Verification of Adequacy of Considering 16 Coherency Modes in Incoherent SSI Analysis of APR1400 NI Structures

1. For the type of detailed finite element (FE) model of the APR1400 nuclear island (NI) structures, using a single index currently available as the convergence criterion for the number of spatial modes to be considered in the incoherent-motion SSI analysis requires further study and verification. As such, it may not be suitable for APR1400 DCD application at this time

   a. The current criteria/index that was used to justify the convergence as presented in the APR1400 Hard Rock High Frequency (HRHF) incoherent analysis report (ref. 1) are based on the rigid foundation assumption and conclusion obtained from analyses using simple Lumped Mass Stick Model. It may not be applicable to a complex refined FE model such as APR1400 NI FE model.

   b. The criteria proposed in ACS SASSI (ref. 2) and SASSI 2000 (ref. 3) focus on the mode truncated error resulting from using a limit number of the modes to reconstruct the coherence matrix developed from the free field incoherent motion prescribed by Abrahamson's hard rock (HR) coherency functions. As such, for a large size and refined FE model with a large number of closely spaced nodes in the foundation/soil interface, a large number of the coherency modes may have to be considered if a small convergence tolerance due to modal truncation error is specified. This type of convergence criteria does not consider the effect of foundation flexibility or the dynamic characteristics of the supporting foundation medium. Actually, the foundation will filter out some of the responses due to higher modes.

2. Reference 1 documents results of HRHF incoherent SSI analysis of the APR1400 NI full model with embedded foundation considering 12 coherency modes. An analysis will be performed for an additional four coherency modes, i.e. modes 13 to 16. The responses of structures will be obtained from the combination of Modes 1 through 16 using the rule of SRSS (square root of sum of the squares). Adequacy of 16 modes for considering the APR1400 NI HRHF incoherent motion effect should be confirmed from comparisons of responses developed from the study outlined as follows:

   a. Compare the 12-modes-combined and 16-modes-combined, 5%-damped in structure response spectra (ISRS) at selected key locations. The convergence acceptance criterion can be set as the differences from the two sets of results being within 5%. The key locations will be determined as follows: 1) the locations that the ISRS are required to be developed in the DCD; and 2) additional locations at foundation level that are expected to be impacted profoundly by the higher incoherent modes.

b. Compare amplitudes of vertical response acceleration transfer function (ATF) due to the vertical input at the key locations as defined in 2a at the foundation level mode by mode from modes 12 to 16, based on the consideration that the vertical response due to vertical input may be affected most sensitively by the addition of higher modes. The amplitude should be small as compared to the SRSS-combined amplitude from the first 12 modes considered and should generally be in a decay pattern from mode to mode.

c. Perform a supplementary study as described below to further confirm that the cumulated effect of modes higher than 16 modes is insignificant and, thus, can be neglected:

1) Perform incoherence SSI analyses (for the vertical direction input only) for principal coherency modes up to 50 using the same method which was applied in Reference 1 based on a simplified basemat model extracted from the full SSI FE model of the APR1400 NI.

2) Simplified basemat model: APR1400 NI basemat sitting on the S9 profile. Foundation shape and mesh are the same as the full model. Additional rigid beams will be installed in the locations of the major shear walls to properly simulate the stiffening effect of the walls to the foundation basemat stiffness.

3) Compare the ATF and Acceleration Response Spectra (ARS) at corners, center of the basemat, and selected locations between walls for the different number of modes.

4) The comparison is expected to demonstrate that the additional thirty plus modes have insignificant effect on the basemat vertical response due to vertical input.

References

1. KEPCO E&C, Evaluation of Effects of HRHF Response Spectra on SSCs, Report No. APR1400-E-S-NR-14004-NP, Rev.1
2. Page 87 of ACS SASSI PREP user Manual, ACS SASSI User Manuals Revision 3, Ghiocel Predictive Technology, Inc,, March 31, 2015
3. Ostadan F. and Deng N., SASSI-SRSS Approach for SSI Analysis with Incoherent Ground Motion (ML090770071), Bechtel National, San Francisco, CA, 2007