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A Feasibility Assessment on the Use of Seismic Experience Data

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Abstract

Investigation of the performance of equipment in past earthquakes (seismic experience data) has recently gained some prominance in nuclear safety. In this paper we describe our assessment of the feasibility of using experience data to address nuclear seismic safety issues on seismic equipment qualification (EQ). Our assessment is performed by estimating how well experience data could address EQ requirements as embodied in U.S. NRC and U.S. national standards. This estimate is systematically performed by (1) evaluating both experience data and standards against a common set of thirty technical issues related to seismic EQ and (2) comparing the two evaluations.

1. Introduction

Recently, an underemphasized (by the U.S. technical community) area of earthquake investigation with important applications to nuclear safety has gained some prominance. This area is the investigation of the performance of equipment in past earthquakes (seismic experience data) in conventional facilities such as fossil fueled power plants, electrical substations, other electric stations, petrochemical plants, other manufacturing and process plants, and other heavy industrial facilities. Our motivation is the need to obtain a better understanding of the performance we should expect of equipment in nuclear power plants in future earthquakes. Few strong earthquakes have affected nuclear power plants in the past, and because of the relative sparseness of nuclear power plants, we should not expect this to change significantly in the future. Thus if we want to take advantage of the bulk of the available experience data, the implications of these data will have to be transferred from conventional to nuclear facilities. This transfer is not straightforward but there are four major reasons it should be performed:

- The equipment in conventional facilities is often quite similar to or even identical to that in nuclear facilities.

- We will look very foolish, if at some future time an earthquake causes an accident at a nuclear power plant, and if at that time our hindsight leads us to observe that the accident had analogues or precursers in the performance of conventional facilities, but we lacked the foresight to take advantage of these data in our efforts on nuclear safety.
- There is a large body of experience data that could be obtained, evaluated, and synthesized. These data have resulted from a number of earthquakes. That this data set is so large and varied means that we may have a highly credible opportunity to observe and avoid any potential future problems in nuclear facilities, and to observe whether or not EQ issues presently thought to be problems are manifested in data.

  These data should be carefully gathered and evaluated for use in seismic PRA (probabilistic risk assessment) and other nuclear seismic safety studies. All seismic PRA studies should then have a section that explicitly demonstrates that scenarios observed in the past are either captured by the methods used in the study or are eliminated by design features of the nuclear facility. This is one heretofore overlooked way to at least partially address the completeness issue in seismic PRAs, which is a known significant issue which affects the credibility of all PRAs.
- The credibility of experience data. Although the quality of experience data may not be as high as that of data from laboratory tests, its credibility is quite high. We are never completely sure that laboratory tests seek out weaknesses as well as natural events, especially as is usually the case in qualification practice, when the laboratory tests stop short of testing to incipient loss or loss of function or structural integrity.

Five recent efforts provide an initial focus on experience data, References [1] - [5]

In Nelson et al [1] detailed investigations are made of the effect of one earthquake on one power plant. Swan and Yanev [4] supplements Nelson et al [1] in that it provices additional information as well as data that corrects other information and judgements in Nelson et al [1]. Yanev and Swan [2] and Smith and Dong [3] are broader and began concurrently with the same objective: To establish more generally whether or not it is the same experience data on nuclear safety issues. After we began Smith and Dong [3], the NRC requested that we rely on Yanev and Swan [2] for data, and that we concentrate our efforts on a feasibility assessment. Nelson et al [1], Yanev and Swan [2], and Smith and Dong [3], and the NRC in Schroeder [5] concluded that it was feasible to use experience data on nuclear safety issues. The NRC's initial requirements and criteria are given in Schroeder [5]. These were based, at least in part, on Smith and Dong [3]. Here we call Yanev and Swan [2] "the SQUG report," as it was funded by the Seismic Qualification Utility Group.

The objective of our paper is to summarize the feasibility assessment we described in Smith and Dong [3], while at Lawrence Livermore National Laboratory.

2. Feasibility Assessment

We summarize our assessment of the feasibility of using experience data to address nuclear safety issues on seismic EQ in this section. Our approach is to develop an overall summary statement evaluating experience data and current seismic EQ requirements. We find it difficult to do this credibly in an overall manner, so we descretize our evaluation into component issues.

We attempt to reduce the bias inherent in any evaluation of this type. Both of these objectives are achieved by identifying component issues that could form a general framework for seismic EQ requirements without reference to, and without regard to the strengths and weaknesses of, experience data and current seismic EQ requirements.

We do this by identifying thirty component technical issues related to seismic EQ. Each issue is considered a "Category of Possible Seismic EQ Requirements and Criteria." That is, seismic EQ standards might be (but presently are not) formulated in terms of requirements and criteria that specifically address some subset of these thirty issues. We believe that these thirty issues comprise a reasonably complete set of the significant issues of this type. Each of the issues is ranked (from high to low the rankings are 3, 2, 1, 0) and a minimum set of 10 issues is identified. The thirty issues are identified in Table I and the minimum set of 10 are those with an importance ranking of 3. These issues and their rankings are discussed in Smith and Dong [3].

We perform our feasibility evaluation of experience data relative to applicable seismic EQ requiremetns for new plants extracted from 12 documents, which are considered most important in terms of seismic EQ:

- U.S. Nuclear Regulatory Commission, Standard Review Plan, Section 3.10, "Seismic and Dynamic Qualification of Mechanical and Electrical Equipment," NUREG-0800, Rev. 2, July 1981.
- U.S. Nuclear Regulatory Commission, Regulatory Guides:
  - o 1.40 - "Qualification Tests of Continuous-Duty Motors Installed Inside the Containment of Water-Cooled Nuclear Power Plants," March 16, 1973.
  - o 1.73 - "Qualification Tests of Electric Valve Operators Installed Inside the Containment of Nuclear Power Plants," January 1974.
  - o 1.100 - "Seismic Qualification of Electric Equipment for Nuclear Power Plants," Rev. 1, August 1977.
  - o 1.148 - "Functional Specification for Active Valve Assemblies in Systems Important to Safety in Nuclear Power Plants," March 1981.
- IEEE Standard for Type Tests of Continuous Duty Class 1E Motors for Nuclear Power Generating Stations, ANSI N41.9-1976, IEEE Std. 334-1974.
- IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations, ANSI/IEEE Std. 344-1975.

- IEEE Standard for Qualification of Safety-Related Valve Actuators, IEEE Std. 382-1980.
- IEEE Standard Seismic Testing of Relays, IEEE Std. 501-1978.
- IEEE Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations, IEEE Std. 649-1980.
- Self-Operated and Power-Operated Safety-Related Valves Functional Specification Standard, ANSI N278.1-1975.
- Functional Qualification Requirements for Power-Operated Active Valve Assemblies for Nuclear Power Plants, ANSI B16.41, Draft 3, Rev. II, June 1981.

We considered ranking each of these 12 standards separately but found it to be impractical. Our ranking of current requirements is thus in an overall sense.

The first part of our assessment consists of evaluating current U.S. NRC and U.S. national standards against this set of thirty issues. The second part consists of evaluating experience data against this same set of thirty issues. These evaluations used the rankings 3, 2, 1, 0 from high to low - see Table I. Our evaluation of current standards on the one hand and experience data on the other is summarized to single numbers for each as indicated in Table I. We find that these numbers or scores are about equal for both the total set of thirty issues and for the minimum set, as shown below:

	Current U.S. NRC NRC & U.S. National Standards	Experience Data
Thirty Issues	91 out of 156 (60%)	97 out of 156 (60%)
Minimum Set of 10	54 out of 90 (60%)	51 out of 90 (60%)

The 156 and 90 are the maximum possible scores - see Table I.

We interpret this finding to mean that experience data has the potential to provide assurance of seismic EQ to about the same degree as current seismic EQ requirements; that is: It is feasible to use experience data for seismic EQ of equipment in nuclear power plants.

3. Conclusions

This paper is written from the perspective of a relatively early assessment of seismic experience data. Since that time the appreciation of the value of seismic experience data has grown as indicated in Anderson [6] and by other papers at this conference. The scope of areas where experience data has been collected has also grown beyond equipment: We now also have data on piping systems, horizontal tanks, turbo-generators, anchorages, ceilings, architectural features, cranes, other equipment classes, structures and conduit.

In this light it is logical to step back and try to obtain some overall insight on the phenomena of seismic experience data. The following are my observations on the subject.

Seismic experience data have in large part been responsible for the initiation of a major re-thinking on how best to achieve seismic safety in nuclear practice and a re-examination of current seismic safety practice. For example: Is routine seismic qualification using shaker tables required for items of equipment that are only slightly modified relative to equipment for which considerable positive experience or test data exists?

Seismic experience data provide a means to place many nuclear safety issues in the perspective of the cold light of whether they are safety issues that can be conceived of but have never or only rarely been observed to occur.

The gathering and evaluation of seismic experience data is in the best engineering traditon of providing a "feedback loop" of field performance for assessment in setting more rational design requirements and criteria.

Seismic experience data points out the limitations of dynamic analysis as a significant contributor to good seismic design practice.

Seismic experience data points the way to develop design requirements and criteria that are more closely related to performance criteria.

Finally, as noted in Smith and Dong [3], IEEE 344-1975 accepts experience data as an alternate means of qualification through acceptance of operating experience. In addtion, the use of experience data for qualification is entirely consistent with the spirit of qualification through similarity discussed in Sections 7.3 and 7.4 of IEEE 344-1975.

References

/1/ NELSON, T.A, R.C. MURRAY, R.D. CAMBELL, J.A. YOUNG, H.A. LEVIN, J.A. MARTIORI, L. REITER, Equipment Response of the El Centro Steam Plant During the October 15, 1979 Imperial Valley Earthquake, Lawrence Livermore National Laboratory, Livermore, CA UCRL-53005 (also published by the U.S. Nuclear Regulatory Commission, NUREG/CR-1655), October 1980.

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/5/ December 28, 1982, letter from F. Schroeder (NRC) to N. Smith (Chairman, Seismic Qualification Utility Group).

/6/ ANDERSON N., USI A-46, Seismic Qualification of Equipment in Operating Plants, NRC/EPRI Workshop on Nuclear Power Plant Re-Evaluation for Earthquakes Larger Than SSE, October 15-17, 1984.

Table I. Summary of feasibility evaluation.

(1) Category	(2) Importance ranking	(3) Current require. ranking	(4) Product (2)x(3)	(5) Experience data ranking	(6) Product (2)x(5)
1. Sampling	3	1	3	2	6
2. Similarity	3	1	3	2	6
3. Mounting simulation	2	2	4	3	6
4. Peripheral attachments	2	2	4	3	6
5. Dummy components	2	2	4	3	6
6. Generic loads	0	-	-	-	-
7. Enveloping load assumption	1	2	2	2	2
8. Required design load	3	2	6	1	3
9. Margin	3	1	3	2	6
10. Tolerances	0	-	-	-	-
11. Single vs. multi-axis testing	3	2	6	2	6
12. Wave form	3	3	9	2	6
13. Fatigue	1	3	3	1	3
14. Fragility	3	1	3	1	3
15. Failures	3	1	3	1	3
16. Functional requirements	3	3	9	2	6
17. Critical parameters	1	1	1	0	0
18. Degradation under test	1	0	0	3	3
19. Response	1	-	0	-	0
20. Unexpected results	1	-	0	-	0
21. Load combination	2	3	6	2	4
22. Load sequencing	2	3	6	2	4
23. Errors	1	0	0	2	2
24. Maintenance	1	0	0	2	2
25. Mounting adequacy	3	3	9	2	6
26. Post earthquake	1	2	2	1	1
27. Value/impact	0	-	-	-	-
28. EQ by analysis	1	3	3	3	3
29. EQ by testing and analysis	1	1	1	1	1
30. In-Situ testing	1	1	1	3	3
Totals	52		91		97

Maximum possible score is 156 (52 x 3).

(1) This is the list of the thirty technical issues against which current EQ requirements and experience data are evaluated.

(2) This is the importance ranking of each of the thirty issues. A zero ranking indicates issues that might be addressed in standards that are not relevant to our evaluation here--see Smith and Dong [3].

(3) and (5) This is the ranking of current EQ requirements and experience data respectively. A "-" indicates that ranking is not relevant to our evaluation here--see Smith and Dong [3].