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IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations

IEEE Power and Energy Society

Sponsored by the
Nuclear Power Engineering Committee

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3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 344™-2013
(Revision of
IEEE Std 344-2004)

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Abstract: Practices are provided for establishing procedures that will yield data to demonstrate that the equipment can meet its performance requirements during and/or following one safe shutdown earthquake event preceded by a number of operating basis earthquake events. This standard may be used to establish tests, analyses, or experienced-based evaluations that will yield data to demonstrate equipment performance claims or to evaluate and verify performance of devices and assemblies as part of an overall qualification effort. Common methods currently in use for seismic qualification by test are presented. Two approaches to seismic analysis are described, one based on dynamic analysis and the other on static coefficient analysis. Two approaches to experienced-based seismic evaluation are described, one based on earthquake experience and the other based on test experience.

Keywords: earthquake, earthquake experience, equipment qualification, IEEE 344™, inclusion rules, nuclear, operating basis earthquake, prohibited features, qualification methods, required response spectrum, response spectra, safe shutdown earthquake, safety function, seismic, seismic analysis, test experience, test response spectrum, type testing

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

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Introduction

This introduction is not part of IEEE Std 344-2013, IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations.

This revision of IEEE Std 344 was developed to expand and clarify guidance for developing programs to qualify Seismic Category I equipment for nuclear power generating stations. IEEE Std 344 can also be used to evaluate structural integrity and position retention of non-safety-related equipment to demonstrate that it will not prevent the satisfactory accomplishment of safety functions of safety-related equipment under seismic conditions. [Equipment that is not required to function but whose failure could adversely affect the safety function of any Seismic Category I equipment or could result in an incapacitating injury to control room occupants and is designed and constructed so that the safe shutdown earthquake (SSE) would not cause a failure are typically referred to as *Seismic Category II equipment*.] Specific areas of amplification were to address seismic qualification programs with higher frequency content as a result of high-frequency ground motion and experience gained since 2004. Clause 7 has been expanded to add discussion of the different treatment of rigid and flexible equipment and to clarify the differences between static, static coefficient, and dynamic (response spectrum and time history) methods of analysis. Guidance is also provided in Annex C to determine equipment fragility level. The goal of fragility testing is to define the highest seismic level at which the equipment item can still perform its safety function.

The equipment to be qualified by procedures or standards based upon this standard can be of many forms; therefore, this standard presents the guidelines for many acceptable seismic qualification methods with the intent of permitting the user to make a judicious selection from the options offered. This standard attempts to define more fully the procedures by which equipment can be seismically qualified. It presents the methods that are known by the Working Group to be practices that are acceptable to the nuclear power generation industry, its equipment suppliers, and the industrial test and analysis facilities utilized by the industry. The clarification and update of methods in this standard reflect an effort to recommend state-of-the-art techniques at the time of publication.

The methods and definitions presented in this revision are not intended to limit other seismic qualification techniques. Exceptions to this standard may be made at any time where it can be shown that the substituted procedure verifies that the equipment can perform its safety function with justifiable methodology. The basis for a technical justification may be, but is not limited to, partial analysis, tests on similar equipment, experience data, or a combination thereof. Engineering judgment may be used in conjunction with these methods. Exceptions to these guidelines, which are founded on a broad base of actual test, analysis, and earthquake experience, supplemented by engineering judgment, may be used to meet the intent of this standard, provided the methods are justified.

Clause 10 and relevant parts of Clause 11 contain guidance for the use of earthquake and test experience data. Use of the experience-based approach in this standard is acceptable for use in nuclear plants if it is consistent with the plant's licensing/regulatory design basis.

Further guidance is presented to address seismic high-frequency content in excess of 33 Hz. Recent studies have identified the potential for certain hard-rock plant sites in the Central and Eastern U.S. to have high-frequency ground motion. As a result of the high-frequency ground motion, the seismic plant response spectra may contain high-frequency content that exceeds the traditional 33 Hz cutoff frequency used in previous qualification programs. To address these hard-rock sites, the qualification and documentation clauses of this document have been updated to include the potential for high-frequency content in the qualification program.

Adherence to this standard to obtain equipment seismic qualification alone will not suffice for assurance of public health and safety since it is the integrated performance of structures, fluid systems, instrumentation systems, electrical systems, and man/machine interface systems of a nuclear power generating station that establish safe operating conditions.

This standard was prepared by Subcommittee 2 Working Group 2.5 (Seismic) of the Nuclear Power Engineering Committee of the IEEE Power and Energy Society.

Contents

IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations

1. Overview

This standard is divided into 11 clauses. Clause 1 provides the scope of this standard. Clause 2 lists normative references to other standards that are useful in applying this standard. Clause 3 provides definitions that are either not found in other standards or have been modified for use with this standard. Clause 4 provides background information on earthquake behavior and on the performance of equipment during simulated seismic events. Clause 5 defines the most commonly used methods for seismic qualification of equipment contained in this standard. Clause 6 provides guidance on the measurement and application of damping in the seismic qualification of equipment. Clause 7 provides procedures for approaches most commonly used to seismically qualify equipment by analysis. Clause 8 provides procedures for the commonly used methods for seismic qualification of equipment by test. Clause 9 provides guidelines for seismic qualification of equipment that cannot be practically qualified by analysis or testing alone. Clause 10 provides guidelines for two approaches to seismically qualify equipment using experience data for a reference equipment class. Clause 11 provides documentation guidelines for the seismic qualification of equipment.

This standard also contains six informative annexes. Annex A explains how to measure the zero period acceleration (ZPA) from seismic test data. Annex B explains frequency content and stationarity of the input waveform. Annex C provides guidance on fragility testing. Annex D explains the use of test duration and response cycles in evaluating equipment response relative to low-cycle fatigue capability. Annex E provides guidance in establishing statistically independent simulated simultaneous multi-axis motions for seismic testing and analysis. Annex F includes bibliographical references.

1.1 Scope

This standard describes methods for establishing seismic qualification procedures that will yield quantitative data to demonstrate that the equipment can meet its performance requirements.

1.2 Purpose

This standard provides methods and documentation requirements for seismic qualification of equipment to verify the equipment's ability to perform its specified performance requirements during and/or after the specified seismic motions.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 323™, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.[1, 2]

IEEE Std 382™, IEEE Standard for Qualification of Actuators for Power-Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Plants.

MIL-S-901D-1989, Requirements for Shock Tests, H. I. (High-Impact); Shipboard Machinery, Equipment and Systems.[3]

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[4]

broadband response spectrum: A response spectrum that describes motion in which amplified response occurs over a wide (broad) range of frequencies.

coherence function: A comparative relationship between two time histories. It provides a statistical estimate of how much two motions are related, as a function of frequency. The numerical range is from zero for unrelated to +1.0 for related motions.

correlation coefficient function: A comparative relationship between two time histories. It provides a statistical estimate of how much two motions are related, as a function of time delay. The numerical range is from –1.0 for inversely related motions, zero for unrelated, to +1.0 for related motions.

critical seismic characteristics: Those design, material, and performance characteristics of an equipment item that provide reasonable assurance that the item will perform its required function under seismic loads.

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