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Division V

INTEGRATED SEISMIC ANALYSIS OF SGDHR SYSTEM OF PFBR

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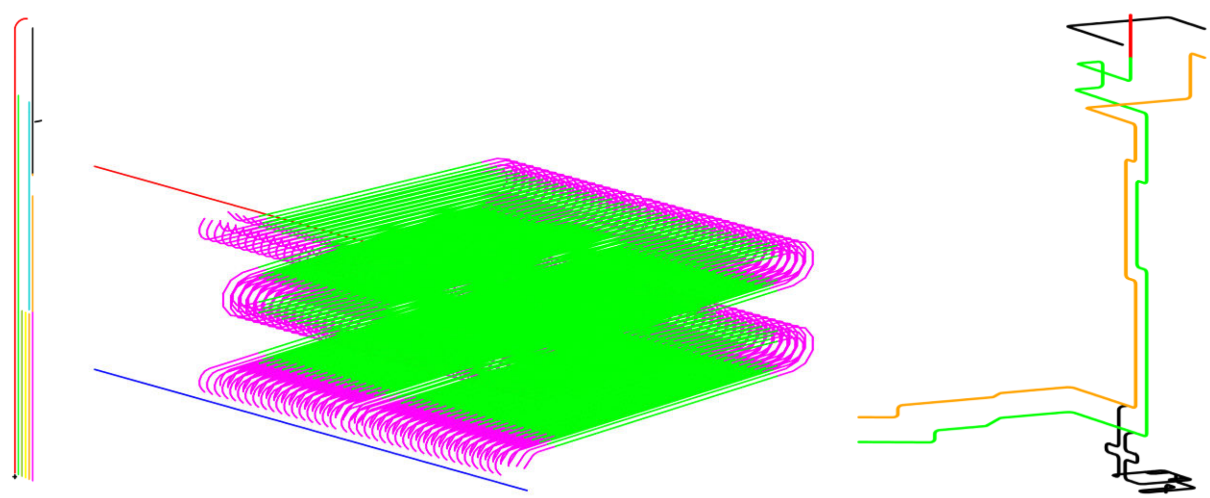
INTRODUCTION

Safety Grade Decay Heat Removal (SGDHR) system is a passive direct reactor cooling system with decay heat exchanger (DHX) absorbing heat from primary sodium pool and dissipating it to atmosphere through air heat exchanger (AHX). SGDHR play a crucial role in the removal of decay heat from the reactor and maintaining it in the shutdown state. Therefore the response of the system to the seismic load is important to ensure its availability.

This paper describes the details of integrated analysis carried out for SGDHR loop for operating base earthquake loadings. The SGDHR piping passes through different elevation of reactor containment building (RCB) and steam generator building (SGB). The piping spans a length of nearly 40m and connects different equipment. The effect of components connecting the piping system is studied by the analysis of integrated model and comparing it with the piping model. Analysis is done for the pipeline and integrated model by multi support response spectra methods, which are compared against multi support time history analysis. The stresses are compared against the requirements of high temperature design rules of RCC-MR.

FEM MODEL

Beam with equivalent properties of the components are used for modelling DHX, AHX, expansion tank and storage tank. The SGDHR main and fast dump lines are modelled in CAST3M using pipe element (Tuya), and the respective connecting equipment and vessels are modelled by beam element (pout). Finite element model of components and piping loop is illustrated in Figure 1.



(a) (b) (c)

Figure 1. (a) DHX model, (b) AHX model, (c) Pipeline model with expansion and storage tank

The nozzle connections between components or vessels and pipeline are modelled with appropriate element. Pipelines penetrating RCB wall in to SGB is anchored to RCB wall by bellow and guard pipe arrangement. These bellows take care of thermal expansion that the lines experience during their normal operation. The bellows are modelled using spring element.

SEISMIC ANALYSIS

Under seismic conditions, vibratory motions of the RCB and SGB are transmitted to the SGDHR piping system through the pipe supports. These supports are taken from the RCB/SGB walls, floors, beams etc. at various elevations. Therefore the excitation to the piping system will be different at different elevations. The supports and equipment anchors are grouped in to six groups.

Analysis of SGDHR system is done by multi support response spectra method and multi support time history method. Floor response spectra (FRS) corresponding to each elevation for 5% damping is extracted from the seismic analysis of nuclear island connected building. Modal combination rule used to combine various modes within a group is SRSS. This resulting solution for each individual group experiencing their respective excitations is combined through SRSS to get the response of entire system.

Artificial spectrum compatible time histories are generated based on FRS. These time histories are used for the multi support time history analysis of the system. Central difference method corresponding to Newmark –β method with a time step of 0.0078 sec is used for the time history analysis of the integrated model. The FRS and the corresponding time histories are shown in Figure 2-7.

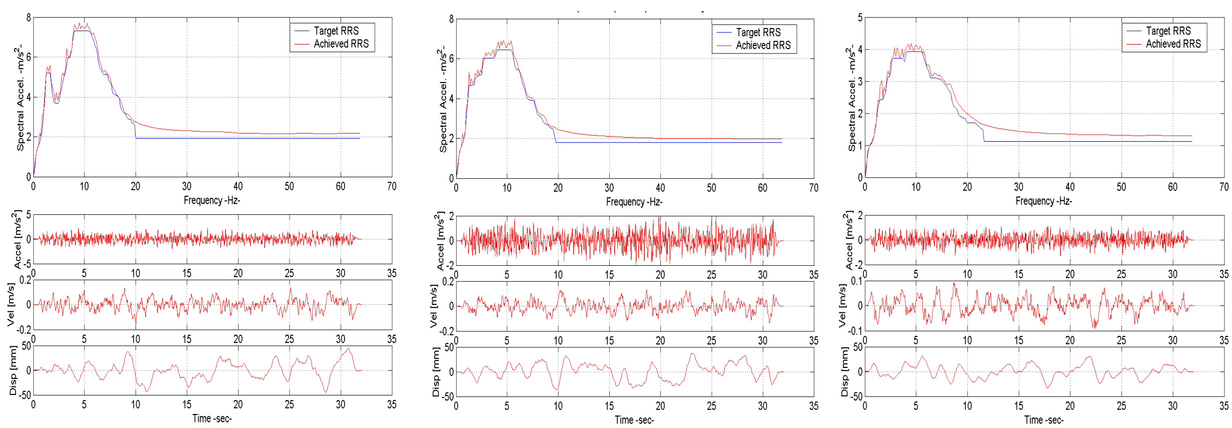


Figure 2. FRS and Spectrum compatible time history for group 1 in X, Y and z direction.

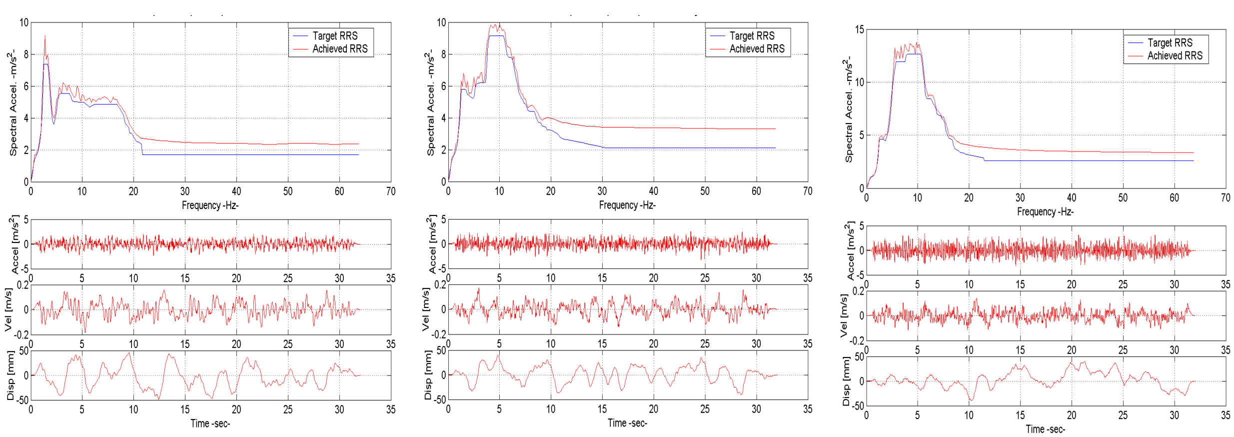


Figure 3. FRS and Spectrum compatible time history for group 2 in X, Y and z direction.

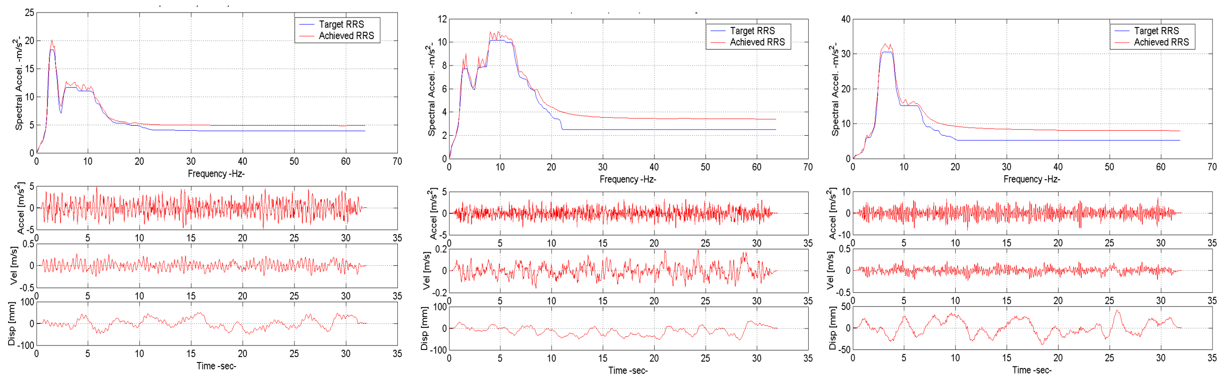


Figure 4. FRS and Spectrum compatible time history for group 3 in X, Y and z direction.

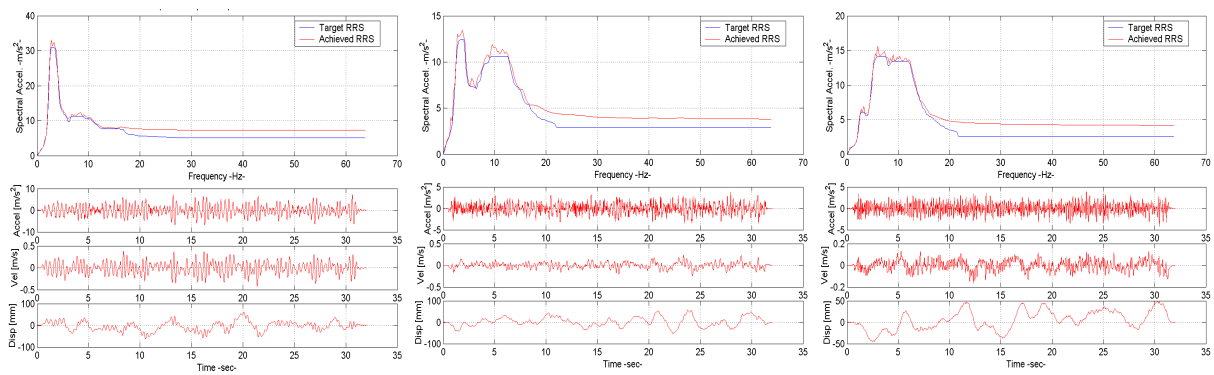


Figure 5. FRS and Spectrum compatible time history for group 4 in X, Y and z direction.

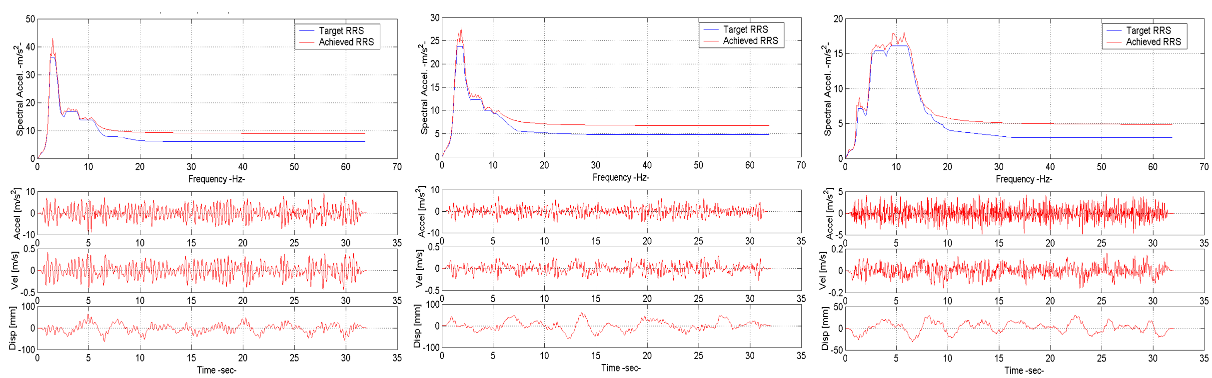


Figure 6. FRS and Spectrum compatible time history for group 5 in X, Y and z direction.

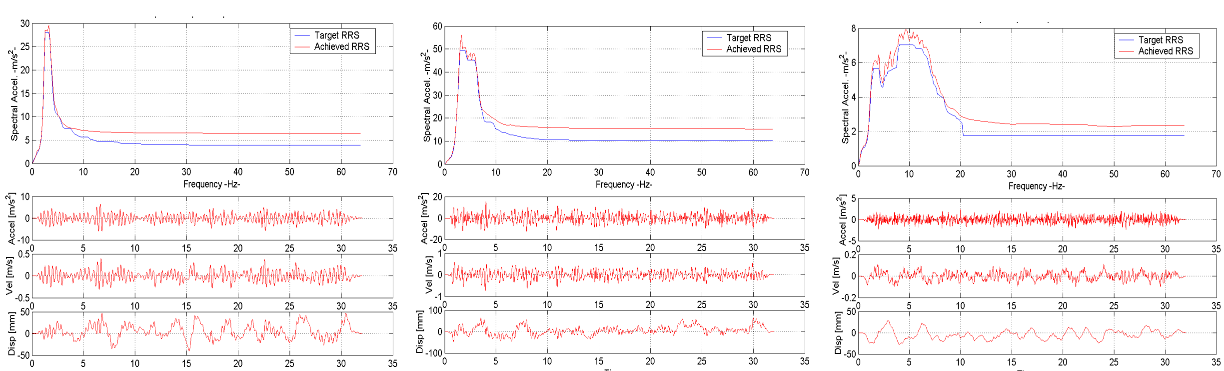


Figure 7. FRS and Spectrum compatible time history for group 6 in X, Y and z direction.

RESULTS

Free vibration analysis is performed prior to the seismic analysis and the natural frequency and mode shapes are extracted. A few dominant modes are shown in Figure 8. Maximum displacement in the piping system is listed in Table 2. Figure 9. shows relative displacement vs. time for the corresponding location listed in Table 2.

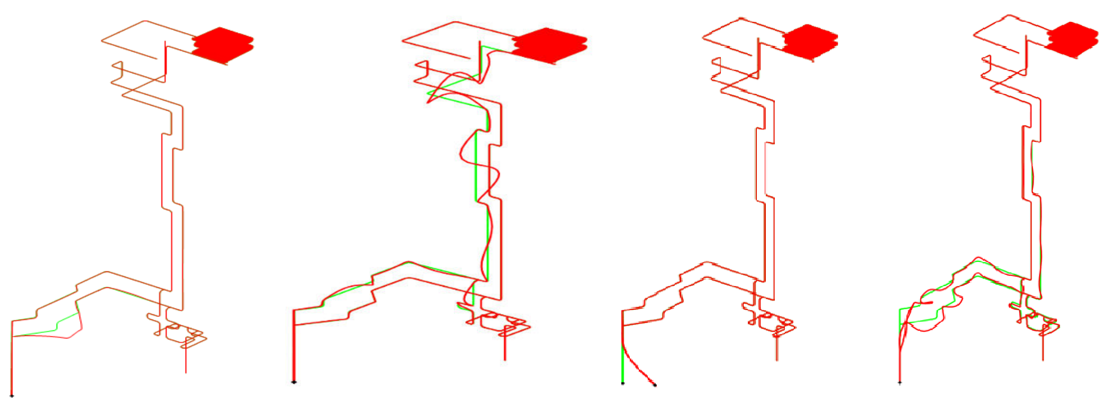
Critical locations for the calculation of stress intensity values for each individual line, as per RB-3600 are selected from Von Mises plot Figure 10. The maximum stress intensities are calculated from integrated analysis, piping analysis and time history analysis. These values are listed in Table 1.

Table1: Maximum stress due to seismic loading

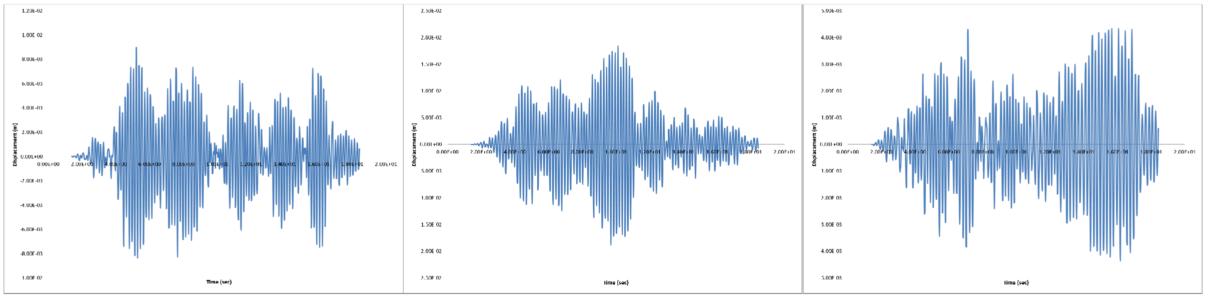
LINE	LOCATION	NODE NO:	Integrated analysis	Piping analysis	Time history analysis	RCCMR level C limit (MPa)
			Pm + Pb (MPa)	Pm + Pb (MPa)	Pm + Pb (MPa)	
DHX out line	Bend	845	169.4	152.1	77.4	182.4
DHX in line	Bend	12098	147.1	126.2	108.1	182.4
Dump lines	Tee	12633	167.4	158.2	80.7	182.4

Table 2: Maximum displacement due to seismic loading

Direction	Node no:	Multi support response spectra		Time history analysis
		Coupled analysis	Uncoupled	
		Displacement	Displacement (mm)	Displacement (mm)
UX	823	9.04	11.1	8.29
UY	12367	20.1	20.4	18.8
UZ	12680	16.0	19.6	4.33



(a) (b) (c) (d)
Figure 8. (a) Mode for DHX out line (6.1Hz), (b) Mode for DHX in line (8.6Hz), (c) DHX mode (6.7Hz), (d) Mode for DHX In and Outline (20.8 Hz)



(a) (b) (c)

Figure 9. (a) Displacement UX for node 823, (b) Displacement UY for node 12367, (c) Displacement UZ for node 12680.

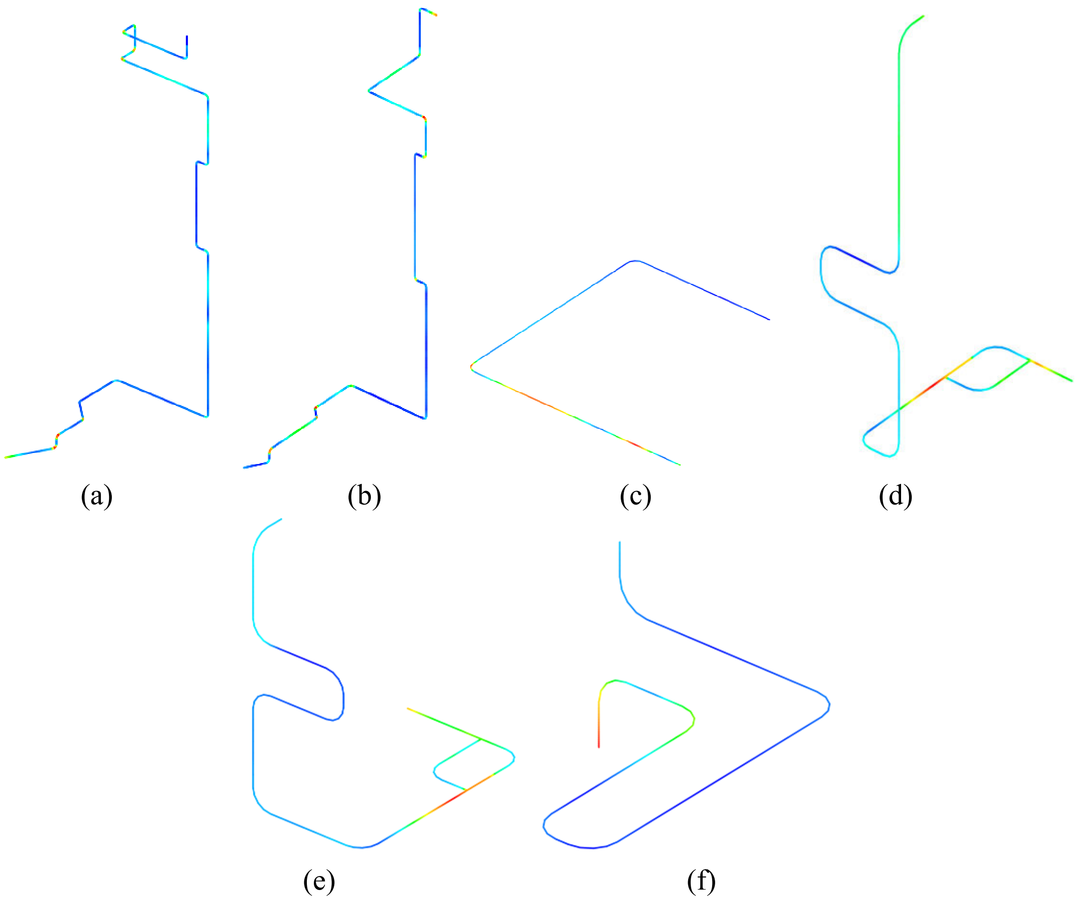


Figure 10. Von mises stress plot for (a) DHX out line, (b) DHX in line, (c) Expansion to AHX line, (d) Dump line1, (e) Dump line 2, (f) Dump line 3.

CONCLUSION

The first vibration mode for the integrated model is 1.5 Hz for the DHX in line. Further, 190 mode shapes are identified in the free vibration analysis. The natural frequency of the DHX is found to be 6.7 Hz, which is in good agreement with the free vibration analysis of DHX. The fundamental mode for the AHX is identified as 5.32 Hz, which is also in close agreement with the free vibration analysis of AHX. Fundamental frequency of the storage tank is 18.4 Hz which has coupling with the dump line vibration modes. The expansion tank has no frequency within the seismic band width of interest. The mode shapes show that the DHX has a greater impact on the loop compared to other components. While the AHX has a fundamental frequency of 5.23 Hz does not affect the response of loop. Therefore, AHX can be analyzed independently by decoupling it from the loop. The dump line is affected by the main line as well as the storage tank. This indicates that the dump line cannot be analyzed separately.

Design check has been performed for 'Level-C conditions as per RCC-MR design rules. The maximum stress intensity Pm +Pb for various lines in the model are listed in Table 2. The maximum stress value of 169.4 MPa occurs at node no: 845. The difference in the maximum stress intensity for integrated and a pipeline analysis is within 10%. Node no. 845 and 12096 are near to DHX, while the node no. 12633 is near to storage tank. The lesser stress value predicted by the pipeline analysis may be due to the equipment effect not considered in the piping analysis. Time history analysis of the SGDHR system indicates that the multi support response spectra method is a conservative approach in analyzing SGDHR system.

Peak deflection in the three orthogonal directions for the loop is presented in Table 2. Integrated multi support analysis predicts higher deflection values compared to integrated time history analysis.

Seismic analyses of the SGHDR loop by multi supported response spectra by both integrated and pipeline analysis lines meet the code requirements of RCC-MR. Comparison between the methods reveals the pipeline need to be analyzed along with DHX and storage tank. Therefore multi support response spectra method is more realistic, conservative and less time consuming in analyzing SGDHR system and can be used for analyzing similar system.

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