Study on the Revisions of Seismic Qualification Standards (IEEE Std 344) of Safety-related Equipment

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1. Introduction

The Periodic Safety Review (PSR) of a nuclear power plant shall be conducted utilizing the latest research findings and operational experience. In the field of seismic qualification, IEEE Std 344 serves as the applicable technical standard for evaluation. The gap analysis shall be performed between the technical standard applied to the plant and the latest version of the standard to identify differences, and, if necessary, the need for safety measures shall be assessed.

2. Overview of the Seismic Qualification Standards

IEEE Std 344 is a standard for verifying the seismic capability of safety-related equipment. The standard defines the performance and functional capability of equipment during and/or after the specified seismic motions, and requires verification that the equipment can perform its safety functions under seismic conditions. The choice of seismic qualification method should be based on the practicality of the method for type, size, shape, and complexity of the equipment configuration, whether the safety function can be assessed in terms of operability or structural integrity alone, and the reliability of the conclusions.

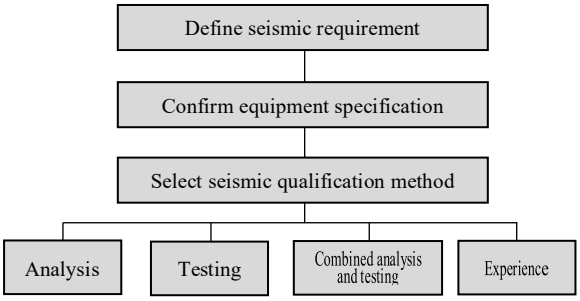

Fig. 1. Typical process for seismic qualification

3. Major Revisions of IEEE Std 344

IEEE Std 344 has undergone revisions after its initial issuance in 1971 - revised in 1975, 1987, 2004, and 2013.

2.1 IEEE Std 344-1971

As the first seismic qualification standard for Class 1E equipment of NPP, the approach of analysis describes general contents, and the seismic simulation of the test presents a sinusoidal (single frequency waveform) – single axis test method [1].

2.2 IEEE Std 344-1975 (Revision of IEEE Std 344-1971)

This is the revised edition in which the technical standard of seismic qualification has been systematized, and since the San Fernando earthquake in 1971, research and understanding of earthquake phenomena have been intensified, making drastic revisions to simulating earthquake.

The analysis method according to the equipment eigenvalue is presented (dynamic analysis, static coefficient analysis, OBE/SSE analysis), and the test method (random motion test, multi-frequency test, multiple-axis test, etc.) to simulate the realistic seismic motion is presented in detail. In addition, test methods (proof test, fragility test, device test, assembly test) were divided by test purpose. [2]

2.3 IEEE Std 344-1987 (Revision of IEEE Std 344-1975)

The use of experience data was added as a qualification method, and the contents of vibration aging were divided into non-seismic and seismic, and specific procedures were presented. Triaxial test have been added to multiple-axis tests and further guidance (statically independent input motion) was specified. A qualification method for a multi-cabinet assembly has been added and a qualification method is presented by classifying equipment mounting conditions (hard-mounted equipment or line-mounted equipment). [3]

2.4 IEEE Std 344-2004 (Revision of IEEE Std 344-1987)

The equipment installation features (support structure and interactions) were required to be considered during seismic qualification. For equipment that is difficult to analysis, a combination method of analysis and testing and a method using experience data were additionally allowed (previously, only testing method was proposed). The method of experience data is described in detail, and experience data divided actual earthquake experience data (EES, Earthquake Experience Spectrum) and test experience data (TES, Test Experience Spectra). [4]

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

The title was changed to "IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations (The previous title is "IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations"). The definition of seismic category I, II equipment and the seismic qualification method of the seismic category II equipment was added. Site conditions similar to Hard Rock High Frequency (HRHF) site in the Central and Eastern United States (CEUS) were required to consider high frequency component of earthquake. [5]

3. Conclusions

In this paper, the revisions of seismic qualification standard (IEEE Std 344) for safety-related equipment of NPP were analyzed. Based on these analyses, the key technical requirements by revision are summarized as follows.

3.1 Method of Simulating Earthquake according to Equipment Mounting Conditions

The equipment mounting conditions are divided into hard and line mounting conditions. Hard-mounted equipment is qualified through the Random motion Multi-Frequency (RMF) test and line-mounted equipment is qualified though the sinusoidal test with the Required Input Motion (RIM) curve as the input motion. [3,4,5]

3.2 Frequency Interval of TRS Analysis

Test Response Spectrum (TRS) should be developed over the frequency range of interest. It is recommended that the TRS be computed with 1/6 octave or narrow bandwidth resolution to generate adequate data over the frequency range of interest. [3,4,5]

3.3 Consideration of Support Structure and Interactions

Seismic qualification of equipment requires consideration of installation features, such as the seismic adequacy of the supporting structure (support assembly, structure, anchorage, floors, walls, of foundation), and the potential for adverse seismic interactions (such as falling of overhead components, proximity impacts, differential displacements, spay, flood, or fire). [4,5]

3.4 Cutoff Frequency Range

Traditionally, the cutoff frequency has been set to 33 Hz, but in the case of a site similar to the CEUS HRHF site condition, the cutoff frequency range should be set by considering the high frequency component of earthquake. It is recommended that the resonance search be carried out at least a factor 1.5 beyond the Required Response Spectrum (RRS) cutoff frequency. [5]

REFERENCES

[1] IEEE Std 344-1971, IEEE Trial-Use Guide for Seismic Qualification of Class I Electric Equipment for Nuclear Power Generating Stations.

[2] IEEE Std 344-1975, IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

[3] IEEE Std 344-1987, IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

[4] IEEE Std 344-2004, IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

[5] IEEE Std 344-2013, IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations.