Seismic Margin Assessment of Hatch Nuclear Plant

Donald P. Moore, Keith D. Wooten
Southern Company Services, Birmingham, AL USA
Robert P. Kassawara
Electric Power Research Institute, Palo Alto, CA USA

INTRODUCTION

The Electric Power Research Institute (EPRI) is sponsoring a Seismic Margin Assessment (SMA) of Plant Hatch Unit 1 for the purpose of assessing the practicality of the recently developed seismic margin methodology (EPRI 1988). This project is being funded by EPRI and Georgia Power Company (GPC). GPC is the owner and operator of Plant Hatch. Plant Hatch is a General Electric boiling water reactor (BWR) - four with a Mark 1 Containment located on a soil site. The plant was placed in commercial operation in 1975 and is located on the Altamaha River near Baxley, Georgia. The Plant Hatch SMA is being implemented by Southern Company Services, Inc. (SCS). Dr. R. P. Kennedy is a consultant to SCS for this project. Also Dr. I. M. Idriss of Woodward-Clyde Consultants (WCC) is the soil consultant and Dr. J. J. Johnson of EQE, Inc. is performing the soil structure interaction analysis (SSI) and generation of the Seismic Margin Earthquake (SME) floor response spectra (FRS).

The Nuclear Regulatory Commission (NRC) and EPRI have developed similar approaches to performing an SMA (EPRI 1988, Budnitz et al 1985, Prassinos et al 1986). The NRC performed a trial SMA of the Maine Yankee Atomic Power Station (Prassinos et al 1987) and EPRI performed a trial SMA of the Catawba Unit 2 Power Plant; both are PWR's on rock sites. The NRC has reviewed the EPRI SMA methodology and finds it an acceptable approach. Both the NRC and EPRI have joined together to evaluate the SMA methodology for a BWR plant on a soil site. GPC has agreed to use Plant Hatch Unit 1 as this trial BWR. The NRC is participating in the program in an independent review capacity under the direction of D. J. Guzy of the NRC Research Branch with an NRC Peer Review group. The NRC is also funding a separate study utilizing the event tree/fault tree modeling of front line and support systems. The EPRI SMA methodology applies the success path modeling approach.

The primary purpose of the SMA is to demonstrate sufficient margin over the Design Basis Earthquake (DBE) and identify the most seismically vulnerable components in the prescribed paths for safe shutdown and to show the inherent seismic margin in the plant shutdown capacity under an earthquake greater than the DBE. GPC/SCS is also performing portions of the USI A-46 review of Plant Hatch Unit 1 in conjunction with the SMA.

PLANT HATCH SEISMIC DESIGN

Plant Hatch Unit 1 was designed in the late 1960's and early 1970's. The original design was performed by Bechtel Power Corporation and SCS. The Operating Basis Earthquake (OBE) and the DBE are specified as Housner type spectrum with a peak ground acceleration (PGA) of 0.08g and 0.15g respectively.

The actual input motion for the SSI analyses were conservatively placed at the foundation level of each building. In 1968 a refraction survey was made of the site from which a single (average) composite value of shear wave velocity of 2450 ft/sec. was obtained for characterization of the soil used in the original SSI analyses. The SSI approach was based upon the elastic half-space theory.

SELECTION OF THE SEISMIC MARGIN EARTHQUAKE

The first step in the SMA is the selection of the Seismic Margin Earthquake (SME). Based on the information available when the selection of the SME was made, the fourth approach given in the methodology (EPRI 1988) of selecting the SME was used for the Plant Hatch SMA. This approach is to select a standard (non site-specific) SME spectrum at a negotiated PGA. The Plant Hatch SME has a PGA of 0.3g and a spectra shape based on NUREG/CR-0098 (Newmark et al 1978) median centered spectrum but modified for magnitude effects using the procedure proposed by Idriss (1988). The selected SME spectra is at least two times larger than the DBE spectrum. The vertical SME ground response is equal to 2/3 the horizontal ground response spectra.

EVALUATION OF LIQUEFACTION POTENTIAL

Liquefaction potential due to the SME in the plant area was evaluated using observations of liquefaction in previous earthquakes as discussed in Appendix C of the SMA Methodology (EPRI 1988). In addition, estimated settlements in the plant area due to dissipation of excess pore water pressure were made.

Due to the variability of the Standard Penetration Test (SPT) data within the plant area, statistical evaluation was conducted to obtain mean and standard deviation (σ) of the data. A minimum required margin of the ratio of shear stress required to cause liquefaction divided by the shear stress induced by the SME of 1.50, 1.30, and 1.05 was selected for the mean, mean-$1/2\sigma$ and, mean-σ SPT values respectively. In order to meet these minimum required margins the allowable peak horizontal ground surface acceleration is approximately 0.28g.

The estimated resulting settlements in the plant area due to an SME were on the order of 1 to 1-1/2 inches, and differential settlements were of similar size. Such settlements are not expected to have detrimental effects on the facilities in the plant area.

EVALUATION OF THE STABILITY OF SLOPES

The critical cross section for evaluation of slope stability was determined to be just South of and adjacent to the water intake structure at the river. Buried service water lines and reinforced concrete electrical conduit banks traverse this area.

Based on calculated factors of safety against sliding it was determined that the slopes would not experience serious instability due to the postulated SME. However, it was felt likely that limited amounts of lateral movement would occur. The maximum lateral movements were estimated to be about 2-1/2 inches.

Preliminary evaluation of the buried butt welded service water piping has indicated there is adequate capacity to survive such lateral slope movement. Also, there is adequate flexibility of the electrical cable in the reinforced concrete electrical conduit banks to handle this slope movement.

SOIL STRUCTURE INTERACTION

Plant Hatch buildings are founded on soil and some are significantly embedded in the soil. Both the frequency and amplitude of response due to seismic excitation for these buildings are greatly affected by SSI. In order to get the predicted structural and equipment response for the SME to be median centered, proper consideration of SSI is needed. Based on the conservatism of the original SSI analysis and other parameters originally used, it was determined that scaling the original FRS was not appropriate. Therefore, Dr. J. J. Johnson of EQE, Inc. was contracted to generate the median centered responses of the major structures for the SME. A properly executed SSI analysis was the key to identifying seismic margin for the Plant Hatch SMA.

Soil Profiles and Their Variation

To address the uncertainties in both the soil stiffness and the SSI analysis, lower, intermediate, and upper soil profiles were developed. The lower and upper range modulus cases were specified as 0.6 and 1.6 times the modulus values of the intermediate case. The same soil material damping is used for all cases.

Structural Models

The original seismic models were reviewed to ensure their adequacy for use in determining the responses for the SME. The original models were two-dimensional models. The Control Building and Intake Structure were judged to possibly have significant torsional responses and, therefore, were converted to three-dimensional models.

SSI Approach

The SSI and structure response analyses of the Hatch buildings was performed using the substructure approach as implemented in the CLASSI system of programs. The substructure approach separates the SSI problem into a series of simpler problems, solves each independently, and superimposes the results. The free-field ground motion is specified at the free surface at the top of finished grade. The control motion is specified as three acceleration time histories that are essentially statistically independent. The spatial variation of motion is defined by vertically propogating waves.

SSI Results

The SSI results produced median responses which were presented as FRS or in-structure response spectra. They were calculated for the three different soil profiles and the three different directions. The format for plotting them was to overplot the response spectra for the three soil profiles while holding all other parameters constant.

A comparison of the peak spectra accelerations (SA) of the DBE and SME spectra point out the large conservatism in the original SSI analysis. In many cases the SA's of the SME spectra were less than or equal to the original DBE SA's. It also points out that it was not possible to estimate median centered response by scaling the original DBE FRS for Plant Hatch.

SUCCESS PATH SELECTION

Two independent functional paths which can achieve and maintain a safe shutdown condition following an SME were chosen. The components of the frontline systems and their required support systems in these paths were identified for the Plant Hatch SMA. Evaluation of these systems addressed the following plant safety functions; reactivity control, core cooling, and reactor coolant systems heat removal. These paths, along with their associated components, fulfill the requirements for both SMA and USI A-46. Therefore, only one list of safe shutdown components had to be developed to cover both programs.

The list of success path components used for the walkdown includes 331 items. The effort to develop the success paths and identify the list of required components totaled 850 manhours.

RELAY CHATTER EVALUATION

An evaluation of relay chatter is being performed for all relays required for the success path components by evaluating the effects of relay chatter or by establishing the seismic adequacy of the relay. For each component, circuits were identified that were required to provide essential plant functions or required to prevent unacceptable conditions.

A particular relay may be required for several different components. 4539 of these combinations of relays and components were evaluated. 4138 combinations were determined to be acceptable and grouped into one of the following categories; chatter acceptble, operator action required, or actuator is immune to chatter. Generic test data (GERS) were used to screen out 250 combinations and 53 were screened out using existing Plant Hatch qualification data. There are 15 relays that have been identified as requiring corrective action and 83 relay combinations that are still unresolved. The SMA relay evaluation has expended 2250 manhours to date. An in-depth report of the Plant Hatch SMA relay evaluation is presented by Wooten et al (1989).

SEISMIC CAPABILITY WALKDOWN

The Seismic Capability Walkdown was performed by two Seismic Review Teams (SRT) both prior to and during the Unit 1 refueling outage. Each SRT consisted of two SCS seismic/structural engineers along with electrical and mechanical engineers as required. The total walkdown effort took 36 team days or approximately 1200 manhours including travel time to and from the plant.

Walkdown Data Sheets were filled out for each item by the SRT's. These sheets were taken from the Seismic Qualification Utility Group (SQUG) Generic Implementation Procedure (GIP) (SQUG 1988) with an additional sheet added to address other items such as the relay portion of the walkdown and seismic interaction for flooding. 35mm pictures were also taken of each item.

The Senior Seismic Review and Advisory Panel (SSRAP) Bounding Spectra (SSRAP 1988) was used to seismically verify most of the equipment. Each item of equipment was also checked for possible seismic spatial interaction concerns. For most items that required an anchorage check, a simple sketch of the component and the anchorage layout was made and attached to the Walkdown Data Sheet. The quality of welds and anchor bolts were also checked. Expansion anchor bolts were checked for tightness, edge distance, bolt spacing, and embedment. The seismic demand for the anchorage check was based on the SME FRS. Relays identified as essential relays were located during the walkdown and checked for proper mounting.

A total of 326 of the 331 success path items were evaluated during the Seismic Capability Walkdown. Five success path items are located inside the reactor vessel and subpile room and will be seismically verified by another method. As of the end of the walkdown, 215 items were seismically verified at an SME level of at least 0.3g and 111 items were classified as unresolved/outliers.

SEISMIC MARGIN ASSESSMENT WORK

The Seismic Margin Assessment work is that portion of the SMA program where additional calculations and/or evaluations are done to screen out or calculate high-confidence-low-probability-of-failure (HCLPF) values for those items not screened out prior to or during the walkdown. The following is a list of unresolved/outlier items and their current status:

DESCRIPTION	NO.	STATUS or RESOLUTION
Anchorage Concerns	16	Modify
Potential Impact from Control Room Light Fixtures	24	Modify
Potential Impact of Panels Containing Essential Relays	8	Bolt Panels Together
Valve Interaction	2	Unresolved
Vertical Pump Casings Supported at Intervals Greater than 20'	5	Unresolved
Determine if Valve Yoke is Cast Iron or Steel	18	Valves are Steel
Potential Impact from Overhead Light Fixtures in Plant	9	Modify
Battery Charger Circuit Cards Unrestrained	1	Install Restraint
Potential of Excess Nozzle Loads on Pumps	3	Evaluation Shows HCLPF greater than 0.3g
No Qualification Data for Diesel Generator Neutral Resistors	3	Unresolved
Vibration Isolation Mounts on Diesel Mounted Relay Box	3	Modify
Valve to Actuator Length Exceeds SSRAP Caveat	1	Unresolved
Valves not available for Review	10	Walkdown on a Later Date
Unable to Locate Essential Relays	8	Resolved

SUMMARY

There are several observations that can be made concerning the Plant Hatch SMA. The evaluation of Plant Hatch soil conditions (i.e., soil liquefaction, slope stability, soil profiles, and the SSI analysis) and the relay evaluation are very significant parts of the SMA effort. The SSI analysis accounted for most of the margin over the plant DBE. This occurred due to the excessive conservatism in the original plant SSI. There were no significant barriers identified during the walkdown that are expected to prevent Plant Hatch from obtaining a reasonable HCLPF value. A majority of the walkdown effort involved the evaluation and inspection of equipment anchorage. The anchorage concerns that were identified were due primarily to poor installation. Combining portions of USI A-46 with SMA was a very cost effective way to perform both programs at Plant Hatch. It is concluded that the EPRI SMA methodology provides a practical, cost effective method to identify seismic margin up to the limits of the earthquake experience data base.

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