A Program for the Resolution of II/I Seismic Interactions

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ABSTRACT

This paper provides an overview of the methodology and the results of a II/I seismic systems interaction study at the Comanche Peak Steam Electric Station (CPSES). This II/I study combines the positive attributes of several different resolution approaches including earthquake experience data, seismic analysis and dynamic impact assessments. The results of this study provide basic insights into the following:

- The number and types of potential II/I interactions which exist in a typical nuclear power plant
- The appropriate methods to be used to resolve II/I seismic interaction issues
- The quantity and types of conditions within a plant which pose credible II/I interactions and could require either a relocation or a redesign

BACKGROUND

Seismic systems interactions have become a widespread issue in the Nuclear Power industry relative to the safety of a nuclear plant during and following an earthquake. The Nuclear Regulatory Commission's Unresolved Safety Issue A-17 addresses five areas of seismic special interactions: II/I failure and falling conditions, seismic deflection/impact, differential motion induced failures, seismic induced spray and flooding, and seismic induced fires. An overview of the other system interaction areas and the status of their resolution can be found in a paper presented at the 1988 Orlando Conference (Harris 1988). Utilities have established various programs to specifically address these system interaction issues and the seismic portions of these efforts have proven to be one of the primary focal points (Consumers Power, 1983, Pacific Gas and Electric, 1984, Power Authority of the State of New York, 1983). Seismic system interaction issues are also currently being addressed as a part of several nuclear industry programs. Unresolved Safety Issue (USI) A-46 involves the seismic qualification of existing equipment in older nuclear plants and addresses a portion of the seismic systems interaction issue. Seismic Probabilistic Risk Assessments (PRA's) and seismic margin studies also address the system interaction issue via expert judgement utilizing very experienced engineers during plant walkdowns (Ravindra, 1987 and Campbell, 1987).
The origins of the seismic II/I system interaction issue is contained within Regulatory Guide 1.29. RG 1.29 stipulates a seismic design classification criteria for nuclear plant components and also identifies a requirement to demonstrate the seismic adequacy of Category II equipment in close proximity to Category I equipment. RG 1.29 states "Those portions of structures, systems, or components whose continued function is not required but whose failure could reduce the functioning of any plant Category I component to an unacceptable safety level should be designed and constructed so that the /SSE would not cause such failure". The II/I seismic system interaction issue relates to the effects of a non-seismically designed component (Category II) failing during an earthquake and subsequently falling or sliding into a Category I safety related component.

OBJECTIVE

The objective of this paper is to present a state-of-the-art approach to evaluate the II/I seismic interaction issue relative to a nuclear power plant. A methodology has been developed to take credit for the inherent seismic ruggedness of many Category II commercial grade equipment items. Recent studies by the NRC and by the Utility industry to resolve the USI A-46 issue (Seismic Qualification of Equipment in Older Operating Plants) indicates that many non-seismically designed equipment are seismically rugged and have significant inherent seismic capability.

The methodology presented can be utilized to evaluate those Category II source components which could potentially pose a risk to the safe shutdown of the plant or inhibit the safety related function of Category I components due to II/I concerns. This approach was developed and implemented at the Comanche Peak Steam Electric Station (CPSES) in Glen Rose, Texas. Comanche Peak is a 2 Unit 1150 MW Pressurized Water NTO8L Reactor with a Westinghouse supplied NSSS system. The II/I evaluation for CPSES included all Unit I areas and all areas which were common to both units.

METHODS

The methodology for addressing seismic II/I issues in a nuclear power plant involve four steps:

- Identify Category I Components
- Identify Potential II/I Interactions
- Evaluate Interactions
- Resolve Unacceptable Interactions (Design a Retrofit or Relocate the Source or the Target)

Every nuclear power plant is required to define their list of Category I components. Thus, the first step of identifying the Category I components can be easily completed by utilizing the existing Category I equipment list. The identification of potential II/I interactions should be generated by experienced personnel based on a careful walkthrough of all plant areas where Category I components are located. A "zone of influence" can be developed to provide the walkthrough team with a consistent basis for identifying conditions for which a Category II component poses a credible hazard to a proximate Category I component. A conservative zone of influence can be computed using equations for rigid body dynamics and the accelerations from the site floor response spectra.

The evaluation of potential seismic interactions involves the major part of the effort for the II/I program and is accomplished using three methods:
Experience Data

Dynamic Impact Assessment

Seismic Analysis

To maximize the programs efficiency, experience data was applied in almost all instances where its application could be justified. The dynamic impact criteria was applied in instances where a relatively small source is postulated to impact a larger and more ductile target, or when the interaction was judged not to be credible due to an intervening structural component. Seismic analysis should be applied in instances where the other two methods are not applicable, since analysis is typically more time consuming and more conservative than the other two alternatives.

Experience Data

EQE has developed a seismic experience data base under the sponsorship of the Seismic Qualification Utilities Group (SQUG) to resolve USI A-46. The data base contains an array of information relative to the performance of equipment components, piping and structures which have been subjected to strong motion earthquakes all over the world. Specific objectives in developing the seismic experience data base include:

- Documentation of all instances of seismic damage and/or failure in facilities that contain equipment similar to those in nuclear power plants. (The root cause of the damage/failure are a primary focus of all earthquake investigations.)
- Definition of the seismic motions (ground accelerations and floor accelerations) for the facilities within the data base.
- Identification of systems, equipment, structures and components that typically are not damaged even in severe earthquakes.
- Identification of minimum standards in equipment installations that will ensure the structural and functional integrity of the component when subjected to an earthquake (Note: the functional integrity was not required to be evaluated for the CPSES program since only non-seismic Category II components were evaluated for I/I effects).
- Generation of sufficient detail during earthquake investigations to demonstrate similarity between the data base component and the corresponding nuclear plant equipment.

The CPSES II/I seismic system interaction program developed structural integrity criteria for classes of Category II source components using the methodology generated by the SQUG Program to resolve USI A-46 relative to Category I safety related components. The application of seismic experience data has been approved by the USNRC and by the USNRC Advisory Committee on Reactor Safeguards. The USNRC has published NUREGs 1030 and 1211 "Seismic Qualification of Equipment in Operating Plants" which conclude that the seismic experience data approach is technically sound and provides the most reasonable approach to qualify existing equipment.

In order to utilize the data base evaluation approach in a I/I program, four conditions are required to be met:

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The seismic motion at each Category II source component location must be enveloped by the Experience Data Bounding Spectra (SQUG 1988).

The source component must fall within the bounding criteria for a given class of similar equipment which have survived strong motion earthquakes.

The anchorage of the equipment must be evaluated and shown to be rugged enough to survive the anticipated seismic environment. EPRI developed a realistic anchorage evaluation methodology which is being utilized in conjunction with experience data to resolve USI A-46, and this methodology was also used to evaluate the adequacy of anchorage for all Category II source components in the CPSES study (URS Corporation, 1987).

The equipment must satisfy a set of miscellaneous restrictions which verify the seismic structural integrity of the source component. These restrictions vary depending on the equipment class and the types of failures which have occurred to equipment in this class in past earthquakes. These restrictions are included to ensure the existence of a minimum level of seismic capacity. Examples of these restrictions include a requirement for positive attachments for all subcomponents and a requirement for establishing adequate flexibility for all attached piping, cables and ducting such that differential displacement does not cause damage to the component.

One of the key elements of the experience data base evaluation approach is that experienced engineers must conduct the evaluation during a thorough walkdown of the pertinent plant areas. These experienced engineers need to have considerable background in seismic design and analysis and in the performance of structures and equipment in actual earthquakes. Experienced engineers are required to ensure the postulation of credible seismic effects.

**Dynamic Impact Assessment**

The dynamic impact criteria address the situation where the Category II source is assumed to fall and impact the Category I target. Engineering judgement is required in the implementation of these criteria and, as stated above, should be done by engineers experienced in the areas of seismic stress analysis, failure/fragility analysis and in actual earthquake effects. The criteria used in this evaluation are listed below:

1. Targets of equal or larger diameter and thickness compared to the source are acceptable interactions (Applies to thick-walled vessels such as heat exchangers, piping, conduit, etc.).

2. Seismically designed intervening components such as structural members, support steel and/or other adequately supported components effectively shield the target from the source and would not permit contact.

3. The source cannot impact the target without striking an intervening component first, and would have insufficient momentum to damage the target.

4. The source cannot impact the target squarely and hence glances off causing no damage.
5. The source impacts the cable tray sides but will not affect the cables within the tray deleteriously.

6. The target component is sufficiently massive and/or ductile to resist damage from the source.

7. The impact, if any, is not considered to cause unacceptable damage because the target is 6" above the source.

Seismic Analysis

Seismic analysis methods were utilized to resolve interactions which were outside the bounds of the earthquake experience database and which could not be resolved using the dynamic impact criteria. These seismic analysis methods are essentially identical to the seismic qualification criteria utilized to qualify Category I components, except that the functionality of the Category II component is not required to be demonstrated. The seismic analysis techniques utilized in these evaluations generally consisted of a conservative equivalent static analysis but, when required, could also involve response spectrum analysis, time history analysis and finite element modelling.

Resolution of Unacceptable Interactions

Those sources which could not be resolved using any of the above three methods were either relocated or were redesigned. Hoists and their attached chains are an example of a group of sources which posed an unacceptable interaction concern due to the swinging effect that can occur during a seismic event. These hoists and chains were resolved by specifying a safe parking location removed from Category I equipment when they are not in use. Examples of sources which had to have some level of redesign in order to alleviate a potential II/I concern are the cabinet doors without positive latching mechanisms and the control room ceiling. Several instances existed at CPSES where cabinets without door latches (such as the fire hose stations) were in close proximity to safety related cabinets containing relays and sensitive switches. Cabinet doors of this configuration have opened and swung on their hinges during past earthquakes and pose an interaction risk for adjacent cabinets containing sensitive relays. The retrofit implemented was a 90 degree throw latch installed on all such cabinets to prevent the door from opening during the earthquake. The control room drop ceiling is also an example of an installation which has consistently proven to be damaged during past earthquakes. The ceiling at CPSES was redesigned to ensure that it could survive the site SSE.

RESULTS

The results of this study are documented in Table 1. The vast majority of those Category II sources which could be shown to be within the zone of influence of a Category I component were found to possess adequate seismic capacity based on earthquake experience data. The earthquake experience data base resolved approximately 1086 identified sources which represents 51% of the total evaluated. The dynamic impact criteria was used to resolve 563 sources or 26% of the total. Seismic analysis was used to resolve another 335 sources which represents 16% of the total. Only approximately 150 out of the 2134 sources were shown to require a retrofit, and many of these retrofits were only implemented because additional seismic analysis or testing would not have been as cost effective as the retrofit itself. For the interactions which were resolved using the dynamic impact assessment, criteria 6 which identifies the target to be more massive/ductile than the source was utilized 74% of the time. Criteria number 3 (intervening component) resolved 19% of the total number of sourced evaluated using the dynamic impact criteria.
CONCLUSIONS

The results of the CPSES II/I system interaction study demonstrate that very few credible system interaction concerns existed at the Unit 1 Comanche Peak Steam Electric Station and those relatively few instances could be corrected with minor retrofits. Category II commercial grade equipment installed using standard commercial installation procedures generally perform very well in actual earthquakes and do not pose a credible seismic interaction hazard. The program described in this paper presents a technically sound, expedient and cost effective method for evaluating these II/I interactions.

REFERENCES


Consumers Power Company (1983). System Interaction Program for Midland Units I and II.


Table 1: Evaluation Results

<table>
<thead>
<tr>
<th>Source Resolution Method</th>
<th>Number Resolved (% of Total)</th>
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</thead>
<tbody>
<tr>
<td>Experience Data Base</td>
<td>1086 (51%)</td>
</tr>
<tr>
<td>Dynamic Impact Criteria</td>
<td>563 (26%)</td>
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<tr>
<td>Seismic Analysis</td>
<td>335 (16%)</td>
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<tr>
<td>Relocation or Retrofit</td>
<td>150 (7%)</td>
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<tr>
<td>Total</td>
<td>2134</td>
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