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A case study of the amplification factor for a tested device of Nuclear Power Plant

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1. Introduction

In general, the cabinets might include seismic sensitive devices (e.g., relays or contactors). In order to verify relay chattering, the functionality during or after an earthquake must be qualified through the shaking table test. The methodology presented in the EPRI report TR-103959[1] or NP-6041[2] is provide the capacity equation for the function during earthquake or the function after earthquake.

The equipment response and capacity variables for the fragility computations based on the dynamic testing includes the cabinet-based test and the device-based test. The cabinet-based test data uses the measured response values at the bottom of the cabinet. In contrast to the cabinet-based test, the device-based test are required if the individual electrical components, such as relays are the source of the test data.

This study shows the conservatism of the cabinet amplification factor (AF_C) presented in EPRI report Methodology for Developing Seismic Fragilities (TR-103959) [1] in the seismic fragility analysis of the tested device.

2. Methods and Seismic fragility analysis

2.1 Seismic Fragility Methodology for Equipment based on Testing

The seismic fragility of electrical cabinet during the test seismic verification uses the methodology given in EPRI report [1]

$$A_m = \frac{TRS_C}{RRS_C} * F_D * F_{RS} * PGA$$

<u>Cabinet-Based Test Data</u>
$TRS_C = TRS * C_T * C_I$
$RRS_C = RRS * C_C * D_R$

<u>Device-Based Test Data</u>
$TRS_C = TRS * C_T * C_I$
$RRS_C = RRS * C_C * AF_C/F_{MS} * D_R$

Where,
A_m : Ground Acceleration Capacity
TRS : Test Response Spectra
RRS : Required Response Spectra
C_C : Clipping Factor for Narrow-banded Demand
C_T : Clipping Factor for Narrow-banded TRS
C_I : Capacity Increase Factor
D_R : Demand Reduction Factor
AF_C : Cabinet Amplification Factor (Clipped)
F_{MS} : Multi-axis to Single-axis Conservatism Factor
F_D : Broad Frequency Input Spectrum Device Capacity Factor
F_{RS} : Response Factor for Building (Structure)
PGA : Reference Earthquake peak Ground Acceleration (or other ground motion parameter)

The differences between the equation for the cabinet-based and the device-based test data is found in the TRS_C and RRS_C terms. In the case of cabinet-based test data the TRS_C is the response spectrum corresponding to the test of the entire cabinet which may contain devices. In general, TRS are broad-band in shape and do not require clipping, and the TRS times C_I is equal to the TRS_C. Usually cabinet tests are conducted using broad-band. However, there may be cases where a narrow-band input, such as a series of sine-beat or sine-dwell tests, was used to cover the frequency band of interest. For these situations the TRS will require clipping.

Table I shown below is the Median amplification factor for each type of cabinet provided in the EPRI report[1]. The HCLF shown in the Table I is the for the amplification factor and is used as comparison indicator of the case analysis results in chapter 2.2.

Panels or buckets within motor control centers (MCC) upon which relays or other elements might be mounted tend to be rather small in size and are well attached to the MCC cabinet so that the panel amplification might be very lower than in the flexible cabinet.

Switchgear have large unbraced sheet metal surfaces for which the amplifications are relatively higher than in the rugged cabinet.

The electrical benchboards and panels associated with main control boards have reasonably stiffly supported panels of moderate unbraced spans located within stiff cabinets so that neither cabinet frequencies nor local panel mode frequencies are likely to be less than about 13Hz. For theses case the AF_C values for the benchboard and panels in Table I can be used

Table Ⅰ. Cabinet Amplification Factor, AF_C

Cabinet Type	Median	β_R	β_U	HCLPF
Motor Control Center	2.8	0.10	0.23	1.62
Switchgear (flexible panels)	4.4	0.13	0.37	1.93

Benchboards and Panels (with frequency ≥13Hz)	3.3	0.11	0.27	1.76

2.2 Comparison of cabinet amplification factor and In-equipment Response Spectra in a device of seismic fragility analysis

This chpater uses the methodology presented in chapter 2.1 to compare the cabinet amplification factor between the ratio IERS(In-Equipment Response Spectra), and the response spectra at a device location in a cabinet, and RRS(Required Response Spectra). In case of the Control Panel, which is nomally installed at the nuclear power plant, and the main assumptions are :

<u>Benchboards and Panel (Case 1,2)</u>

- Device-based shaking table test
- Located at the top of the structure
- 5% damping
- Failure mode : Founction during earthquake(relay chattering)

The IERS presented above is derived from a FEM(Finite Element Model) analysis, a response spectrum that can include the FRS of the Nuclear Power Plant.

In accordance with IEEE-323[3], RRS is regenerated by adding at least 10% of margins to account for the uncertainty of FRS(Floor Response Spectra).

In general IERS envelope RRS and are shown in Fig. 1,2.

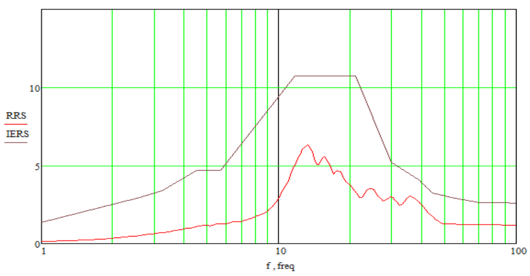

Fig. 1. RRS vs IERS (Case 1)

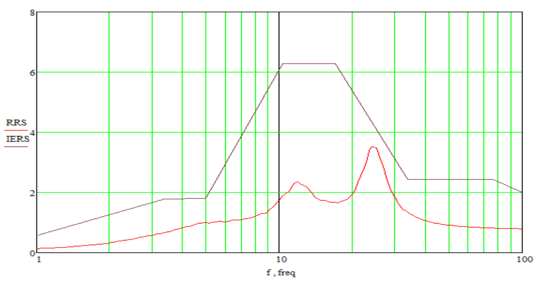

Fig. 2. RRS vs IERS (Case 2)

Considering the RRS with amplification factor, it tends to be larger than IERS, in some cases IERS are larger.

Table Ⅱ shows that the average of the RRS with AF_C and IERS ratios over 3.5Hz. The mean of case 1 and 2 are 1.38 and 1.32 and, respectively the standard deviation are alos 0.46 and 0.36, respectively.

Table Ⅱ. Comparison of cabinet amplification and IERS

	Case 1	Case 2
Mean of $\frac{RRS_{AFc}}{IERS}$	1.38	1.32
Starndard Deviation of $\frac{RRS_{AFc}}{IERS}$	0.46	0.36

Table Ⅲ shows the HCLPF ratio of benchboards presented in th EPRI report[1] and cases(HCLPF for the mean of the RRS with AF_C and IERS given in Table Ⅱ). Each ratio is 2.75, 2.42 which shows an additional margin of 175% and 142% when the amplification presented in the EPRI report[1] is applied.

Table Ⅲ. The comparision of the amplification between Benchboards & Panels(EPRI report) and case

	Case 1	Case 2
HCLPF	0.64	0.73
Ratio	2.75	2.42

3. Conclusions

In general, seismic fragility analysis for a device is performed using the cabinet-based test data. When using the cabinet-based test data, detailed seismic fragility analysis of a particular device cannot be performed because the real response spectra at the device location is unknown.

As shown in the case above, using the AF_C provided in Table Ⅰ, the seismic fragility analysis results are conservative. Therefore, for device detail analysis, IERS at the location of a device mounted in the cabinet is reproduced to perform the seismic fragility analysis.

Further study is needed to ensure that margin of EPRI report [1] through further case studies.

REFERENCES

[1] Electric Power Research Institute (EPRI), “Methodology for Developing Seismic Fragilities”, EPRI TR-103959, Final Report. June 1994

[2] Electric Power Research Institute, “A Methodology for Assessment of Nuclear Power Plant Seismic Margin (Revision 1)”, EPRI NP-6041-SL, Final Report, August 1991

[3] The Institute of Electrical and Electronics Engineers, Inc., “IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations”, IEEE std. 323, January 2004