RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**267-8301**
SRP Section:	**03.07.03 – Seismic Subsystem Analysis**
Application Section:	**3.7.3**
Date of RAI Issue:	**10/22/2015**

Question No. 03.07.03-2

In accordance with 10 CFR 50 Appendix S, the staff reviewed the seismic subsystem analysis for the APR1400 standard design. Out of 13 areas reviewed following the SRP 3.7.3 Rev. 4 guidance, four of them reference DCD sections other than DCD Section 3.7, as listed below:

> Section 3.7.3.10, Basis for Selection of Frequencies, refers to Section 3.9.2.2.4, Basis for Selection of Frequencies
>
> Section 3.7.3.11, Interaction of Other Systems with Seismic Category I System, refers to Section 3.12.3.7, Non-Seismic/Seismic Interaction (II/I)
>
> Section 3.7.3.12, Multiply-Supported Equipment and Components with Distinct Inputs, refers to Section 3.9.2.2.8, Multiple-Supported Equipment Components with Distinct Inputs
>
> Section 3.7.3.13, Torsional Effects of Eccentric Masses, refers to Section 3.9.2.2.10, Torsional Effects of Eccentric Masses

However, the scope of subsystems covered by these DCD 3.7.3 sections may be broader than the scope covered by the referenced sections. For example, in addition to the inconsistency between the titles of DCD Section 3.7.3.11 and Section 3.12.3.7, Section 3.7.3.11 covers the interaction of all (non-Seismic Category I) systems with Seismic Category I systems, while the text of DCD Section 3.12.3.7 covers only the II/I interaction of piping systems. The applicant is requested to resolve this inconsistency and also to confirm there are no other scope inconsistency issues for the other three sections.

Response

Based on the SRP sections applicable to each of the items mentioned above, each item will be revised as follows.

3.7.3.10 Basis for Selection of Frequencies

The fundamental frequencies of components and equipment are selected to be less than one-half or more than twice the dominant frequencies of the support structure to avoid resonance. The equipment is adequately designed for the applicable loads if the equipment frequencies are within this range.

3.7.3.11 Interaction of Other Systems with Seismic Category I Systems

The non-seismic Category I subsystems are designed to be isolated by either a constraint or barrier or are remotely located from any seismic Category I SSC. Otherwise, adjacent non-seismic Category I subsystems are analyzed according to the same seismic criteria as applicable to seismic Category I SSC.

3.7.3.12 Multiply-Supported Equipment and Components with Distinct Inputs

The seismic response of multiply-supported equipment and components with distinct inputs are obtained by either the response spectrum approach or the time history approach.

Of the response spectrum approaches, the uniform support motion (USM) method is applied with a uniform response spectrum (URS) that envelops all of the individual response spectra at the various support locations. In addition, the maximum relative support displacements are imposed on the supports in the most unfavorable combination. The final responses are obtained by the absolute summation of responses due to inertial effects and relative displacements. As an alternative to the USM method, the independent support motion (ISM) method can be employed such that all of the criteria presented in NUREG-1061 related to the ISM method are satisfied.

When the time history approach is applied, time histories of support motions may be used as input excitations to the subsystems.

3.7.3.13 Torsional Effects of Eccentric Masses

To consider the torsional effects of eccentric masses in seismic Category I subsystems, the eccentric masses are included in the mathematical model as eccentric masses located in their center of gravity coupled by, as applicable, either rigid members or elastic members with their own properties.

Impact on DCD

DCD Tier 2, Subsections 3.7.3.10, 3.7.3.11, 3.7.3.12, and 3.7.3.13 will be revised, as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

3.7.3.10 Basis for Selection of Frequencies

~~Basis for selection of frequencies is addressed in Subsection 3.9.2.2.4.~~ See No.1 of page 2.

3.7.3.11 Interaction of Other Systems with Seismic Category I Systems

~~Interaction of other systems with the seismic Category I system is addressed in Subsection 3.12.3.7.~~ See No.2 of page 2.

3.7.3.12 Multiply-Supported Equipment and Components with Distinct Inputs

~~Multiply-supported equipment and components with distinct inputs are addressed in Subsection 3.9.2.2.8.~~ See No.3 of page 2.

3.7.3.13 Torsional Effects of Eccentric Masses

~~Torsional effects of eccentric masses are addressed in Subsection 3.9.2.2.10.~~ See No.4 of page 2.

3.7.4 Seismic Instrumentation

Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plant," of 10 CFR Part 50 (Reference 2), requires that suitable instrumentation be provided so that the seismic response of nuclear power plant features important to safety can be evaluated promptly after an earthquake. It also requires shutdown of the nuclear power plant if vibratory ground motion exceeds the OBE ground motion.

The seismic monitoring system meets the relevant requirements of 10 CFR Part 50, Appendix S. The seismic monitoring system provides information on the vibratory ground motion and the resultant vibratory responses of the representative seismic Category I structures during a seismic event.

The seismic monitoring system is not a safety system and does not have any effect on safety systems or equipment. The seismic monitoring system is designed for high accuracy, reliability, and to minimize the maintenance and surveillance activities required to support the system.

1. The fundamental frequencies of components and equipment are selected to be less than one-half or more than twice the dominant frequencies of the support structure to avoid resonance. The equipment is adequately designed for the applicable loads if the equipment frequencies are within this range.

2. The non-seismic Category I subsystems are designed to be isolated by either a constraint or barrier or are remotely located from any seismic Category I SSC. Otherwise, adjacent non-seismic Category I subsystems are analyzed according to the same seismic criteria as applicable to seismic Category I SSC.

3. The seismic response of multiply-supported equipment and components with distinct inputs are obtained by either the response spectrum approach or the time history approach.
Of the response spectrum approaches, the uniform support motion (USM) method is applied with a uniform response spectrum (URS) that envelops all of the individual response spectra at the various support locations. In addition, the maximum relative support displacements are imposed on the supports in the most unfavorable combination. The final responses are obtained by the absolute summation of responses due to inertial effects and relative displacements. As an alternative to the USM method, the independent support motion (ISM) method can be employed such that all of the criteria presented in NUREG-1061 related to the ISM method are satisfied.
When the time history approach is applied, time histories of support motions may be used as input excitations to the subsystems.

4. To consider the torsional effects of eccentric masses in seismic Category I subsystems, the eccentric masses are included in the mathematical model as eccentric masses located in their center of gravity coupled by, as applicable, either rigid members or elastic members with their own properties.

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RAI No.:	**267-8301**
SRP Section:	**03.07.03 – Seismic Subsystem Analysis**
Application Section:	**3.7.3**
Date of RAI Issue:	**10/22/2015**

Question No. 03.07.03-4

In accordance with 10 CFR 50 Appendix S, the staff reviewed the seismic subsystem analysis for the APR1400 standard design. The DCD Section 3.7.3.1.1 states that the equivalent static method would be used for the seismic analysis of components if a dynamic analysis would not be performed. The description of the load factor (1.5, or smaller if adequately justified) and the peak spectral acceleration of the applicable required response spectra is consistent with the SRP 3.7.2 guidance regarding the equivalent static load method described in SRP 3.7.2 II.1.B.iii (SRP 3.7.3 II.10, Use of Equivalent Vertical Static Factors refers to SRP 3.7.2, II.10 that references SRP 3.7.2 II.1.B). However, the DCD does not address the other two aspects of the SRP 3.7.2 guidance:

> II.1.B.i: Justification is provided that the system can be realistically represented by a simple model and the method produces conservative results in terms of responses; and
>
> II.1.B.ii: The simplified static analysis method accounts for the relative motion between all points of support.

These two aspects are important to ensure that the equivalent static load method is applicable to the subject subsystem. As such, per 10 CFR 50 Appendix S, the applicant is requested to augment the DCD description of the equivalent static load method to ensure that this method is appropriately justified and applied for the APR1400 subsystems.

Response

DCD Tier 2, Subsection 3.7.3.1.1 will be revised to address the two aspects of SRP 3.7.2 mentioned above as follows;

> “When the equivalent static load method is used for the seismic analysis of components, i) justification of the adequacy of the analysis models and conservatism of the analysis results are to be provided by showing that the analysis results obtained from the equivalent static

load method are more conservative than those of a dynamic analysis, such as response spectrum analysis method or time history analysis method, ii) the responses obtained from relative motion between points of support, if any, are combined with the response from the inertial loads, and iii) the…"

Impact on DCD

DCD Tier 2 Subsection 3.7.3.1.1 will be revised, as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

3.7.3.1.1 Use of Equivalent Static Load Method of Analysis

In the seismic analyses of components, the equivalent static load method would be used if a dynamic analysis is not performed. ~~The~~ static seismic acceleration coefficient is equal to 1.5 times the peak g level in the applicable required response spectra. A value less than 1.5 times could be used if its conservatism and justification are verified. The equivalent seismic static load is the product of the equipment or component mass and the static seismic acceleration coefficient.

See page 2.

3.7.3.1.2 Determination of Number of Earthquake Cycles

The procedure used to account for the fatigue effect of cyclic motion associated with seismic excitation recognizes that the actual motion experienced during a seismic event consists of a single maximum or peak motion and some number of cycles of lesser magnitude. The total or cumulative usage factor can also be specified in terms of a finite number of cycles of the maximum or peak motion. Based on this consideration, seismic Category I subsystems, components, and equipment are designed for a total of two SSE events with 10 maximum stress cycles per event (20 full cycles of the maximum SSE stress range). Alternatively, an equivalent number of fractional vibratory cycles to that of 20 full SSE vibratory cycles may be used (but with an amplitude not less than one-third [1/3] of the maximum SSE amplitude) when derived in accordance with Appendix D of IEEE Std. 344-2004 (Reference 23).

3.7.3.2 Procedure Used for Analytical Modeling

The criteria and bases described in Subsection 3.7.2.3 are used to determine whether a component or structure will be analyzed as a subsystem. The modeling techniques incorporate either a single- or multi-degree of freedom subsystem consisting of discrete masses connected by spring elements. The associated damping coefficients are consistent with Table 3.7-7. The degree of complexity of each model is sufficient to accurately evaluate the dynamic behavior of the component.

When the equivalent static load method is used for the seismic analysis of components, i) justification of the adequacy of the analysis models and conservatism of the analysis results are to be provided by showing that the analysis results obtained from the equivalent static load method are more conservative than those of a dynamic analysis, such as response spectrum analysis method or time history analysis method, ii) the responses obtained from relative motion between points of support, if any, are combined with the response from the inertial loads, and iii) the…

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Application Section:	**3.7.3**
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Question No. 03.07.03-5

In accordance with 10 CFR 50 Appendix S, the staff reviewed the modal combination method in response spectrum analysis of APR1400 subsystems, as described in DCD Subsection 3.7.3.5, Combination of Modal Responses. The DCD indicates that the SRSS method is used to combine the modal responses when the modal frequencies are well separated; otherwise, the modal responses are combined in accordance with NRC RG 1.92. However, the DCD does not provide the criteria to be used to determine whether the modal frequencies are well separated. Per SRP 3.7.3 II.7 guidance, an acceptable modal combination method in response spectrum analysis of subsystems is the same as described in SRP Section 3.7.2, Subsection II.7, which is consistent with the NRC RG 1.92, Rev. 3 including the definition of closely spaced modes. DCD Subsection 3.7.2.7 appears to be consistent with SRP 3.7.2 II.7 regarding the modal combination method. Since DCD Subsection 3.7.3.5 does not provide the necessary criteria, per 10 CFR 50 Appendix S, the applicant is requested to specify and justify the criteria to be used for the purpose of determining whether modal frequencies are well separated.

Response

DCD Tier 2, Subsection 3.7.3.5 will be revised to provide the criteria to be used to determine whether modal frequencies are well separated as follows;

1. "For combination of modal responses of subsystems, Subsection 3.7.2.7 can be referred for details."

2. "The criteria for determining how modal frequencies are separated are specified in RG 1.92 as the definition of modes with closely spaced frequencies."

The definition of modes with closely spaced frequencies is a function of the critical damping ratio and is as follows;

(1) For critical damping ratios ≤ 2%, modes are considered closely spaced if the frequencies are within 10% of each other (i.e., for $f_i < f_j$, $f_j \leq 1.1 f_i$)

(2) For critical damping ratio > 2%, modes are considered closely spaced if the frequencies are within five times the critical damping ratio of each other (i.e., for $f_i < f_j$ and 5% damping, $f_j \leq 1.25\ f_i$, for $f_i < f_j$ and 10 damping, $f_j \leq 1.\ 5\ f_i$)

Impact on DCD

DCD Tier 2, Subsection 3.7.3.5 will be revised, as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

3.7.3.3 Analysis Procedures for Damping

The analysis procedure used to account for the damping in subsystems conforms with Subsections 3.7.1.2 and 3.7.2.15.

3.7.3.4 Three Components of Earthquake Motion

Seismic responses resulting from analysis of subsystems due to three components of earthquake motions are combined in the same manner as the seismic response resulting from the analysis of building structures as specified in Subsection 3.7.2.6.

3.7.3.5 Combination of Modal Responses

See No.1 of page 2.

When a response spectrum method of analysis is used to analyze a subsystem, the maximum responses such as accelerations, shears, and moments in each mode are calculated regardless of time. If the frequencies of the modes are well separated, the SRSS method of mode combination gives acceptable results; however, where the structural frequencies are not well separated, the modes are combined in accordance with NRC RG 1.92.

See No.2 of page 2.

3.7.3.6 Use of Constant Vertical Static Factors

In general, seismic Category I subsystems are analyzed in the vertical direction using the methods specified in Subsection 3.7.3.1. No constant vertical static factors are used for subsystems.

3.7.3.7 Buried Seismic Category I Piping, Conduits, and Tunnels

During an earthquake, buried structures such as piping, conduits, and tunnels respond to various seismic waves propagating through the surrounding soil as well as to the dynamic differential movements of the buildings to which the structures are connected. The various waves associated with earthquake motion are P (compression) waves, S (shear) waves, and Rayleigh waves. The stresses in the buried structure are governed by the velocity and angle of incidence of these traveling waves. However, the wave types and their directions during an earthquake are very complex. For design purposes, the seismic-

1. For combination of modal responses of subsystems, Subsection 3.7.2.7 can be referred for details.

2. The criteria for determining how modal frequencies are separated are specified in RG 1.92 as the definition of modes with closely spaced frequencies.
The definition of modes with closely spaced frequencies is a function of the critical damping ratio and is as follows;
(1) For critical damping ratios ≤ 2%, modes are considered closely spaced if the frequencies are within 10% of each other (i.e., for fi < fj, fj ≤ 1.1fi)
(2) For critical damping ratio > 2%, modes are considered closely spaced if the frequencies are within five times the critical damping ratio of each other (i.e., for fi < fj and 5% damping, fj ≤ 1.25 fi, for fi < fj and 10 damping, fj ≤ 1. 5 fi)