## KHNPDCDRAIsPEm Resource

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**Subject:** APR1400 Design Certification Application RAI 182-8160 (03.07.01 - Seismic Design Parameters)
**Attachments:** APR1400 DC RAI 182 SEB1 8160.pdf; image001.jpg

KHNP,

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Please submit your RAI response to the NRC Document Control Desk.

Thank you,

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**Hearing Identifier:** KHNP_APR1400_DCD_RAI_Public
**Email Number:** 230

**Mail Envelope Properties** (cb4a225cbd1741a289d35f3612d4b9ff)

**Subject:** APR1400 Design Certification Application RAI 182-8160 (03.07.01 - Seismic Design Parameters)
**Sent Date:** 8/31/2015 10:22:22 AM
**Received Date:** 8/31/2015 10:22:23 AM
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**Priority:** Standard
**Return Notification:** No
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**Expiration Date:**
**Recipients Received:**

# REQUEST FOR ADDITIONAL INFORMATION 182-8160

Issue Date: 08/31/2015
Application Title: APR1400 Design Certification Review – 52-046
Operating Company: Korea Hydro & Nuclear Power Co. Ltd.
Docket No. 52-046
Review Section: 03.07.01 - Seismic Design Parameters
Application Section: 3.7.1

QUESTIONS

03.07.01-1

10 CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion associated with the safe shutdown earthquake (SSE) ground motion through design, testing, or qualification methods. In accordance with 10 CFR 50 Appendix S, the staff reviewed the adequacy of the target power spectral density (PSD) functions used to demonstrate that the synthetic acceleration time histories used for seismic analysis of the SSCs have sufficient power over the frequency range of interest.

The DCD states that the development of synthetic acceleration time histories for the certified seismic design response spectra (CSDRS) and the hard rock high frequency (HRHF) response spectra (RS) is consistent with the SRP 3.7.1 Option 1 Approach 1 criteria, which include a provision of assessing the power sufficiency of the synthetic acceleration time histories in the frequency range of interest. This assessment needs to compare the PSDs estimated for the time histories with target PSD functions compatible with the design RS (DRS). DCD Sections 3.7.1.1.2 and 3.7.1.1.3; technical report APR1400-E-S-NR-14001-P, Rev. 0, “Seismic Design Bases;” and technical report APR1400-E-S-NR-14004-P, Rev. 1, “Evaluation of Effects of HRHF Response Spectra on SSCs,” provide information on the development of the target PSD functions to be compatible with the corresponding DRS. The staff reviewed the submitted documents and determined that the information requested below is needed in order to determine the acceptability of the target PSD.

### a) Identification of the NUREG/CR-5347 time history simulation method

The above-referred documents indicate that the time history simulation method described in NUREG/CR-5347 was used to develop target PSD functions. The staff could not find the term “time history simulation method” in NUREG/CR-5347 and it is not clear to the staff whether it refers to the procedure utilizing Equations (7), (8), and (9) of Appendix B of NUREG/CR-5347. Therefore, the applicant is requested to clearly identify the time history simulation method.

In addition, the method presented in the two technical reports, APR1400-E-S-NR-14001-P, Rev. 0 and technical report APR1400-E-S-NR-14004-P, Rev. 1, utilizes the computer code SIMQKE to generate 30 artificial time histories based on random phasing. Each time history is developed to match the 2% damped DRS. The average of the PSD functions of these 30 resultant time histories is used to define the target PSD. In this process, it is not clear to the staff where and how the time history simulation method is used. As such, the applicant is requested to explain how the time history simulation method was used in the process and update the HRHF report as appropriate, since it is incorporated by reference (IBR).

### b) Target PSD for the horizontal CSDRS below 9 Hz

Section 3.7.1.1.2 of the DCD and Section 3.2.4 of APR1400-E-S-NR-14001-P, Rev. 0, indicate that for frequencies lower than 9 Hz, the target PSD for the CSDRS in the horizontal direction is the same as that described in the SRP 3.7.1, Appendix A; while for frequencies between 9 Hz and 50 Hz, the target PSD was developed using 30 simulated time histories which match individually the 2% damped RS. Since a

PSD function does not have a frequency-by-frequency independent relationship with the response spectra, the target PSD below 9 Hz was technically not determined appropriately. It appears to the staff that the target PSD based on the 30 time histories is applicable to the entire frequency range and there is no obvious need to use any part of the target PSD described in Appendix A of SRP 3.7.1. The applicant is requested to utilize the target PSD function based on the 30 simulated time histories or justify the hybrid approach that involves the target PSD provided in Appendix A of SRP 3.7.1 below 9 Hz.

### c) Target PSD for the Vertical CSDRS

DCD Section 3.7.1.1.2 describes that the target PSD for the vertical CSDRS was developed using a one-time scaling method, in which the horizontal target PSD provided in Appendix A of SRP 3.7.1 was scaled for one time (without iterations) by a frequency-dependent scaling factor. This scaling factor was calculated as the squared, frequency-by-frequency ratio of the vertical CSDRS to the RG 1.60 horizontal RS. This approach would be acceptable if the two RS are very close; however, the vertical CSDRS is not close to the RG 1.60 horizontal RS. In fact, had the one-time scaling method been adequate, it could have been used for the development of the target PSD functions for the APR1400 horizontal CSDRS and the HRHF RS so that there would be no need to generate 30 time histories for each RS. Therefore, the applicant is requested to demonstrate that the one-time scaling method produced an adequate approximation of the target PSD for the vertical CSDRS or redevelop the target PSD based on an appropriate method (e.g., the simulation method used for the HRHF RS and the horizontal CSDRS).

### d) Magnitude of Target PSD Functions

Figure 3-11 of APR1400-E-S-NR-14001-P, Rev. 0, “Seismic Design Bases” shows the smoothed ensemble-mean PSD and the piece-wise log-log linear PSD from the 30 time histories, and Figure 3-12 shows the target PSD and the minimum required PSD. Both figures are for the horizontal CSDRS anchored at 0.3 g. However, the PSD functions shown in Figure 3-11 differ significantly from Figure 3-12 (and other PSD figures after Figure 3-12). The applicant is requested to justify this difference.

### e) Upper limit of 80 Hz for HRHF Target PSD

Technical report APR1400-E-S-NR-14004-P, Rev. 1 states that the APR1400 HRHF RS-compatible target PSDs were developed in the frequency range of 0.3 Hz to 80 Hz. It is understood that 0.3 Hz is consistent with Appendices A and B of SRP 3.7.1; however, the report does not provide a basis for the choice of 80 Hz. It is recently recognized during the development of Appendix B of SRP 3.7.1 Rev. 4 that the upper bound frequency in the PSD assessment should be consistent with the DRS shape. For a DRS with a zero period acceleration (ZPA) frequency, the ZPA frequency can be used as the upper bound frequency for the development of the target PSD. However, the horizontal and vertical HRHF DRS do not exhibit a definitive ZPA (zero period acceleration) frequency. As such, the applicant is requested to justify the use of 80 Hz as the upper bound frequency for the development of target PSDs.

03.07.01-2

10 CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion associated with the safe shutdown earthquake (SSE) ground motion through design, testing, or qualification methods. In accordance with 10 CFR 50 Appendix S, the staff reviewed the adequacy of the synthetic acceleration time histories used for seismic analysis of the SSCs. The APR1400 DCD indicates that a single set of time histories were developed in the three orthogonal directions for both the certified seismic design response spectra (CSDRS) and the hard rock high frequency (HRHF) response spectra (RS), following SRP 3.7.1 Option 1 Approach 1. In order for the staff to understand whether the method and parameters associated with the time history generation are

consistent with the guidance of SRP Acceptance Criteria 3.7.1 II.1.B, the applicant is requested to provide additional information related to the fallowing aspects of the development of the synthetic acceleration time histories.

### a) Justification of seed recorded time histories

Section 3.7.1.1.2 of the DCD, "Design Ground Motion Time History," indicates that the initial seed motions for the development of the design ground motions are recorded ground motions from the Northridge earthquake. The DCD does not provide justification for the selection of these Northridge ground motions as seed motions. The staff recognizes that some discussion on the choice of the Northridge time histories is provided in APR1400-E-S-NR-14001-P, Rev. 0, "Seismic Design Bases." Since this report is not incorporated by reference, the applicant is requested to provide appropriate justification for the seed motions in the DCD.

As described in Section 3.2.2 of APR1400-E-S-NR-14001-P, Rev. 0, the recorded seed time histories, from the M6.7 Northridge earthquake, has a time increment of 0.02 s, which corresponds to a Nyquist frequency of 25 Hz. Furthermore, Figures 3-4 and 3-5 of this technical report show that the frequency contents are only up to about 8~9 Hz for the two horizontal directions. However, Section 3.2.3 of this technical report indicates that the applicant re-digitized the time histories to 0.005 s. Therefore, the applicant is requested to (1) provide a description and a justification of the method used for the re-digitization of the seed recorded time histories, and (2) provide an explanation why the seed recorded motions for the two horizontal directions are considered acceptable given that they have power only up to 8~9 Hz (not to 50 Hz).

### b) Provide numerical values to demonstrate that the synthetic acceleration time histories meet the SRP 3.7.1 Option 1 Approach 1 spectral matching criteria

Section 3.7.1.1.2 of the DCD provides some numerical information on the design time histories, such as time increment (0.005 s), correlation coefficients (<0.16), and duration (20.48 s). However, it does not provide the necessary numerical values for the design time histories that show how they meet the SRP 3.7.1 Option 1, Approach 1 criteria, although the DCD generally concludes that those criteria are met. Some of the information is provided in graphical form but is difficult to extract/interpret from the figures. Therefore, the applicant is requested to provide, preferable in a tabular format, the following additional information of the design time histories for both the CSDRS and the HRHF RS and revise the DCD and the HRHF report, as appropriate:

(1) Strong motion durations for all three directions
(2) Peak values (A, V, D)
(3) How many points of the response spectra were below each DRS
(4) The lowest percentage below the DRS

### c) Provide the time histories for staff's confirmatory analyses

In light of the different ways to develop target PSD, normalize Fourier spectra, and estimate PSDs from time histories, the staff decided to perform a confirmatory analysis of the APR1400 design time histories. As such, please provide the following information in digital format (e.g., text files):

(1) The CSDRS and HRHF RS
(2) The target PSDs
(3) The PSDs estimated from the time histories
(4) The six synthetic acceleration time histories

03.07.01-3

10 CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion

associated with the safe shutdown earthquake (SSE) ground motion through design, testing, or qualification methods. In accordance with 10 CFR 50 Appendix S, the staff reviewed the adequacy of the method to estimate the power spectral density (PSD) functions for the acceleration time histories for the certified seismic design response spectra (CSDRS) and the hard rock high frequency (HRHF) response spectra (RS). In order for the staff to understand whether the PSD functions were estimated using a method consistent with the guidance of SRP Appendices A and B, the applicant is requested to provide the following additional information.

**a) Explain the method used to estimate PSD for the CSDRS time histories**

In DCD Section 3.7.1.1.2, the PSDs of the design acceleration time histories are compared to the corresponding target PSD. However, the method to estimate the PSD from an acceleration time history is not provided. Therefore, the applicant is requested to provide a description of the method for the PSD estimation and justify any difference of the method as compared to the guidance provided in SRP 3.7.1. The provided information should include the definition of the strong motion duration, portion of the time history used to compute the Fourier spectra, PSD smoothing, and any normalization parameters used in Fourier transform and PSD calculation.

**b) Justification of the method used to estimate PSD for the HRHF time histories**

Section 3.5.3 of APR1400-E-S-NR-14004-P, Rev. 1, "Evaluation of Effects of HRHF Response Spectra on SSCs," describes the method used to calculate the PSD function from an acceleration time history. It utilizes an "equivalent stationary strong-motion duration" as the strong motion duration. The equivalent stationary strong motion is defined as the time for a P1-to-P2 rise of the cumulative Arias intensity, divided by (P2-P1). The applicant stated, "the equivalent stationary duration $T^i_s$ for the entire time histories as determined from Eq. (3-3) is the duration over which the total energy of the time history is built up from 0 to 100 percent with the constant slope S." In this statement, the parameters P1, P2, and S are not defined. As such, the applicant is requested to provide these three parameters for the three HRHF acceleration time histories. In addition, it appears that the PSD estimate is very sensitive to the choice of P1 and P2; for example a P1=0 and P2=100% will lead to an equivalent stationary strong-motion duration $T_s$ equal to the total duration of the time history. As such, the applicant is also requested to provide a justification for the values of P1 and P2.

Eq. (3-4) is described in Section 3.5.3 as the one-sided PSD, but it appears to be the two-sided PSD formula. Please confirm the validity of Eq. (3-4) and explain how this equation is implemented in the development of target PSDs and in estimating the PSD function for each time history (i.e., one-sided vs two-sided).

Eq. (3-5), the amplitude of the Fourier spectrum, is provided in terms of continuous time *t* and the integration is performed over the entire time history. Please provide the corresponding equation for the discrete Fourier transform implemented for the APR1400.

Appendices A and B of SRP 3.7.1 indicate that PSD should be estimated based on the strong motion duration. Therefore, the staff requests that the applicant provide a justification for the use of equivalent stationary strong-motion duration. Similarly, the applicant is requested to explain why the entire time histories were used in the Fourier transform. The use of the equivalent stationary strong-motion duration, which is shorter than the entire duration as shown in Figure 3-27 of APR1400-E-S-NR-14004-P, Rev. 1, together with the entire time history used in the Fourier transform, may overestimate the PSD for those frequencies that have very low magnitude but span the entire time history.

03.07.01-4

10 CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion associated with the safe shutdown earthquake (SSE) ground motion through design, testing, or qualification methods. DCD Section 3.7.1.3, Appendix 3.7A, and APR1400-E-S-NR-14001-P, Rev. 0, “Seismic Design Bases,” provides information related to the DCD generic soil profiles, which were used in the various soil structure interaction (SSI) analyses of the APR1400 Seismic Category I structures. In accordance with 10 CFR 50 Appendix S, the staff reviewed this information related to the supporting media and determined that the following additional information should be provided to assist the staff’s evaluation.

### a) Strain compatible (not low strain) soil profiles should be used for DC/COL soil profile comparison

Since magnitude/distance properties are not appropriate to be specified in the DCD, the range of soil profiles in the standard design are typically considered as strain-iterated. In the end, the combined license application (COLA) will need to compare their appropriate strain compatible properties (based on site-specific data and ground motion parameters) when developing ground motion response spectra (GMRS) with the range of profiles considered in the DCD. Furthermore, COLA profiles cannot easily be defined as “bounded” by the profiles used for the DCD. Since both low strain soil profiles and strain iterated soil profiles are provided in DCD Section 3.7.1.3, DCD Appendix 3.7A, and APR1400-E-S-NR-14001-P, Rev. 0, the applicant is requested to clearly indicate in these documents that the COLA strain iterated soil profiles should be compared to the strain iterated generic soil profiles. It is understood that COLA comparison of soil profiles is addressed separately in Section 2.5. Therefore, any revision of SRP 3.7.1 related information should be performed in connection with any required revision of DCD Section 2.5 including COL information items.

### b) Treatment of DCD soil degradation models

It is not clear what is the purpose of specifying the modulus reduction and damping curves in the DCD as described in Section 3.7.1.2 because the SSI analyses in the DC stage only requires a range of generic soil profiles typically considered as strain iterated. Three soil degradation models are used in Section 5.1 of APR1400-E-S-NR-14001-P, Rev. 0: (1) curves for sand from EPRI TR-102293, (2) soft rock from Silva’s report, and (3) rock from SHAKE. These curves do not always exhibit a clear trend (as evidenced in Figures 5-11, 5-12, and 5-13) to be consistent with the expected behavior of sand, soft rock and rock. As discussed in the above RAI question, consideration of soil/rock degradation is not necessary in the DCD because the SSI analyses in the DCD start typically with postulated range of strain iterated soil profiles. As such, the three degradation models should be treated as part of a demonstration of the DCD method and how the DCD demands and ISRS were reached. Accordingly, the applicant is requested to include a COL information item for the COLA to use methods/models/data suitable for its site and any use of these three DCD soil degradation models must be justified to be appropriate for the site in COLA.

### c) Strain compatible P-wave velocities

DCD Section 3.7A.2.2 indicates that separate horizontal and vertical site response analyses were performed to get the strain compatible properties for the nine low-strain soil profiles, which are then used as equivalent linear properties in the SSI analyses. The strain compatible properties for the two horizontal directions were averaged to obtain a single set of strain compatible properties for the two horizontal directions. Tables 3.7A-1 through 3.7A-9 show both the low strain and strain compatible soil profiles. On the other hand, Section 2.2 of the HRHF technical report, “Site Response Analysis,” indicated that the horizontal site response analyses considered soil degradation but the vertical site response analyses uses the low-strain compression wave velocities. It appears that strain compatible P-

wave velocities were used for the CSDRS related analyses but the low strain P-wave velocities were used for the HRHF site response analysis.

The applicant is requested to identify what P-wave velocities were used in the SSI analysis for the HRHF related evaluation, and provide the basis for the inconsistent application of the P-wave velocities in the site response analyses and/or SSI analyses for CSDRS and HRHF evaluations.

Previous recommendations for site-specific SSI analyses indicated use of strain compatible properties for S-wave velocities and corresponding low strain velocities for P-wave velocities. However, that approach has recently been modified (ASCE Standard 4 for example) since these differences can lead to stability problems in SSI analyses. For example, Section C5.2 of the draft ASCE 4 (July 3, 2013) states that "Poisson's ratios at low strain levels should be maintained for strain-compatible soil properties, except for saturated soils for which the minimum P-wave velocity of saturated soil should be maintained." The DCD and APR1400-E-S-NR-14001-P, Rev. 0 present different Poisson's ratios for the low strain soil profiles and the strain compatible soil profiles. Therefore, the applicant is requested to:

(1) Explain the method used to develop the strain compatible P-wave velocities
(2) Explain how that method used in the DCD compares to the currently recommended approach (i.e., maintaining the low strain Poisson's ratio as described in the draft ASCE 4).

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