred and the instrumentally displayed amplitude of acceleration

**3.5**
**recording device**
device that records measurement values as a function of time

**3.6**
**trigger**
electro-mechanical or logic device that initiates a corrective or protective action whenever a setpoint value is crossed

Note 1 to entry: Lower and upper setpoints are common in numerous control systems, hence "exceeded" does not apply in the literal sense.

**3.7**
**setpoint**
predetermined threshold value at which follow-up actions are initiated



## 4 Requirements for the seismic instrumentation

### 4.1 General requirements

The seismic instrumentation system being installed in the NPP is in general an individual I&C system part of the overall I&C system of the NPP. The seismic instrumentation system shall be classified according to its importance to safety. Classification shall be performed in accordance with the requirements of IEC 61226 or other equivalent practices for NPPs.

The seismic instrumentation shall be seismically qualified for operability during and after a seismic event according to relevant IEC standards.

Concerning the qualification of the system, IEC/IEEE 60780-323 or equivalent requirements shall be applied, in particular and specifically for seismic qualification IEC/IEEE 60980-344 or equivalent shall be applied.

The seismic instrumentation shall be provided with the objective of

a) detecting and quantifying the seismic effects at the plant site and at the power plant itself,

b) measuring the accelerations, recording the acceleration time histories and storing these data, and

c) enabling the comparison (of these data) with the design quantities basic to the design of the power plant.

It shall be ensured that, whenever trigger levels are exceeded, these are detected and displayed by the seismic instrumentation for the plant inspections specified in ISO 4917-1.

NOTE 1 Plant inspections in buildings containing safety-related components are addressed in ISO 4917-6. The definitions in ISO 4917-6 explain the relationship to OBE and SL-1 definitions.

It should be ensured that, immediately after a seismic event, it is determined and displayed whether the criteria for the inspection level specified in ISO 4917-1 have been exceeded or have been significantly exceeded for a shutdown level as specified in ISO 4917-6. This requires that, immediately after the recording has ended, the recorded acceleration time histories, the resulting response spectra as well as a comparison of the resulting response spectra with the ground response spectrum (free field response spectrum) or with the analytic building response spectra are made available. Depending on national requirements, additional elements such as CAV (Cumulative Absolute Velocity) can be defined.

The recorded acceleration time histories shall be appropriate for analytical verifications.

NOTE 2 Analytical verifications can be, for example, dynamic calculations or comparisons of spectra of safety-related components and safety-related building structures.

## 4.2 Instrument location

Acceleration acquisition systems shall be provided at free field. Additional acquisition systems should be installed inside the reactor building.

NOTE 1 The seismic design is based on the free field response spectrum. A comparison of the response spectrum measured in the free field with the corresponding site-specific free field response spectrum (used for design) allows to evaluate the whole power plant, because the reaction forces of the power plant were determined analytically in the design process based on the site-specific free field response spectrum.

NOTE 2 Due to the analytical methods used, the building response spectra contain certain degrees of conservativeness. Therefore, a comparison of the response spectra measured inside a building and the corresponding building response spectra only allows an evaluation for the instrument location. However, the data measured inside the building can be used for control purposes and for the verification of the analytical models.

NOTE 3 Acceleration values inside the buildings can be calculated from the free field measurement in case of an earthquake. This corresponds to the plant design procedure specified in ISO 4917-1 through ISO 4917-4.

NOTE 4 Examples for instrument locations can also be found in IAEA-TECDOC-1956, RG 1.12, RFS I.3.b or KTA 2201.5.

For the locations in the free field, defined in ISO 4917-1, and inside the reactor building it shall be ensured that the free field response spectra and the building response spectra, defined in ISO 4917-1, (in each of three orthogonal directions) derived from the measured acceleration time histories are appropriate for the evaluation in accordance with ISO 4917-6.

The structure for mounting the instrument, the local topography and the soil inhomogeneity at the location shall only have a negligible effect on the measurement of free field accelerations. Furthermore, the location of the acceleration acquisition system in the free field shall be chosen such that any influence of buildings on the measured data can be excluded. The acceleration acquisition system shall be placed at a minimum distance from other buildings. The choice of locations shall be based on the plant design engineer in consultation with the seismologists and instrumentation specialist, who should jointly select the proper locations for measuring free field acceleration. The minimum distance to the reactor building should be at least twice the largest length of the reactor building foundation and the minimum distance to other buildings should be at

least the largest ground-plan dimension of the respective building. Smaller distances are allowed in well-justified cases.

If the reference horizons of the site spectrum (used for design) and of the location of the free field instrumentation do not coincide, a corresponding transformation of the site spectrum relative to the reference horizon of the location shall be performed.

It is recommended to install at least three acceleration acquisition systems in the reactor building if 3-dimensional effects are of interest. Two of these in the lowest building level and one in an upper level of the reactor building, for example pool floor level; the horizontal distance between the lower acceleration sensors should be as large as possible. For only 2-dimensional effects, one location at the lowest building level is sufficient. The locations of the acceleration acquisition systems should be chosen such that a direct comparison of the measured data with the corresponding design quantities is possible. At their location, there should be only negligible operation-related effects on the measurements.

The axes of the acceleration sensors of the acceleration acquisition systems usually should be oriented parallel to the axes of the coordinate system used for the seismic analysis of the reactor building.

The acceleration acquisition systems shall be accessible for the necessary operating and maintenance procedures. The acceleration acquisition systems shall be designed and installed such that an evaluation of the recorded data is not adversely affected, for example, by damages to components or civil structures that fail during an earthquake nor by a superposition of the measured seismic signal with seismically induced oscillations of neighboring components nor by internal flooding that will possibly occur.

The acceleration sensors of the acceleration acquisition systems shall be mounted such that no movements relative to the mounting support can occur.

In the case of multi-unit power plants, a single mutual free field acceleration acquisition system is sufficient, provided that similar soil conditions exist for all plant units and for the location of the acceleration acquisition system. Otherwise, more than one free field acceleration acquisition system will be necessary.

In the case of multi-unit power plants, basically each reactor building should be equipped with seismic instrumentation. In well-justified cases, for example similar building structure and similar soil conditions, this requirement can be waived.

For soil site with shallow sediments (for example up to 30 m) over rock, where significant site amplification is expected, it is recommended to install an additional acceleration acquisition system at rock level.



## 5 Instrumentation characteristics

### 5.1 General requirements

At all locations the seismic instrumentation shall enable a reliable comparison between the response spectra of the inspection level (if any) and the design basis earthquake and the response spectra of the actual seismic event.

Even in the event of a loss of off-site power, it is recommended that 24 h recording and 10 min continuous recording are possible and verifiable.

Maintenance and testing of the instruments shall be carried out in accordance with the manufacturer recommendations.

Periodically test interval, for example every year, and test instructions shall be determined.

### 5.2 Acceleration acquisition system

The acceleration acquisition system should be designed and installed such that accelerations within the measurement range are measured with an error of not larger than 1 % of the full scale value of the measurement range.

The characteristics of the acceleration acquisition system are defined as follows. Other characteristics values can be defined. Examples can be found in IAEA-TECDOC-1956.

a) Acceleration sensor:

1) In the frequency range of 0,1 Hz to at least 30 Hz (for soil sites), the amplitude frequency response should not deviate by more than ±10 % from the amplitude setpoint. For rock sites a higher upper frequency is recommended, for example for hard rock sites 100 Hz. No resonances are permissible in this frequency range. It is permissible to arithmetically correct the amplitude frequency response.

2) The dynamic range of the sensor should be at least 60 dB. If only a lower dynamic range is required, then a system with this lower dynamic range can be deployed. The cross-axis sensitivity for acceleration components orthogonal to the sensor axis should not exceed 3 %.

3) The difference between the background noise level and the lower limit of the measurement range should be at least 20 dB.

4) The specifications shall be met within a defined temperature range in accordance with the local extreme weather conditions at the site, including safety margins. For arctic conditions, a heating system can be installed. Other environmental condition can be considered, depending on the site impacts.

b) Recording device:

1) The dynamic range of the recording device should be at least 72 dB. The measurement values of all channels shall be recorded. The time offset between the channels should not be larger than 5 ms.

2) The recordable frequency range should at least extend from less than or equal 0,1 Hz up to at least 30 Hz for soil sites. The upper limit should be increased up to 50 Hz if ground improvements are made. For rock sites an upper limit of 100 Hz is recommended.

3) It should be ensured that a frequency resolution of 0,1 Hz can be achieved by digital post-processing of the recorded data.

4) Aliasing effects shall be prevented.

5) The recording device should record the acceleration time history from at least 40 s before activation of the trigger. This time can be adjusted to a lower or a higher value depending on the seismic situation.

NOTE 1 With a recording starting 40 s before the activation of the trigger, earthquakes up to about 320 km can be detected.

c) Data recording trigger:

1) For triggering the data recording, a corresponding threshold value shall be set in the recording device for all three measurement directions.

2) To suppress non-earthquake related interferences, a low-pass filter with a cut-off frequency of 10 Hz should be applied for the triggering signal.

3) The vertical as well as the two horizontal seismic excitations shall trigger the data recording.

d) Alarm trigger:

1) For triggering an alarm, a corresponding threshold value shall be set in the recording device for all three measurement directions.

2) The frequency range to be covered should range from 0,1 Hz up to at least 30 Hz (for soil sites). For rock sites an upper bound value of 100 Hz is recommended.

3) The vertical as well as the two horizontal seismic excitations shall trigger the alarm.

The acceleration sensor and the recording device shall be permanently in operation, storing the acceleration time histories on a temporary buffer having a capacity of at least 24 h. Permanent storage of data from the recorded buffer shall start as soon as the trigger threshold is exceeded. This record should include 40 s preceeding the activation and up to 30 s after the last exceeding of this threshold, as specified above under b) 5). Data storage capacity depends on seismicity and, as a general recommendation, should be sufficient to record at least a 60 min duration onwards from the moment of exceeding the data recording trigger threshold and the beginning of the recording.

NOTE 2 This design requirement for the seismic instrumentation ensures that, in addition to data from the main earthquake, any possible fore- and aftershocks can also be recorded and stored.

It should be possible to remove the sensors to enable regular inspections. At least their transfer behavior shall be tested mechanically, for example by subjecting them to a tilting table test.

It should be possible to activate an automatic and periodic self-testing program for testing the system by which the following points are tested and documented:

— trigger test for each channel;

— data storage test (reading and writing);

— battery voltage test of all built-in batteries.

If a measurement location is not available during the self-test, then it shall be ensured that the self-test is performed only at one measurement location at a time or the system shall be installed redundantly on different trains.

It should be possible to check the functionality of the sensor in its installed condition, for example by an external excitation.

## 6 Actuation and alarms

The threshold values for data recording triggers in the reactor building should be adjusted to site specific acceleration limit values considering seismicity, for example not more than 0,1 $m/s^2$ for low to moderate seismicity regions. The threshold value for the data recording trigger in the free field should be adjusted to a site specific acceleration limit value considering seismicity, for example not more than 0,2 $m/s^2$ for low to moderate seismicity regions. By means of appropriate circuitry, fail-safe operation shall be ensured such that the data recording will be actuated at all instrument locations, even if only a single data recording trigger threshold is exceeded at only a single measurement location.

If a trigger threshold is regularly exceeded by non-seismic related events, this measuring device should, for example be relocated to another location. Increasing the acceleration trigger threshold is permissible only if no other measures are successful.

The threshold values for alarms shall be adjusted to the acceleration limit values that correspond to the maximum accelerations specified or calculated for the inspection levels at the respective locations.

The following alarms shall be documented in the main control room or in a control room annex:

a) actuation of data measurement and recording;

b) actuation of any one of the alarm triggers;

c) loss of the external power supply to the instrumentation specified in Clause 4.

These alarms shall be interconnected to initiate a group alarm, that shall be optically and acoustically annunciated in the main control room.

A comparison of the response spectra of the seismic event with the design basis response spectra as well as an assessment whether the inspection level was exceeded or significantly exceeded shall be made available in the main control room or an annex to the control room immediately after the seismic event.