

RE-VALIDATION OF THE EQUIPMENT SEISMIC QUALIFICATION ADEQUACY DUE TO THE CHANGE OF REQUIRED RESPONSE SPECTRA

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ABSTRACT

In cases where a new set of the floor response spectra curves are generated in the course of nuclear plant design, all safety related seismic category I system, structure and components shall be re-validated for their seismic design adequacy under the effect of the new response spectra requirement.

This paper recommends a two-tier of screening process; floor response spectra is screened first, and followed by equipment screening. After this screening process is completed, only a limited number of the new response spectra and a small population of the Seismic Category I equipment would need to be considered for the re-validation. As such, the reduced scope of work can lead to a systematic and cost-effective method for re-validation of the existing equipment qualification results due to new RRS effects.

I. INTRODUCTION

In some of the nuclear plants, several sets of seismic response spectra curves are available for use in re-validation of the seismic design adequacy of the system, structure and components. The existence of a different sets of the required response spectra (RRS) curves is mainly attributed to the following factors:

1. Different earthquake input data are utilized for the building seismic response analysis to generate the RRS for the plant seismic design application, such as Housner's Ground Spectra, U.S. Regulatory Guide 1.60 "Design Response Spectra for Seismic Design of Nuclear Power Plants", or the plant site specific ground spectra.
2. Seismic design consideration of the nuclear power plant is state of the art. The dynamic analysis method and the modeling technique are improved through the accumulated experience, and a more realistic seismic response can be obtained by using advanced analytical methods and improved modeling techniques. Therefore, the RRS generated from a refined building model is different from one obtained from the original model.
3. Seismic design acceptance criteria have been revised over time, such as NRC Regulatory Guides and Standard Review Plan, etc. An updated building seismic response analysis is therefore required to be performed in order to meet the revised seismic design acceptance criteria, which results in a new set of RRS.

When a new set of RRS is generated, it is reasonable to assume that all safety related Seismic Category I system, structure and components are required to be re-validated for their seismic design adequacy under the effect of the new RRS requirement. Due to the constraints on the available resources and schedule, it may be difficult or impractical to re-validate every piece of the Seismic Category I equipment for the new RRS effects. This paper provides a systematic procedure for determining the impact of the RRS differences on the existing equipment seismic qualification results and developing a cost-effective method to select the representative equipment from twenty-five classes of nuclear power plant equipment to be re-validated for the new RRS effects.

2. RRS Comparison Approach

This section discusses the selection of parameters to characterize the input change, comparison of the RRS, and classification of RRS differences into groups according to the comparison results.

The above steps constitute a screening procedure for selection of a limited number of new floor response spectrum curves required for considered in re-validating the existing equipment qualification results.

2.1 RRS Comparison Parameters

In order to characterize the differences between new RRS (*Set B*) and original RRS (*Set A*), a set of parameters, which are associated with the essential characteristics of the response spectra curves, shall be established as follows:

- i. Peak spectral values,
- ii. Frequency shift of the peak spectral value, if any,
- iii. The relative spectral magnitude for the entire frequency range,
- iv. Zero Period Acceleration (ZPA), and
- v. The relative magnitude of the vertical peak spectral value vs. the horizontal peak spectral value.

In general, input changes to the RRS as related to any one of the above parameters may impact the existing equipment qualification results. Thus, the above parameters will also be considered as criteria in the process to determine the impact of the RRS difference on the equipment qualification results.

2.2 RRS Comparison

With the parameters established, the RRS comparison proceeds with the following steps:

- i. Compare or list the numerical values of each parameter for RRS Set A and Set B
- ii. Establish the impact criteria for each parameter identified above. This "impact criteria" is defined as "limit" of parameters for the RRS comparison purposes. Parameters which exceed a certain limit are such that RRS differences may impact the equipment qualification results. Impact criteria for some parameters are generic. For example, if the new RRS peak spectral value exceeds more than 10% of the original peak, this new RRS may impact the qualification results. The impact criteria for parameter related to the peak spectral value is set to be 10%. However, the impact criteria for other parameters are plant (site) specific, such as parameters associated with the frequency shift of the peak spectral, and the relative magnitude of the vertical spectral value vs. the horizontal

peak spectral value. In such instances the impact criteria for such parameters will be established in accordance with the site specific characteristics as exhibited in the RRS.

- iii. Assess the RRS difference of each parameter and determine whether or not such difference will impact the qualification results according to the above impact criteria established for each parameter.
- iv. Indicate the assessment results for the floor response spectra curves at the selected floor elevations of interest. This assessment can be any one of the following:
 - a. No impact on the qualification results:

Example: Set A > Set B for the entire frequency range, or if there is an exceedance of Set B over Set A in some frequency range, the difference is minor and will not impact the qualification results.

- b. The difference will have an impact on the qualification results:

Example: 1) The peak spectral values remain the same, however, the peak frequency range shifts to the left side at around 4 to 8 Hz instead of 6 to 10 Hz, or;

2) The new peak spectral value exceeds more than 10% of the original peak, or;

3) The new ZPA exceeds more than 10% of the original ZPA, or;

4) The new vertical peak spectral exceeds 1.0g.

Any one of the above RRS differences may impact the existing equipment qualification results.

2.3 Screening of the New RRS

Based on the detailed RRS comparison, the new RRS can be classified into three categories with respect to the degree of their impact on the equipment qualification results, and these categories will serve as the screening guideline to select the new RRS for equipment re-validation and are as follows:

i. Category A

This category applies when Set A envelopes Set B for the entire or majority of the frequency range. Small exceedances of Set B over Set A are permitted. When this condition occurs, RRS (Set B) will not impact the qualification results and it is not required to re-validate the seismic qualification results of the equipment mounted on this floor for the Set B effect.

ii. Category B

This category applies when there is an exceedance of Set B over Set A in some frequency range, however, such a difference can be justified as not affecting the qualification results. This justification is accomplished by a qualitative justification approach. Equipment mounted on this floor will not be selected for re-validation.

iii. Category C

This category applies when the RRS difference between Set A and Set B is such that it may impact the equipment seismic qualification results for certain types of qualification methods. For example, due to the peak spectral frequency shift to the left side of the original peak, such a change may impact the qualification results obtained by the random input proof test and the modal response spectral analysis method. Also, for the case where the ZPA of Set B increases, the sine-beat test results may not be in accordance with IEEE Standard 344 requirements. Therefore, all equipment mounted on a Category C floor that were seismically qualified by any one of the above three qualification methods are recommended to be selected for re-validation due to the new RRS effect.

Based on the above classification of the RRS difference, it can be concluded that when the new RRS is designated as "Category C," these RRS to be screened for possible equipment re-validation.

3.0 SCREENING OF EQUIPMENT FOR RE-VALIDATION

As discussed above, the input change (RRS difference) may impact the equipment response. The degree of the impact depends on the characteristics of the transfer function which differs according to qualification methods and dynamic characteristics of the equipment. Therefore, even though the new RRS has been screened for equipment re-validation, it does not imply that all Seismic Category I equipment mounted on this floor need to be re-validated because the input change may not impact the qualification results due to a specific qualification method used. Hence it is necessary to establish a procedure to screen the equipment for re-validation.

3.1 Attributes for Equipment Screening

The following attributes, as a minimum, are recommended to be considered in screening the floor/wall mounted equipment which are located on a floor designated as "Category C", for re-validation.

- i. Margin of safety (M.S.)
- ii. Resonant frequencies
- iii. Seismic qualification methods, which consist of
 - Analysis
 - Modal response spectrum method
 - Equivalent static analysis method
 - Static analysis method
 - Test
 - Random multiple frequency test
 - Single frequency test

3.2 Equipment Screening Procedure

All Seismic Category I equipment mounted on the "Category C" floor will go through the following screening process in order to select which pieces of equipment required re-validation.

- i. List all RRS difference found for each "Category C" floor.
- ii. Group the Seismic Category I equipment into 25 types of equipment as follows:

- Tanks
- Motor Control Center
- Motor Generator
- Distribution Panel
- Switchgear
- Fan and Motor
- Air Handling Unit
- Transformer
- Panels
- Compressor
- Chillers
- Battery

- Battery and Rack
- Transmitter
- Electrical Penetration
- Pumps
- Relays
- Filter/Damper
- Switch
- Instrument Rack
- Valves
- Heat Exchanger
- Circuit Breaker
- Remote Shutdown Panel
- Board and Inverter
- Diesel Generator

- i. Screen out the line-mounted components from the above equipment lists, i.e., valves, dampers and relays
- ii. Screen the existing qualification reports of above listed equipment for re-validation in accordance with the equipment screening attributes (see Section 3.1). This screening can identify whether or not the RRS difference will impact the qualification results. The example of screening is provided in the following:

Example:

RRS Difference	Equipment Screened for re-validation
• Peak frequency range shifts to the left side	- Equipment qualified by random multiple frequency test or by modal response spectrum method and the resonant frequencies are located within the shifted frequency range.
• Peak spectral value increases more than 10%	- Equipment qualified by random input test or by modal response spectrum method unless the fundamental frequency is away from the peak spectral frequency range.
• New ZPA exceeds more than 10% of the original ZPA	- Equipment qualified by sine-beat test or by static analysis method with M.S. < 10%.
• New vertical peak spectral exceeds 1.0g	- Equipment anchorage need to be checked for uplift effect.

- Note:**
1. The RRS difference for a given "Category C" floor can be any one of the above individual cases or a combination of any number of the individual cases.
 2. Equipment is not required for re-validation if its qualification method is not the one indicated above for a given RRS difference.

4.0 DISCUSSION AND CONCLUSION

The methodology for re-validation of the new RRS effects on equipment qualification results recommended in this paper has been applied in plant and has demonstrated to be a cost-effective approach. Using this approach only 5% of the Seismic Category I equipment in the plant required re-validation.

The recommended methodology is also applicable to the following cases:

1. To provide a quick preliminary evaluation of the qualification adequacy of the replacement equipment in the operating plant during the bid evaluation. In general, the equipment can be qualified for a generic and not a plant-specific application.
2. To effectively evaluate the seismic qualification adequacy of the outliers found in A-46 and/or IPEEE plants based on the available generic seismic qualification reports

