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NUCLEAR POWER PLANT INSTRUMENTATION FOR EARTHQUAKES

A. INTRODUCTION

In 10 CFR Part 20, "Standards for Protection Against Radiation," licensees are required to make every reasonable effort to maintain radiation exposures as low as is reasonably achievable. Paragraph IV(a)(4) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires that suitable instrumentation must be provided so that the seismic response of nuclear power plant features important to safety can be evaluated promptly after an earthquake. Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50 requires shutdown of the nuclear power plant if vibratory ground motion exceeding that of the operating basis earthquake ground motion (OBE) occurs.[1]

This guide describes seismic instrumentation that is acceptable to the NRC staff for satisfying the requirements of Part 20 and Appendix S to Part 50.

The information collections contained in this regulatory guide are covered by the requirements of 10 CFR Part 50, which were approved by the Office of Management and Budget, approval number 3150–0011. The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number.

B. DISCUSSION

When an earthquake occurs, it is important to take prompt action to assess the effects of the earthquake at the nuclear power plant. This assessment includes both an evaluation of the seismic instrumentation data and a plant walkdown. Solid-state digital time-history accelerographs installed at appropriate locations will provide time-history data on the seismic response of the free-field, containment structure, and other Seismic Category I structures. The instrumentation should be located so that the response may be compared and evaluated with the design basis and so that occupational radiation exposures associated with their location, installation, and maintenance are maintained as low as reasonably achievable (ALARA).

Instrumentation is provided in the free-field and at foundation level and at elevation in Seismic Category I structures. Free-field instrumentation data will be used to compare measured response to the engineering evaluations used to determine the design input motion to the structures and to determine whether the OBE has been exceeded (see Regulatory Guide 1.166). The instruments located at the foundation

[1]Regulatory Guide 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Postearthquake Actions," provides criteria for plant shutdown after an earthquake.

level and at elevation in the structures measure responses that are the input to the equipment or piping and will be used in long-term evaluations (see Regulatory Guide 1.167, "Restart of a Nuclear Power Plant Shut Down by a Seismic Event"). Foundation-level instrumentation will provide data on the actual seismic input to the containment and other Seismic Category I structures and will be used to quantify differences between the vibratory ground motion at the free-field and at the foundation level. Instrumentation is not located on equipment, piping, or supports since experience has shown that data obtained at these locations are obscured by the vibratory motion associated with normal plant operation.

The guidance in Regulatory Guide 1.166 is based on the assumption that the nuclear power plant has operable seismic instrumentation, including the equipment and software needed to process the data within 4 hours after an earthquake. This is necessary to determine whether plant shutdown is required. This determination will be made by comparing the recorded data against OBE exceedance criteria and by evaluating the results of the plant walkdown inspections that take place within 8 hours of the event.

It may not be necessary for identical nuclear power units on a given site to each be provided with seismic instrumentation if essentially the same seismic response at each of the units is expected from a given earthquake.

An NRC staff evaluation of seismic instrumentation noted that instruments have been out of service during plant shutdown and sometimes during plant operation. The instrumentation system should be operable and operated at all times. If the seismic instrumentation or data processing hardware and software necessary to determine whether the OBE has been exceeded is inoperable, the guidelines in Appendix A to Regulatory Guide 1.166 should be used.

The characteristics, installation, activation, remote indication, and maintenance of the seismic instrumentation are described in this guide to help ensure (1) that the data provided are comparable with the data used in the design of the nuclear power plant, (2) that exceedance of the OBE can be determined, and (3) that the equipment will perform as required.

It is important that all the significant ground motion associated with an earthquake is recorded. This is accomplished by specifying how long before and after the actuation of the seismic trigger the data should be recorded. Settings for the instrumentation's pre-event memory should be correlated with the maximum distance to any potential epicenter that could affect a specific site. The "P" wave may not be recorded with only a 3-second memory setting. Also, when an event occurs at some distance and the trigger threshold limit is not exceeded until 15 or 20 seconds into the event, a part of the record, although at low amplitude, is lost. A 30-second value may be more appropriate and is within the capabilities of current digital time-history accelerographs at no additional cost.

The appendix to this guide provides definitions to be used with this guidance.

C. REGULATORY POSITION

The type, locations, operability, characteristics, installation, actuation, remote indication, and maintenance of seismic instrumentation described below are acceptable to the NRC staff for satisfying the requirements in 10 CFR Part 20 and Paragraph IV(a)(4) of Appendix S to 10 CFR Part 50 for ensuring the safety of nuclear power plants.

1. SEISMIC INSTRUMENTATION TYPE AND LOCATION

1.1 Solid-state digital instrumentation that will enable the processing of data at the plant site within 4 hours of the seismic event should be used.

1.2 A triaxial time-history accelerograph should be provided at the following locations:

1. Free-field.
2. Containment foundation.
3. Two elevations (excluding the foundation) on a structure inside the containment.
4. An independent Seismic Category I structure foundation where the response is different from that of the containment structure.
5. An elevation (excluding the foundation) on the independent Seismic Category I structure selected in 4 above.
6. If seismic isolators are used, instrumentation should be placed on both the rigid and isolated portions of the same or an adjacent structure, as appropriate, at approximately the same elevations.

1.3 The specific locations for instrumentation should be determined by the nuclear plant designer to obtain the most pertinent information consistent with maintaining occupational radiation exposures ALARA for the location, installation, and maintenance of seismic instrumentation. In general:

1.3.1 The free-field sensors should be located and installed so that they record the motion of the ground surface and so that the effects associated with surface features, buildings, and components on the recorded ground motion will be insignificant.

1.3.2 The in-structure instrumentation should be placed at locations that have been modeled as mass points in the building dynamic analysis so that the measured motion can be directly compared with the design spectra. The instrumentation should not be located on a secondary structural frame member that is not modeled as a mass point in the building dynamic model.

1.3.3 A design review of the location, installation, and maintenance of proposed instrumentation for maintaining exposures ALARA should be performed by the facility in the planning stage in accordance with Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable."

1.3.4 Instrumentation should be placed in a location with as low a dose rate as is practical, consistent with other requirements.

1.3.5 Instruments should be selected to require minimal maintenance and in-service inspection, as well as minimal time and numbers of personnel to conduct installation and maintenance.

2. INSTRUMENTATION AT MULTI-UNIT SITES

Instrumentation in addition to that installed for a single unit will not be required if essentially the same seismic response is expected at the other units based on the seismic analysis used in the seismic design of the plant. However, if there are separate control rooms, annunciation should be provided to both control rooms as specified in Regulatory Position 7.

3. SEISMIC INSTRUMENTATION OPERABILITY

The seismic instrumentation should operate during all modes of plant operation, including periods of plant shutdown. The maintenance and repair procedures should provide for keeping the maximum number of instruments in service during plant operation and shutdown.

4. INSTRUMENTATION CHARACTERISTICS

4.1 The design should include provisions for in-service testing. The instruments should be capable of periodic channel checks during normal plant operation.

4.2 The instruments should have the capability for in-place functional testing.

4.3 Instrumentation that has sensors located in inaccessible areas should contain provisions for data recording in an accessible location, and the instrumentation should provide an external remote alarm to indicate actuation.

4.4 The instrumentation should record, at a minimum, 3 seconds of low-amplitude motion prior to seismic trigger actuation, continue to record the motion during the period in which the earthquake motion exceeds the seismic trigger threshold, and continue to record low-amplitude motion for a minimum of 5 seconds beyond the last exceedance of the seismic trigger threshold.

4.5 The instrumentation should be capable of recording 25 minutes of sensed motion.

4.6 The battery should be of sufficient capacity to power the instrumentation to sense and record (see Regulatory Position 4.5) 25 minutes of motion over a period of not less than the channel check test interval (Regulatory Position 8.2). This can be accomplished by providing enough battery capacity for a minimum of 25 minutes of system operation at any time over a 24-hour period, without recharging, in combination with a battery charger whose line power is connected to an uninterruptable power supply or a line source with an alarm that is checked at least every 24 hours. Other combinations of larger battery capacity and alarm intervals may be used.

4.7 Acceleration Sensors

4.7.1 The dynamic range should be 1000:1 zero to peak, or greater; for example, 0.001g to 1.0g.

4.7.2 The frequency range should be 0.20 Hz to 50 Hz or an equivalent demonstrated to be adequate by computational techniques applied to the resultant accelerogram.

4.8 Recorder

4.8.1 The sample rate should be at least 200 samples per second in each of the three directions.

4.8.2 The bandwidth should be at least from 0.20 Hz to 50 Hz.

4.8.3 The dynamic range should be 1000:1 or greater, and the instrumentation should be able to record at least 1.0g zero to peak.

4.9 Seismic Trigger

The actuating level should be adjustable and within the range of 0.001g to 0.02g.

5. INSTRUMENTATION INSTALLATION

5.1 The instrumentation should be designed and installed so that the mounting is rigid.

5.2 The instrumentation should be oriented so that the horizontal components are parallel to the orthogonal horizontal axes assumed in the seismic analysis.

5.3 Protection against accidental impacts should be provided.

6. INSTRUMENTATION ACTUATION

6.1 Both vertical and horizontal input vibratory ground motion should actuate the same time-history accelerograph. One or more seismic triggers may be used to accomplish this.

6.2 Spurious triggering should be avoided.

6.3 The seismic trigger mechanisms of the time-history accelerograph should be set for a threshold ground acceleration of not more than 0.02g.

7. REMOTE INDICATION

Triggering of the free-field or any foundation-level time-history accelerograph should be annunciated in the control room. If there is more than one control room at the site, annunciation should be provided to each control room.

8. MAINTENANCE

8.1 The purpose of the maintenance program is to ensure that the equipment will perform as required. As stated in Regulatory Position 3, the maintenance and repair procedures should provide for keeping the maximum number of instruments in service during plant operation and shutdown.

8.2 Systems are to be given channel checks every 2 weeks for the first 3 months of service after startup. Failures of devices normally occur during initial operation. After the initial 3-month period and 3 consecutive successful checks, monthly channel checks are sufficient. The monthly channel check is to include checking the batteries. The channel functional test should be performed every 6 months. Channel calibration should be performed during each refueling outage at a minimum.

D. IMPLEMENTATION

The purpose of this section is to provide guidance to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with the specified portions of the Commission's regulations, this guide will be used in the evaluation of applications for construction permits, operating licenses, combined licenses, or design certification submitted after January 10, 1997. This guide will not be used in the evaluation of an application for an operating license submitted after January 10, 1997, if the construction permit was issued prior to that date.

Holders of an operating license or construction permit issued prior to January 10, 1997, may voluntarily implement the methods described in this guide in combination with the methods in Regulatory Guides 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Postearthquake Actions," and 1.167, "Restart of a Nuclear Power Plant Shut Down by a Seismic Event." Other implementation strategies, such as voluntary implementation of portions of the cited regulatory guides, will be evaluated by the NRC staff on a case-by-case basis.

APPENDIX

DEFINITIONS

Acceleration Sensor. An instrument capable of sensing absolute acceleration and transmitting the data to a recorder.

Accessible Instruments. Instruments or sensors whose locations permit ready access during plant operation without violation of applicable safety regulations, such as those of the Occupational Safety and Health Administration (OSHA) or regulations dealing with plant security or radiation protection safety.

Channel Calibration (Primary Calibration). The determination and, if required, adjustment of an instrument, sensor, or system such that it responds within a specific range and accuracy to an acceleration, velocity, or displacement input, as applicable, or responds to an acceptable physical constant.

Channel Check. The qualitative verification of the functional status of the instrument sensor. This check is an "in-situ" test and may be the same as a channel functional test.

Channel Functional Test (Secondary Calibration). The determination without adjustment that an instrument, sensor, or system responds to a known input of such character that it will verify the instrument, sensor, or system is functioning in a manner that can be calibrated.

Containment—See Primary Containment and Secondary Containment.

Nonaccessible Instruments. Instruments or sensors in locations that do not permit ready access during plant operation because of a risk of violating applicable plant operating safety regulations, such as OSHA, or regulations dealing with plant security or radiation protection safety.

Operating Basis Earthquake Ground Motion (OBE). The vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public will remain functional. The value of the OBE is set by the applicant.

Primary Containment. The principal structure of a unit that acts as the barrier, after the fuel cladding and reactor pressure boundary, to control the release of radioactive material. The primary containment includes (1) the containment structure and its access openings, penetrations, and appurtenances, (2) the valves, pipes, closed systems, and other components used to isolate the containment atmosphere from the environment, and (3) those systems or portions of systems that, by their system functions, extend the containment structure boundary (e.g., the connecting steam and feedwater piping) and provide effective isolation.

Recorder. An instrument capable of simultaneously recording the data versus time from an acceleration sensor or sensors.

Secondary Containment. The structure surrounding the primary containment that acts as a further barrier to control the release of radioactive material.

Seismic Isolator. A device (for instance, laminated elastomer and steel) installed between the structure and its foundation to reduce the acceleration of the isolated structure, as well as the attached equipment and components.

Seismic Trigger. A device that starts the time-history accelerograph.

Time-History Accelerograph. An instrument capable of sensing and permanently recording the absolute acceleration versus time. The components of the time-history accelerograph (acceleration sensor, recorder, seismic trigger) may be assembled in a self-contained unit or may be separately located.

Triaxial. Describes the function of an instrument or group of instruments oriented in three mutually orthogonal directions, one of which is vertical.

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this regulatory guide. The regulatory analysis, "Revision of 10 CFR Part 100 and 10 CFR Part 50," was prepared for these amendments, and it provides the regulatory basis for this guide and examines the costs and benefits of the rule as implemented by the guide. A copy of the regulatory analysis is available for inspection and copying for a fee at the NRC Public Document Room, 2120 L Street NW. (Lower Level), Washington, DC, as Attachment 7 to SECY–96–118.

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