3D Attach E Seismic Qualification Techniques

E.1 Purpose

The purpose of this attachment is to provide the methodology for establishing the seismic qualification of mechanical, electrical, and instrumentation and control (I&C) equipment. An acceptable method for complying with the NRC regulations with respect to the seismic qualification of electrical and mechanical equipment is described in RG 1.100, Revision 3 (as described in Section 3.10.2). This states that the procedures described in IEEE Std 344-2004 are acceptable to the NRC staff for satisfying the NRC regulations pertaining to seismic qualification of electrical and mechanical equipment. Section 3.10 describes the methods for seismic qualification of mechanical, electrical, and instrumentation and control (I&C) equipment. This methodology is also based on the recommended methods and criteria in IEEE Std 382-2006[1] (Reference 2), and incorporates guidelines from Sections 3.7, 3.9, and 3.10. Table 3.10-1—List of Seismically and Dynamically Qualified Mechanical and Electrical Equipment, provides a list of mechanical equipment that is being seismically qualified in accordance with IEEE Std 344 (Reference 1). Table 3.11-1—List of Environmentally Qualified Electrical/I&C Equipment, provides a list of electrical and I&C equipment that is located in a harsh environment and is being seismically qualified in accordance with IEEE Std 344 (Reference 1). Table 3.10-1 also provides a list of electrical and I&C equipment that is not located in a harsh environment but is seismically qualified in accordance with IEEE Std 344 (Reference 1).

E.2 Definitions

This section defines the terms used in this attachment.

Operating Basis Earthquake

For the U.S. EPR, the operating basis earthquake (OBE) is defined as one-third of the safe shutdown earthquake (SSE) as detailed in Section 3.7, and within the following definition for an SSE.

Safe Shutdown Earthquake

According to 10 CFR 50, Appendix S, an SSE is an earthquake that is based on an evaluation of the maximum earthquake potential considering the regional and local geology, seismology, and specific characteristics of local subsurface material. It is the earthquake that produces the maximum vibratory ground motion for which certain structures, systems, and components (SSC) are designed to remain functional and

1. Section 3.11 provides the justification for the use of the latest version of the IEEE standards referenced in this section that have not been endorsed by existing Regulatory Guides. AREVA maintains the option to use current NRC-endorsed versions of the IEEE standards.

within applicable stress, strain, and deformation limits. As such, the SSE terminology of Appendix S is defined for a specific site. The U.S. EPR standard plant design is not based on conditions for a specific site. Within this document the term SSE will refer to the standard plant design SSE. The standard plant design SSE for the U.S. EPR is defined in Sections 3.7 and 3.7.1.

The systems and components that are designed to remain functional and within applicable stress, strain, and deformation limits are those necessary to verify the following:

- The integrity of the reactor coolant pressure boundary.
- The capability to shut down the reactor and maintain it in a safe condition.
- The capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the guideline exposures of 10 CFR 50.34(a).

Seismic Category I Equipment

Seismic Category I equipment is the SSC required to withstand the effects of the SSE without losing the capability to perform safety-related functions. The designation of Seismic Category I equipment conforms to RG 1.29, Revision 4. The methodology for the selection of Seismic Category I equipment that requires seismic qualification in accordance with IEEE Std 344 (Reference 1) is provided in Section 3.10.

Active Equipment

Active equipment is equipment that is required to perform a mechanical motion while fulfilling a safety-related function during and after a seismic event.

Passive Equipment

Passive equipment is equipment that is only required to maintain structural or pressure boundary integrity after a seismic event.

Similarity

Similarity is an instance in which equipment is of a type that has been previously qualified, differing only in size or in the specific qualified devices located in the assembly or structure.

E.3 Seismic Qualification Methods

The scope of Seismic Category I equipment that requires seismic qualification is defined in Section 3.10. The seismic qualification is performed in accordance with IEEE Std 344 (Reference 1) and incorporates the requirements from Sections 3.7, 3.9, and 3.10. The qualification can be demonstrated through testing, analysis, a combination of testing and analysis, similarity, and by use of experience data. The method of qualification must be selected based on the appropriateness of the method for the size, type, complexity, and functional requirements of the subject equipment.

E.3.1 Qualification by Testing

Qualification by testing is the preferred qualification method for equipment that must perform an active function during and after a seismic event. The type of seismic test that is recommended depends on the type of equipment, its function, the methods of mounting, and the type of seismic motion expected according to Section 3.10.2. The different methods of qualification by testing are presented in Section E.5 of this attachment.

E.3.2 Qualification by Analysis

Qualification by analysis is selected when equipment can be accurately modeled and when it is verified that the structural integrity of the equipment sufficiently demonstrates that it will perform its design-intended function during and after a seismic event. In addition, when a complete seismic test is not practical, a combination of testing and analysis can be performed as described in Section 3.10.2. Different methods for qualification by analysis are presented in Section E.6.

E.3.3 Qualification by Similarity

Qualification by similarity is appropriate when the equipment is similar to an item previously qualified, differing only in configuration details such as size or arrangement of specific qualified devices located in the assembly or structure. The purpose of qualification by similarity is to avoid the impracticality of testing or analyzing numerous configurations of equipment that is essentially the same. Qualification by similarity shall demonstrate the similarity of equipment (i.e., demonstrate dynamic similarity), the applicability of the previous test and analysis, and assess the need for supplemental device testing. Specific details associated with qualification by similarity are presented in Section E.7.

E.3.4 Qualification by Experience

As noted in Section 3.10, seismic qualification based on experience, per Section 10 of IEEE Std 344-2004, is not utilized by AREVA. This does not prevent the use of applicable test data from previous qualification of similar equipment.

E.4 Requirements

E.4.1 Damping

Damping represents the energy dissipation within a structure while it is responding to applied seismic inertia loads. The level of damping depends on many factors including the materials used, the methods of mounting, and the type of loading as addressed in Section 3.7.1.2 and in RG 1.61, Revision 1. Typical damping values used in seismic analysis are listed in Table 3.7.1-1—Damping Values for Safe Shutdown Earthquake.

E.4.1.1 Application of Damping in Testing

Equipment is subjected to seismic inertia loads defined by the required response spectra (RRS) for qualification of equipment by testing. Any practical value of damping can be used in the RRS for testing. It is not necessary to use a predefined damping value because the comparison of the test response spectra (TRS) and the RRS is performed for a TRS damping value that is equal to or greater than that used for the RRS. Both the RRS and TRS are described further in Section E.5.1.

E.4.1.2 Application of Damping in Analysis

Qualification of equipment by analysis uses a math model that accurately represents its behavior. The damping value used for the RRS is based on the behavior of the equipment. The damping values used in the analysis are provided in Section 3.7.1.2 and Table 3.7.1-1, unless they are obtained from testing or otherwise justified.

E.4.2 Interface Requirements

Seismic EQ is employed, when required, to verify the structural integrity and operability of equipment. Seismic EQ must provide reasonable assurance that equipment does not adversely interact with nearby commodities. Adequate clearance between components is provided to preclude interference from excessive equipment displacements or deformations. Excessive displacements of the equipment may also adversely impact attached cables and conduits. These displacements and deformations can be measured during a seismic test or predicted by analysis.

E.4.3 Mounting Simulation

The mounting conditions and methods for the equipment to be tested or analyzed must simulate the expected inservice or installed conditions of the equipment. The flexibility of intermediate supporting structures must be considered in the testing or analysis of the equipment. There must be enough cable slack between the equipment and connected cable trays and conduits to prevent additional restraints from changing the dynamic response of the equipment.

E.4.4 Simulation of Seismically Induced Fatigue

According to information provided in Sections 3.7.3, 3.10, and the definition of OBE, consideration of explicit design and qualification cases for the OBE is not a design requirement for the U.S. EPR. However, low-level seismic effects (i.e., fatigue) that might occur from the vibrations of seismic events preceding an SSE event are considered in the seismic qualification process. For qualification by testing in accordance with IEEE Std 344 (Reference 1), the requirement to simulate fatigue is included in the seismic qualification process in terms of five one-half SSE events followed by one full SSE event using the approach from SECY 93-087 (Reference 3) and as described in Section 3.7.3.2.

E.4.5 Safe Shutdown Earthquake

The RRS is developed for the SSE support locations and is derived from the seismic analysis of structures. The flexibility of intermediate supporting structures is taken into account to determine the RRS. The RRS at the location of the equipment forms the design basis for the qualification of the equipment.

E.4.6 Other Dynamic Loads

In addition to normal operating loads and seismic loads, other vibratory loads such as hydrodynamic loads, if applicable, must be evaluated for their effect on Seismic Category I equipment in accordance with IEEE Std 344 (Reference 1).

E.5 Qualification by Test

Qualification by testing is the preferred method for EQ. As described in Section 3.10.2 and in accordance with IEEE Std 323-1974 (Reference 4), the overall qualification program shall be performed in its proper sequence. The test plan includes pretest functional baseline tests, environmental aging, non-seismic vibration aging (e.g., vibration from piping, pumps, and motors among others), SSE-based seismic inertia tests, and post testing inspection. Other types of vibration, such as hydrodynamic loadings, should be simulated and included with the seismic qualification. Only the seismic qualification of equipment is addressed within this section.

Many factors, including the type of equipment, its safety function, and its location (i.e., hard-mounted or line-mounted) must be considered to determine the type of test that is used to establish the seismic qualification of equipment.

Since the OBE defined in Section 3.7 is one-third of the SSE, consideration of design or qualification cases for an OBE is not a requirement for the design of the U.S. EPR, and the COL applicant is therefore not required to perform explicit response or design analyses. Qualification by testing for the U.S. EPR is only performed according to the SSE event, and the simulation of seismically induced fatigue effects from low-level seismic events preceding the SSE are specified in terms of full or fractional SSE events. In accordance with IEEE Std 344 (Reference 1), Appendix D and information included in Section 3.7.3.2, for the simulation of seismically induced fatigue effects, the SSE test is preceded by either five tests at the one-half SSE or by a number of fractional peak cycles equivalent to the maximum peak cycles for five one-half SSE events.

In accordance with IEEE Std 344 (Reference 1), multi-frequency testing is the preferred qualification method. It is normally used unless single frequency tests can be justified. Single frequency tests are justified when the equipment is line mounted and the seismic input motion is dominated by one frequency (see Section E.5.2). Single frequency testing is also used to determine the natural frequency of equipment. Regardless of the type of testing utilized, the TRS must envelop the RRS over the frequency range of interest at comparable levels of damping for the test input motion (see Section E.4.1.1). The peak test amplitude for each sine beat is at least that required in IEEE Std 382 (Reference 2), or the maximum g-level specified by analysis at the mounting location of the equipment.

In addition, IEEE Std 344 (Reference 1) allows single or multi-axis testing. The test input motion must conservatively simulate the earthquake motion at the location of the equipment. The seismic qualification of hard-mounted and line-mounted equipment, as detailed in IEEE Std 344 (Reference 1) and IEEE Std 382 (Reference 2) is addressed in Sections E.5.1 and E.5.2, respectively.

E.5.1 Qualification of Hard-Mounted Equipment

The goal of seismic simulation is to reproduce the earthquake motion in a realistic manner. Earthquake motion occurs simultaneously and randomly in three directions. Triaxial, multi-frequency testing provides the best simulation for earthquake seismic motion. However, according to IEEE Std 344 (Reference 1) single-axis, biaxial and triaxial tests are allowed. Regardless of which method of testing is used, the test shall use multi-frequency input motion and conservatively simulate the seismic event at the equipment mounting location.

For simulation of the seismic event in the qualification of equipment by testing the equipment is subjected to seismic inertia loads defined by the RRS. The RRS is included in the equipment procurement specifications and serves as the minimum specification for motion of the shake table used to perform the qualification testing. As detailed in Sections 3.7, 3.7.2, and 3.7.3, the basis for the RRS is provided by the in-structure response spectra (ISRS) developed at the location of the equipment according to the building or subsystem analysis for multi-frequency testing, and for either single-axis, biaxial, or triaxial testing. The ISRS defines the RRS for components mounted directly to the floor or wall location for which the RRS are generated. For some components (e.g., those mounted on secondary subsystem supports or devices mounted in electrical cabinets, but are qualified separately) the RRS reflects the additional amplification of the ISRS due to the flexibility of the equipment supporting structure. The TRS is the response spectrum used for the measured time-history motion actually achieved by the test shake table. Acceptable seismic qualification is demonstrated by showing that the TRS envelopes the RRS, for comparable damping values, over the frequency range of interest.

The three methods of testing are described in the following sections.

E.5.1.1 Single-Axis Testing

Single-axis testing can be used when it is demonstrated that a component responds independently in the three orthogonal directions and there is low or no cross coupling between the axes. It can also be used when a device is normally installed on a panel that amplifies motion in one direction only, or when it is restrained to motion in one direction. When single-axis testing is used, justification for its use shall be provided in the SQDP, Tab H-15.

Simulation of seismically induced fatigue effects are considered as previously outlined and as detailed in Section 3.7.3.2.

E.5.1.2 Biaxial Testing

The input motion, during a biaxial test, should be applied in the vertical direction and one principal horizontal direction.

When independent random input motions are used, the test is performed in two steps, with the equipment rotated 90° horizontally about the vertical axis for the second step.

When independent random input motions are not used, the test is performed in four steps. The first step is done with the input motions in phase, and the second step with the input motions 180° out of phase. The third and fourth steps are repeated with the equipment rotated 90° horizontally about the vertical axis from the first and second steps.

Simulation of seismically induced fatigue effects are considered as previously outlined and as detailed in Section 3.7.3.2.

E.5.1.3 Triaxial Testing

Triaxial testing is done with a simulator capable of independent random input motions in the three orthogonal directions. Simulation of seismically induced fatigue effects are considered as previously outlined and as detailed in Section 3.7.3.2.

E.5.2 Qualification of Line-Mounted Equipment

Due to structural filtering, the required seismic input motion for line-mounted equipment is dominated by one frequency, namely the frequency of the piping or duct in the vicinity of the equipment mounting location. Consequently, single frequency testing can be used to perform the seismic qualification of line-mounted equipment (e.g., valve and damper actuators and their accessories) as described in IEEE Std 344 (Reference 1). Additional multi-frequency testing is required in cases where the equipment is both hard-mounted and line-mounted.

The steps required to seismically qualify line-mounted equipment are detailed in the following sections.

E.5.2.1 Vibration Aging Test

The vibration aging test is required for line-mounted equipment to simulate the normal plant-induced vibrations, including system transient loads and other dynamic loads (see Section E.4.6). This test is performed by exposing the equipment to a sinusoidal motion of 0.75g magnitude, with the frequency sweeping from 5 Hz to 100 Hz to 5 Hz at a rate of two octaves per minute as detailed in IEEE Std 382 (Reference 2).

E.5.2.2 Resonance Testing

It is recommended that line-mounted equipment be structurally rigid. As addressed in Section E.5.4, unless otherwise justified, resonance search testing is used to determine the natural frequency of the equipment.

E.5.2.3 Seismic Simulation Test

A seismic simulation test is required to demonstrate that the equipment can perform its design-intended safety-related function during and after the SSE event, assuming it has been preceded by lower-level seismic events that seismically age the equipment. Additional test requirements are used to simulate the effects of seismically induced aging or fatigue.

Per IEEE Std 382 (Reference 2), the effect of OBE vibratory motion is simulated by exposing the equipment to two sinusoidal sweeps at two-thirds of the required input motion (RIM) or two-thirds SSE level in each exis followed by a single frequency sine-beat test at the full SSE level in the same axis. In the sinusoidal sweeps at OBE level, the frequency is varied from 2 Hz to 40 Hz to 2 Hz at a rate of not more than one octave per minute. The duration of each test is equal to the time required to establish full operability of the equipment in its active and inactive functions or 10 seconds, whichever is longer. The guidance to perform five OBE tests prior to SSE is accomplished by performing two sine sweeps which provide equivalent dynamic effect of five OBEs (Reference 2, Annex B and Section B.2).

The test at the full SSE level is performed using a single frequency sine-beat test, as recommended in IEEE Std 382 (Reference 2) and IEEE Std 344 (Reference 1), and by exposing the equipment to a continuous series of sine beat tests at one-third octave intervals, over the frequency range of 2 Hz to 40 Hz. The peak test amplitude for each sine beat test is at least that required by IEEE Std 382 (Reference 2), or the maximum SSE g-level specified by analysis at the mounting location of the equipment. When necessary, the equipment is tested in more than one orientation to account for various possible mounting directions. The duration of each test is at least 15 seconds or the time required for the equipment to perform its required safety function.

E.5.2.4 Qualification of Active Valves with Extended Structures

Active valves with extended structures are qualified by testing or by a combination of testing and analysis. Attached appurtenances, such as operators, limit switches, and solenoid valves are qualified by seismic testing as recommended in IEEE Std 382 (Reference 2) and IEEE Std 344 (Reference 1).

The valve itself, with the extended structure, is qualified by a static pull test. During the test, equivalent static loads (ESL) are applied to the valve in the direction that would cause the highest stresses or deflections at the base of the extended structures. The design pressure in the valve is simultaneously applied to the valve during the static pull test. The valve must then perform its safety-related function while in the deflected position, within the specified operating time limits.

The ESL are calculated using the higher of the seismic accelerations per IEEE Std 382 (Reference 2), or the actual seismic accelerations obtained from the piping analysis at the valve extended structure. It is noted that flexible valve assemblies are included in the models used for the piping analysis (see Sections 3.9.2 and 3.12). The corresponding amplified acceleration levels at the valve are then used to calculate the ESL for use in the testing.

If the extended structure of the valve is supported, the ESL to be applied in the test at the location of the support is obtained from the piping analysis. To accurately account for seismic motion from the piping and loads from the support at the extended structures, the bending moment at the base of the extended structure during the test is at least equal to that obtained from the piping analysis, unless otherwise justified.

E.5.3 Operational Conditions

In accordance with IEEE Std 344 (Reference 1), when equipment is being tested, the performance of its safety functions during the seismic testing must be monitored. The actual duration of the seismic test must be long enough for the component to perform its required safety functions, while being subjected to the seismic excitation at the required level.

E.5.4 Resonance Search Testing

Resonant search testing is used to determine the equipment natural frequency. The testing is usually performed using a low amplitude continuous sweep frequency search, with a steady-state low-level sinusoidal input of 0.2g. A maximum sweep rate of two octaves per minute is recommended to make sure that the applicable modes have time to respond to the input motion as recommended in IEEE Std 344 (Reference 1). During resonance testing, sufficient monitoring equipment is used to identify the applicable modes; both structural and functional (e.g., relay chatter).

It is generally preferable for line-mounted items, such as valve assemblies, to be rigid. The rigidity of the test fixture has a significant effect on the accuracy of the results. Therefore, especially for large equipment, monitoring is conducted to identify coupled test fixture or equipment modes that do not reflect the flexibility of the equipment. In those circumstances, additional testing or analysis is conducted, when required, to verify the natural frequency of the component.

E.6 Qualification by Analysis

As stated in Section E.3.2, qualification by analysis is acceptable when equipment can be accurately modeled and when there is reasonable assurance that structural integrity of the equipment sufficiently demonstrates that it will perform its design-intended function during a seismic event.

Two different methods of qualification by analysis are described in this section: static analysis and dynamic analysis. The method used is based on the complexity of the equipment and supporting structure, its dynamic properties, the loads to be considered, and the available design margin. A dynamic analysis is normally performed when a static analysis is too conservative or can not be justified.

E.6.1 Modeling

Seismic qualification by analysis is acceptable only when the equipment can be accurately modeled. The analysis model (hand or computer) must be able to predict the impact of seismic excitations and normal loads on critical component stresses, deformations, and performance and function, as applicable. For complex equipment or systems, a combination of analysis and testing can serve as an aid to verify the validity of the analysis model. Modal testing is used, when necessary, to correlate the frequencies determined in the analysis with the measured response.

The boundary conditions used in the analysis must properly represent the actual equipment anchorage, unless it can be shown that the assumptions made will yield conservative results.

E.6.2 Qualification by Static Analysis

Qualification by static analysis involves application of ESL to approximate the effects of dynamic loading and follows the guidelines of Section 3.7.3.1.4. The ESL is computed using the dead weight of the component multiplied by a dynamic or seismic load factor (DLF) to represent the appropriate seismic acceleration coefficient at the mounting location. This DLF accounts for the dynamic amplification associated with the dynamic properties of the equipment, the characteristics of the seismic loading, and the effects from the participation of multiple modes in the response.

The static analysis is performed as follows:

- Determine the DLF in each direction of loading.
- Calculate responses (i.e., loads, stresses, or deformations).
- Combine the responses from the three directions of loading.

E.6.2.1 Determine the Dynamic Load Factor

Single-Degree-of-Freedom Equipment

If the equipment is structurally simple, it can be modeled as a single-degree-of-freedom (SDOF) system. For this equipment, the calculation of the DLF is based on a factor of 1.0 applied to the acceleration selected from the RRS because the response is due to only a single natural frequency. The ESL for the design of the equipment modeled as an SDOF system is determined as follows:

- If the frequency of the SDOF system is not calculated, the peak of the applicable response spectra is used for calculating the ESL.
- If the frequency is calculated and the equipment is found to be rigid, the applicable zero period acceleration (ZPA) is used for calculating the ESL.
- If the frequency is calculated and the equipment is found to be flexible, the applicable peak spectral acceleration is used for calculating ESL unless a smaller value is justified.

Simple System Equipment

A simple system is defined as being a frame type structure, such as members physically similar to beams and columns that can be represented by a simple model. The response of a simple system potentially includes multi-mode effects. The seismic loading is determined as follows:

- If the frequency of the simple system is not calculated, a DLF equal to 1.5 times the peak of the applicable response spectra is used.
- If the frequency is calculated and the equipment is found to be rigid, a DLF equal to 1.0 times the ZPA is used.
- If the frequency is calculated and the equipment is found to be flexible, a DLF equal to 1.5 times the applicable peak spectral acceleration is conservatively used, unless a smaller factor is justified.

E.6.2.2 Calculate Responses

As applicable, the ESLs determined using the DLFs calculated according to Section E.6.2.1 are applied in the hand calculation or computer model, Loads in each of the three directions of earthquake excitations are applied independently, and corresponding responses (i.e., loads, stresses, or deformations) are calculated.

E.6.2.3 Combine the Responses

The combined response is determined by taking the square root of the sum of the squares (SRSS) of responses of each of the three components of earthquake motion at each point of the structure or math model. The SRSS combination is performed, as described in Sections 3.7.3.6 and 3.7.3.7, which conform to RG 1.92, Revision 2. The basis for the SRSS combination is the assumption that it is unlikely that the peak values of the three responses for a given component will occur simultaneously.

E.6.3 Qualification by Dynamic Analysis

For flexible equipment, a dynamic analysis is performed when a static analysis is too conservative or can not be justified. The dynamic analysis uses either the response spectrum method or the time history method presented in Section 3.7.3.1.

A computer model that adequately represents the dynamic response of the equipment is generated. An adequate number of degrees of freedom are included in the model to capture the primary response of the item. Section 3.7.3.3 presents the criteria for the determination of an adequate number of degrees of freedom, namely when the addition of more degrees of freedom does not result in more than a 10 percent increase in the total responses of interest. These criteria also meet the requirements of IEEE Std 344 (Reference 1).

E.6.3.1 Response Spectrum Analysis

The response spectrum analysis is performed in four steps:

1. Calculate mode shapes and frequencies.
2. Calculate equipment responses (i.e., loads, stresses or deformations) for each mode.

3. Combine the responses from each mode to determine total equipment response to each direction of earthquake loading.

4. Determine response to the three directions of earthquake loadings.

The seismic response of equipment in any one direction of earthquake motion is obtained using the guidelines provided in Section 3.7.3.7, in which the modal responses are combined by the SRSS method, except for closely spaced modes. Closely spaced modes are modes with frequencies differing by 10 percent or less of the next lower frequency. Closely spaced modes are grouped so that the difference between the highest and lowest frequencies in any group does not exceed 10 percent. The seismic response from the modes in any group is taken as the absolute summation of the individual modal responses, and the group response is combined with the other modes using the SRSS method.

The total equipment response to the three directions of earthquake motion is obtained using the methodology described in Sections 3.7.3.6 and E.6.2.3.

All modes in the flexible range, with frequencies up to the ZPA cutoff frequency of 40 Hz as addressed in Section 3.7.3.7, must be considered. In addition, an adequate number of modes must be considered to make sure that the responses associated with high frequency modes (i.e., higher than the cutoff frequency or ZPA) are taken into account. For some equipment, a significant portion of the equipment mass may not be accounted for in the low frequency modal analysis. The effects of this missing mass are considered in the analysis as addressed in Section 3.7.3.7.

The total combined response to high frequency modes are then combined with the total combined response from lower frequency modes as described in Section 3.7.3.7.

E.6.3.2 Time History Analysis

Time history analysis is the preferred method for seismic analysis when a piece of equipment exhibits a non-linear response (e.g., changing stiffness or frequencies under increasing load). This analysis is also used to generate response spectra at a specific component location, such as an instrument inside a cabinet panel. When the maximum time history responses to the three components of earthquake motion are calculated separately, the maximum combined response is calculated as described in Sections 3.7.3.6 and E.6.2.3. When the responses to the three components of earthquake motion are statistically independent and applied simultaneously, the responses may be obtained individually for each of the three independent components and combined algebraically at each time step to obtain the total response time history. This approach is further detailed in Section 3.7.3.6, which demonstrates that the approach conforms to RG 1.92.

E.7 Qualification by Similarity

IEEE Std 344 (Reference 1) provides information about the qualification of equipment by similarity for equipment similar to a type that is previously qualified either by test or analysis, and which differs only in size or in the specific qualified devices located in the assembly or structure. In such cases, it is neither practical nor necessary to test every variation of the basic qualified configuration. For these situations, the qualification of the various configurations is demonstrated by similarity using the previous test or analysis qualification. Where qualification is achieved by extrapolation of qualification results based on test, analysis, or combination of the two, the excitation, physical system, and safety function are taken into consideration. The need for additional qualification of the specific devices located in the assembly or structure is evaluated in each instance.

Qualification by similarity is not considered to be the same process as qualification by comparison to reference equipment classes derived from either earthquake experience or test experience data addressed in IEEE Std 344 (Reference 1). The use of such experience data is presented in the following sections.

E.8 Deleted

E.9 Performance Criteria

The performance criteria for equipment that is being seismically qualified in accordance with IEEE Std 344 (Reference 1) are as follows:

- Passive components must maintain their structural or pressure boundary integrity during and after a seismic event.
- Active components must remain operable during and after the seismic event, while maintaining their structural integrity.
- Excessive displacements and deformations must be prevented or accounted for to make sure that no adverse interaction occurs with adjacent commodities or components.

Implementation of these criteria is described in more detail in the following sections.

E.9.1 Structural Integrity

Structural integrity of a component can be verified by analysis or testing. If qualified by analysis, it must be verified that critical component stress limits and deformations are acceptable according to the applicable regulations, codes and standards (such as the ASME B&PV code with the applicable sections, AISC, and ANSI standards). If qualified by testing, the equipment must be able to withstand applied seismic inertia loads and other applicable loads without any structural failures or anomalies.

E.9.2 Operability

Operability of a component can be demonstrated by analysis or by test. If qualified by analysis (i.e., typically mechanical components), operability is based on resulting deflections or deformations in critical components and on comparisons to allowable levels in applicable design specifications and manufacturer recommendations. If qualified by testing, the test must demonstrate that the equipment will perform its safety function during and after the seismic test, as required.

E.10 References

1. IEEE Std 344-2004, "Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," Institute of Electrical and Electronics Engineers, 2004.

2. IEEE Std 382-2006, "Standard for Qualification of Actuators for Power-Operated Valve Assemblies with Safety Related Functions for Nuclear Power Plants," Institute of Electrical and Electronics Engineers, 2006.

3. SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water (ALWR) Designs," Nuclear Regulatory Commission, July 1993.

4. IEEE Std 323-1974, "Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," Institute of Electrical and Electronics Engineers, 1974.

Next File