Study On the Seismic Fragility Assessment of Interconnected Electrical Cabinets

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1. Introduction

Electrical Cabinet in Nuclear Power Plant

- Seismic qualification of the safety related components in NPP.

- Analysis of a single cabinet comparative to interconnected cabinets.

- Dynamic characteristic of a single cabinet cannot be extrapolated to the interconnected cabinets IEEE-693.

- Cabinets may have different dynamic characteristics.

3. Purpose of the study

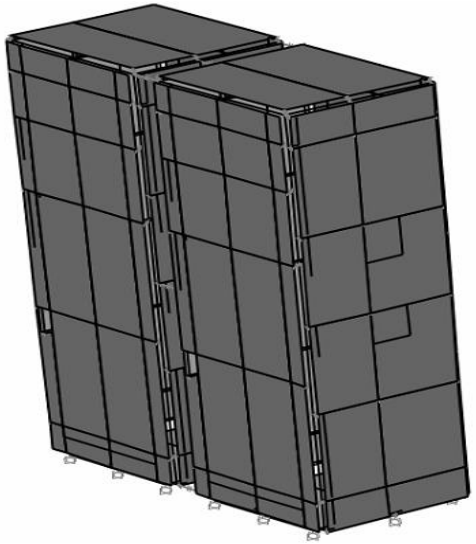
Grouping Effect of Electrical Cabinets

❖ Dynamics characteristic of cabinet considering the grouping effect

❖ Numerical consideration for the seismic analysis

❖ Effect on the Seismic Capacity Evaluation

<Godno et al 2012>

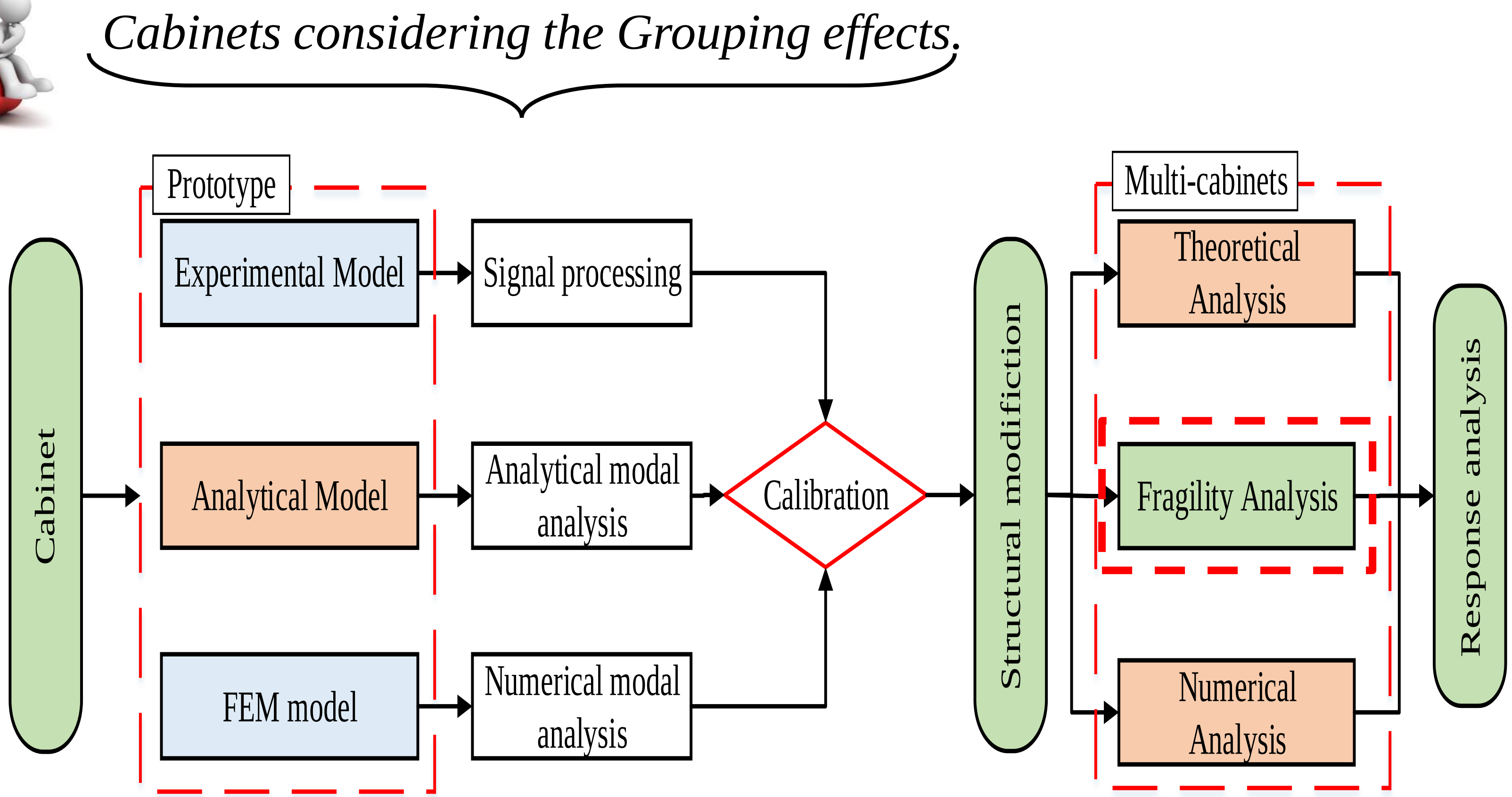


2. Scope of the Work

- ❖ Construct an analytical model for a single cabinet based on the experimental model.
- ❖ Construct analytical model for the interconnected cabinets
- ❖ Review on the modal characteristics of the cabinets
- ❖ Compute the seismic response and compare the seismic capacity of the cabinets

<Goodno et al 2011>

3. Methodology



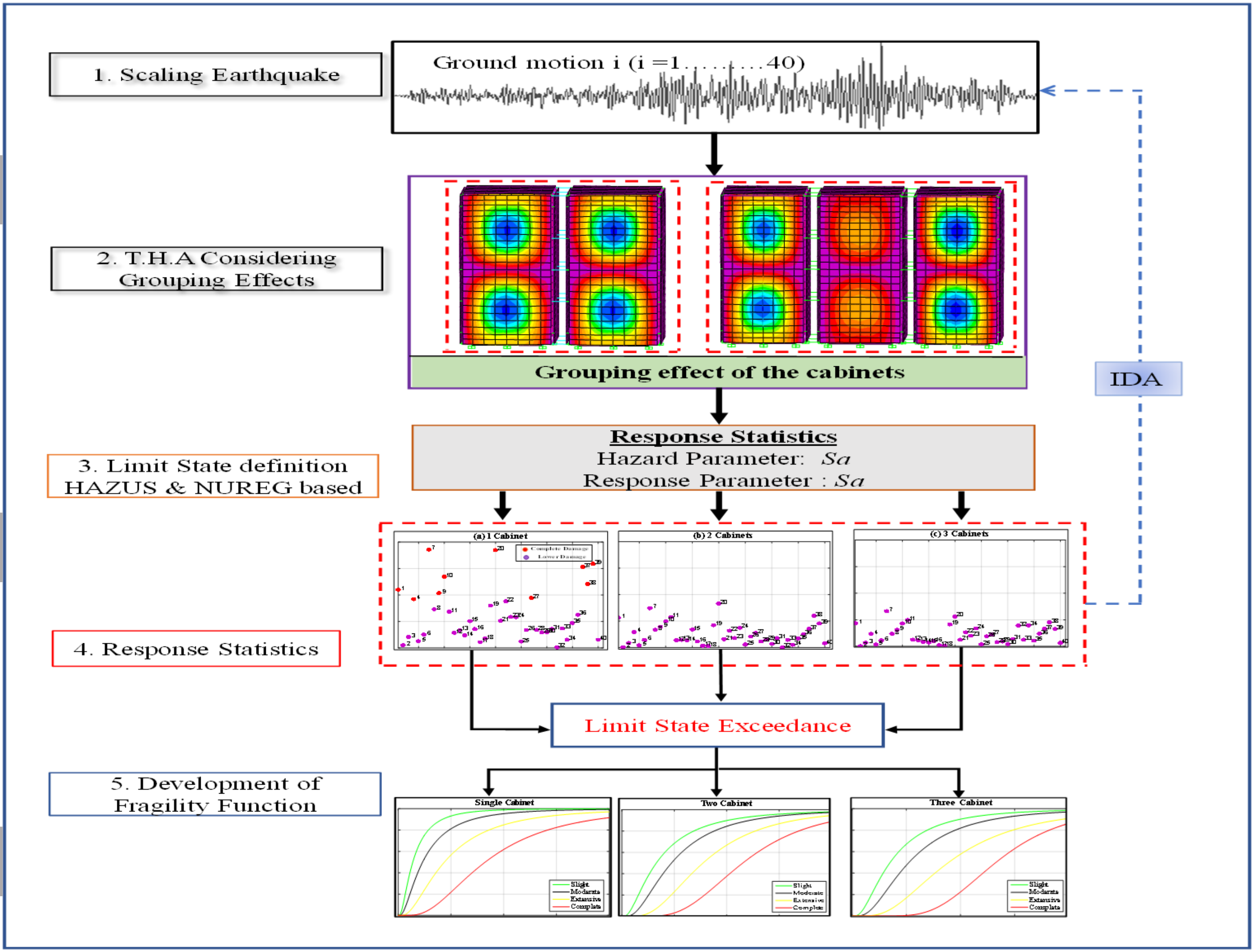
<Assessment of the seismic response due to grouping effect>

3. Methodology

Step 1

Step 2

Step 3

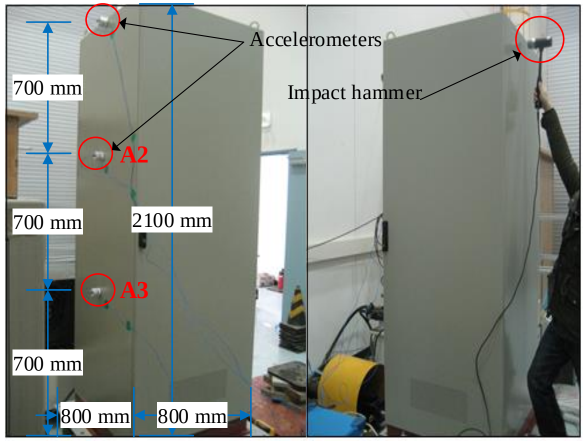


<Schematic Procedure for the fragility analysis >

4. Modal Identification

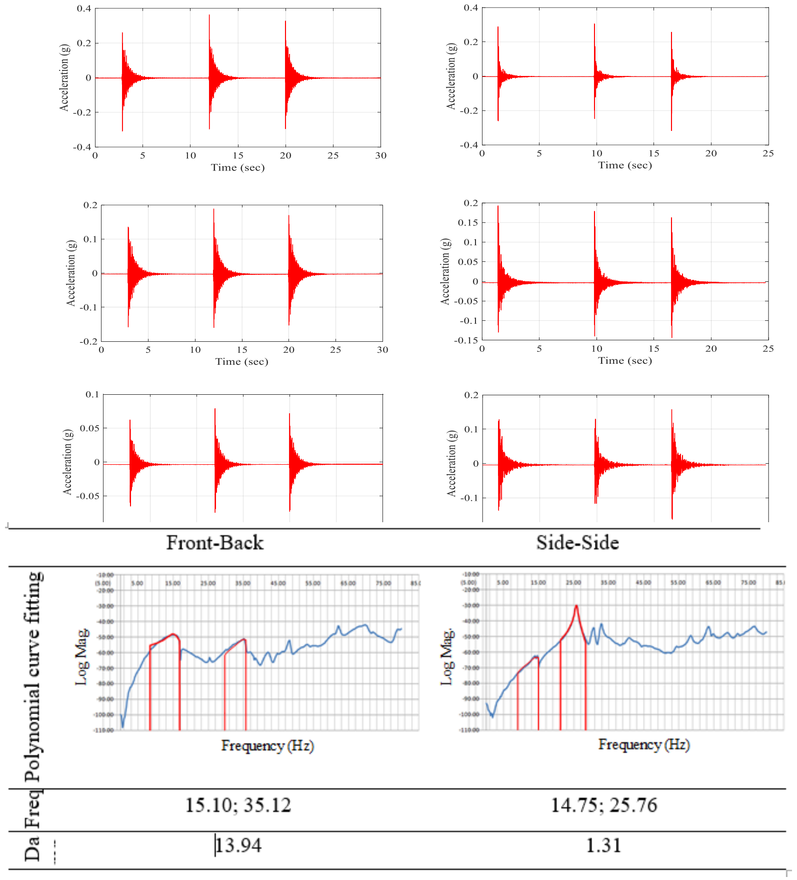
Modal properties of a single cabinets

Experimental Setup



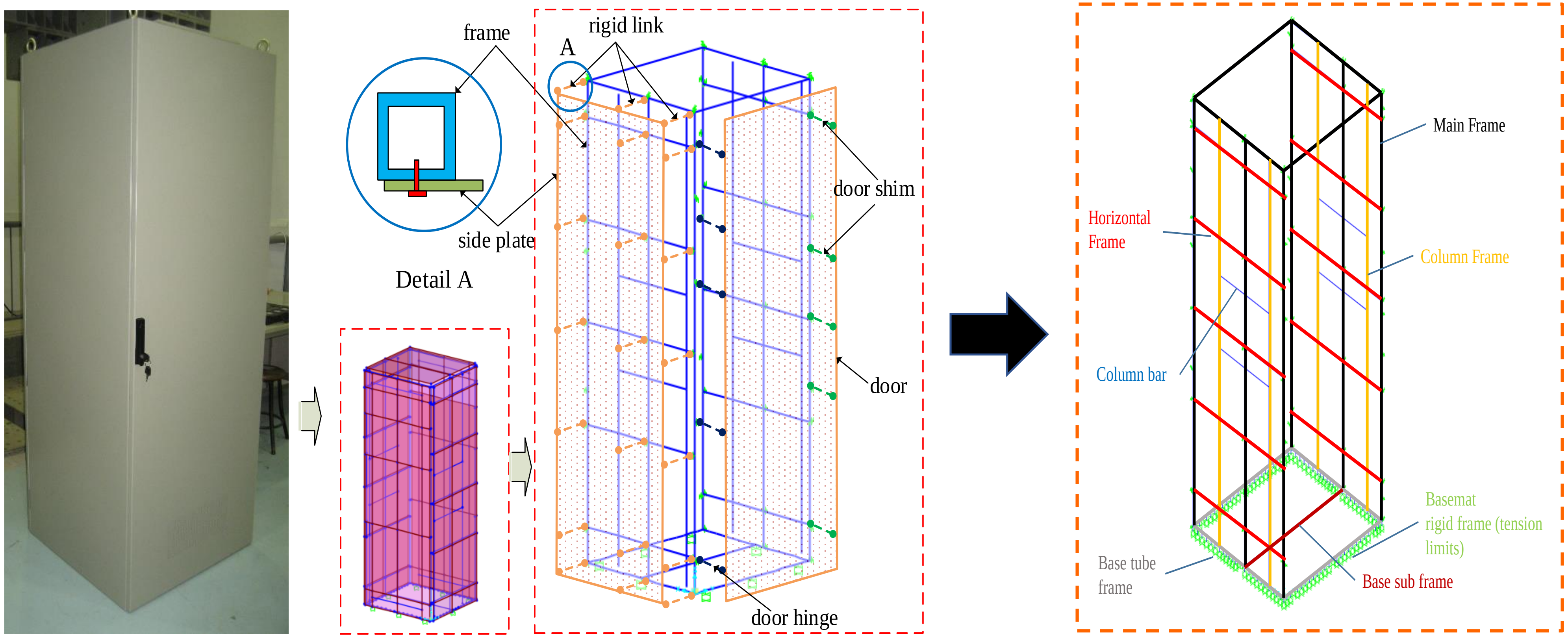
<Dimension and accelerometers setup>

Experimental Results



<Transfer functions >

Modeling of a single cabinets



<Numerical detailing of the cabinet>

5. Modal Properties

Validation of the FE model

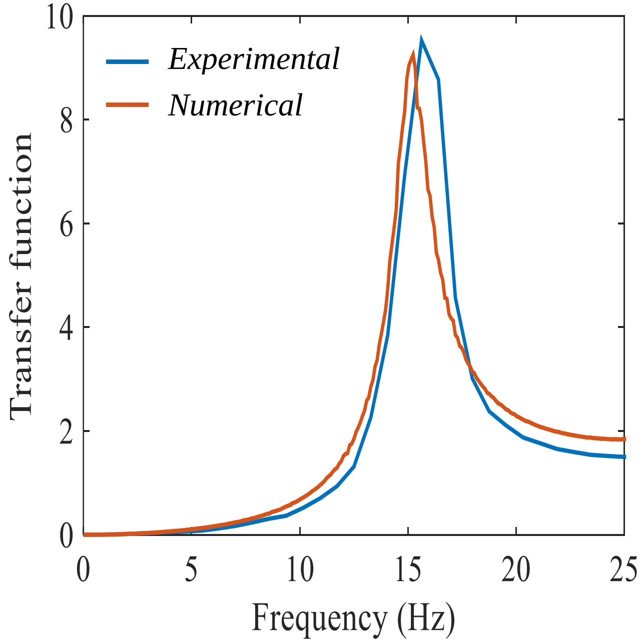


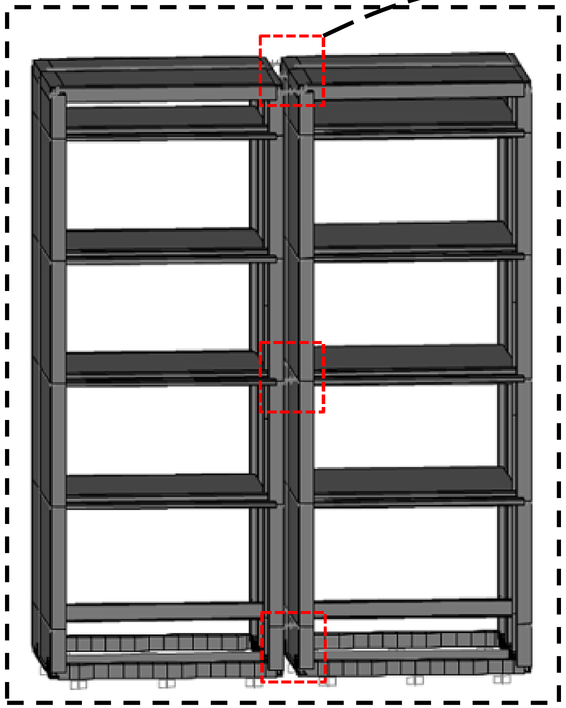
Table I. Natural frequencies (Hz) of the electrical cabinet

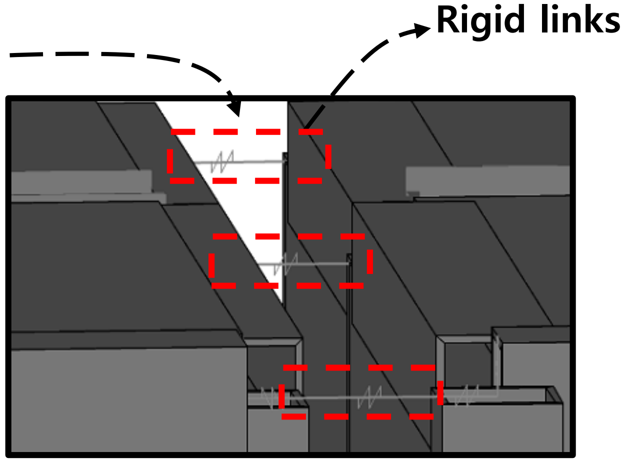
Direction	Mode	Test	FEM
Front-Back	1	15.10	14.08
	2	35.12	31.02
Side-to-Side	1	14.75	14.17
	2	25.76	28.98

<Correlation between Numerical and Experimental analysis >

4. Finite Element Modelling

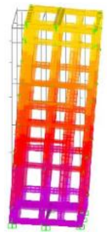
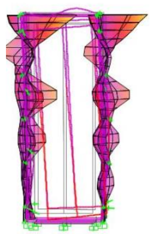
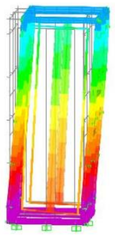
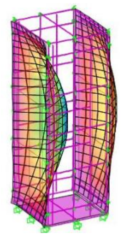
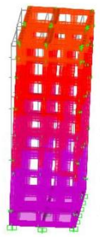
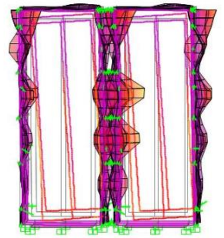
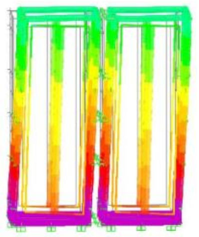
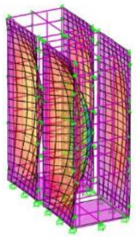
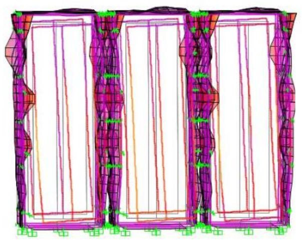
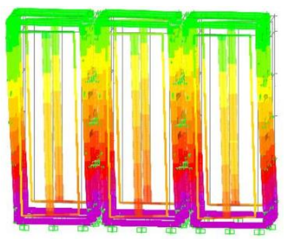
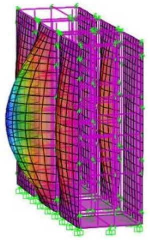
Interconnected Cabinets (Grouping effect)





Rigid links were assigned as boundary condition between the cabinets and will not induce any effect of the dynamics of cabinets.

<Interconnected Electrical Cabinets>

No.	X direction		Y direction	
	1st mode	2nd mode	1st mode	2nd mode
1 Cabinet				
2 Cabinets				
3 Cabinets				

<Significant modes of vibration>

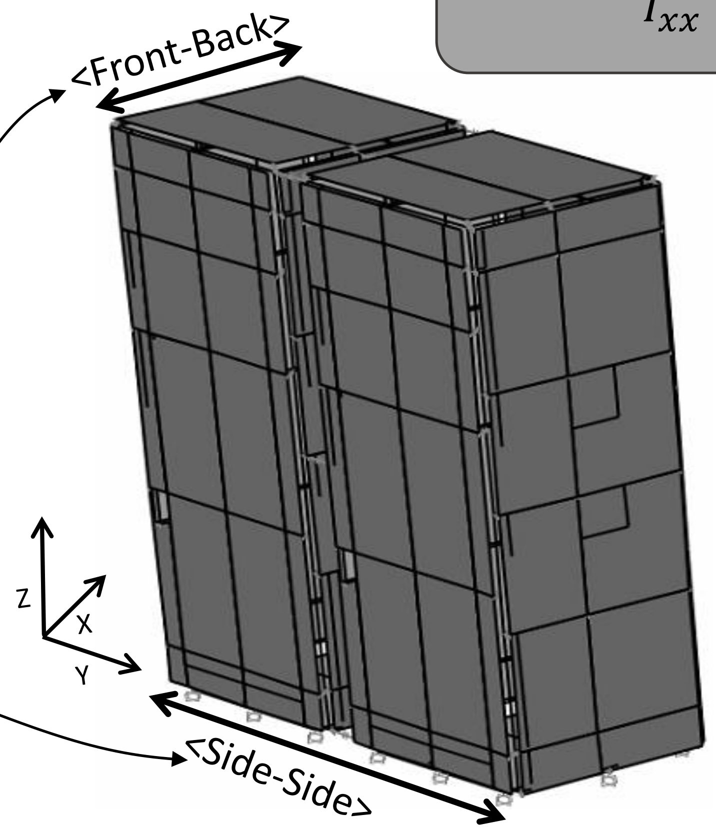
5. Modal Properties

- Grouping effect changes the natural frequency of the cabinets
- Stiffness Increases due to the number of cabinets

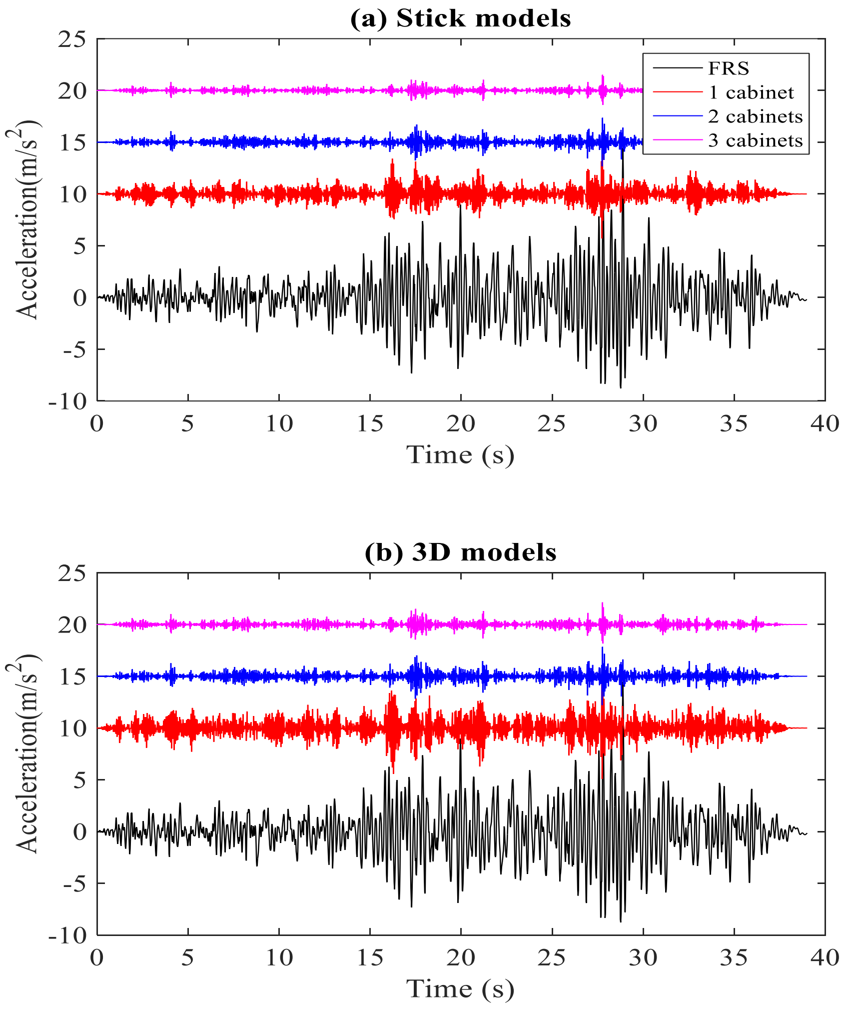
Differecne in Inertia
$I_{xx} < I_{yy}$

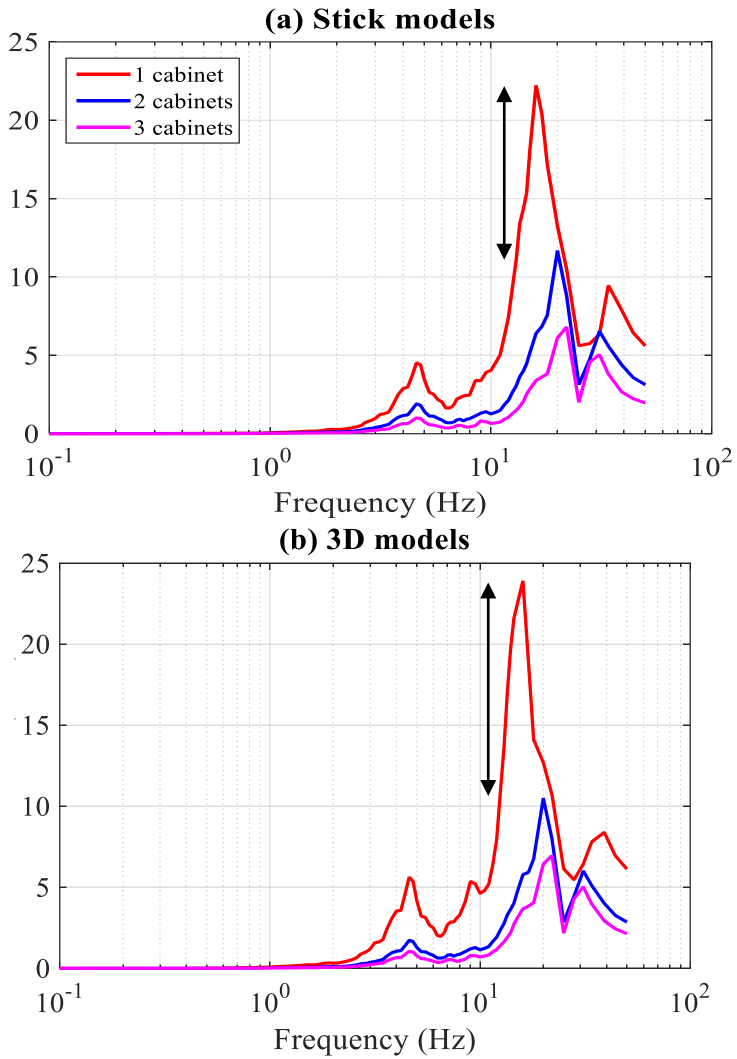
Table 1 Natural frequency and grouping effect

	Frequency (Hz)		
No	1-Cabinet	2-Cabinet	3-Cabinet
Front-Back	14.55	15.24	15.76
Side-Side	15.12	20.15	21.61

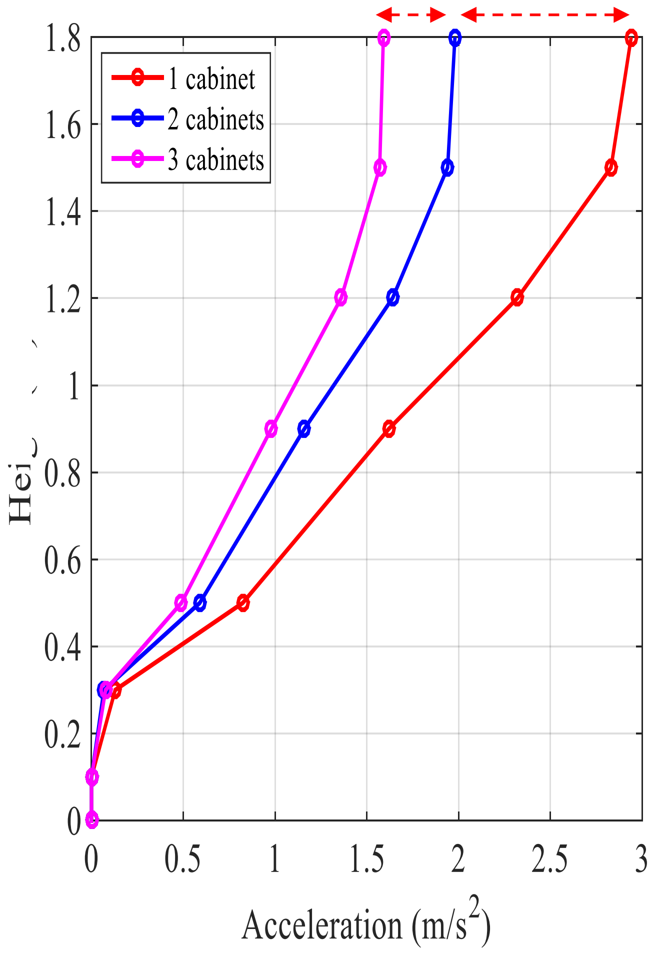


5. Effect on the Seismic Response





<Acceleration response>

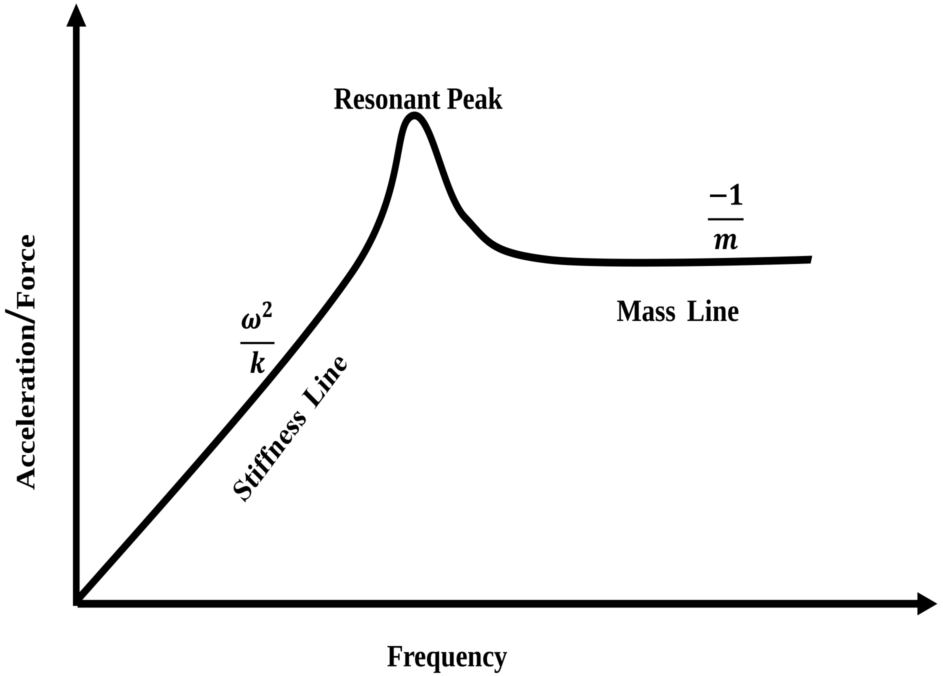


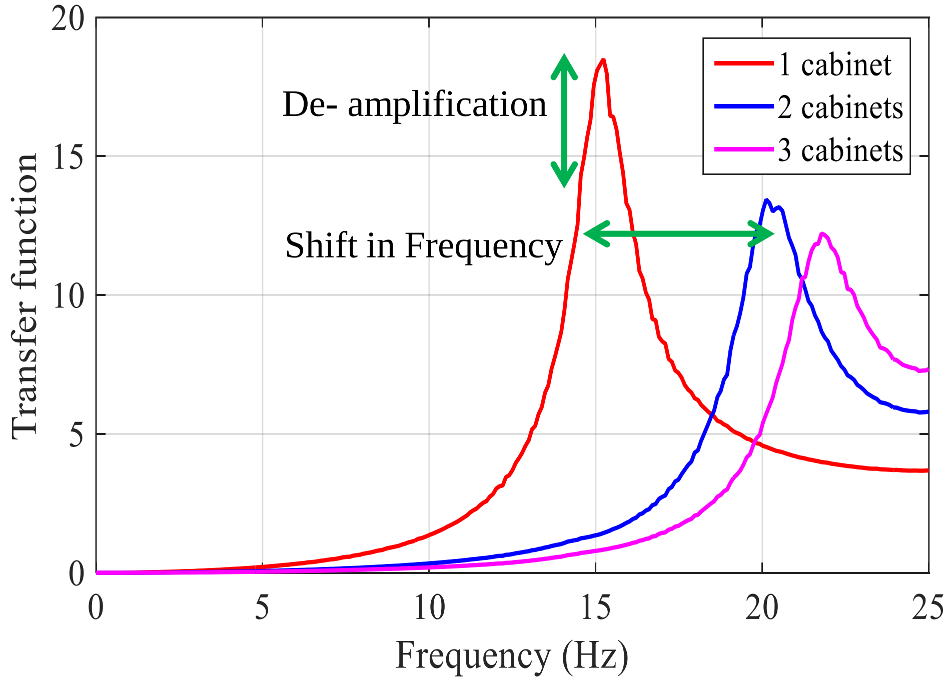
<Response at discrete points>

5. Seismic response

❖ Resonant peak is controlled by the stiffness of the system (ω^2/k) (Stiffness line)

❖ After the resonance, the inertance $(-1/m)$ of a mode explains the properties of the peak response (mass line).





<Frequency response>

5. Seismic Fragility Assessment

Analytical Method

$$Fragility = P[LS \leq D|IM]$$

$$P(DS|IM) = \Phi\left[\frac{1}{\beta}\ln\left(\frac{IM}{\theta}\right)\right]$$

Φ is the standard normal cumulative distribution function (CDF).

$$Likelihood = \prod_{i=1}^{m}\left[P(DS|S_{\bar{a},i})\right]^{p_i}\left[1 - P(DS|S_{\bar{a},i})\right]^{1-p_i}$$

m is the number of Sa levels and Π denotes of the product over all levels

$$\{\hat{\theta}, \hat{\beta}\} = \underset{\theta,\beta}{\arg\max}\ \ln(Likelihood)$$

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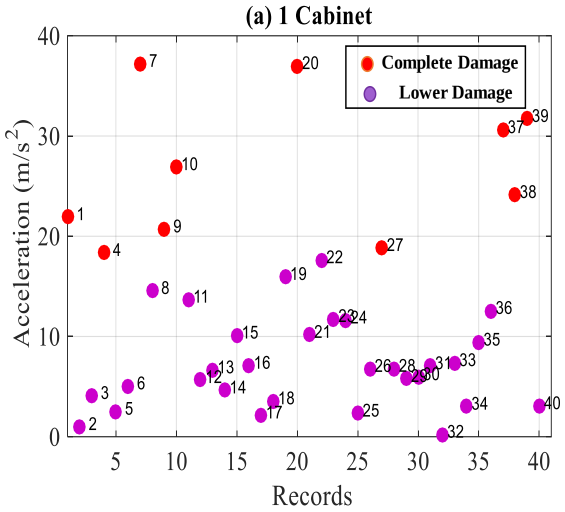
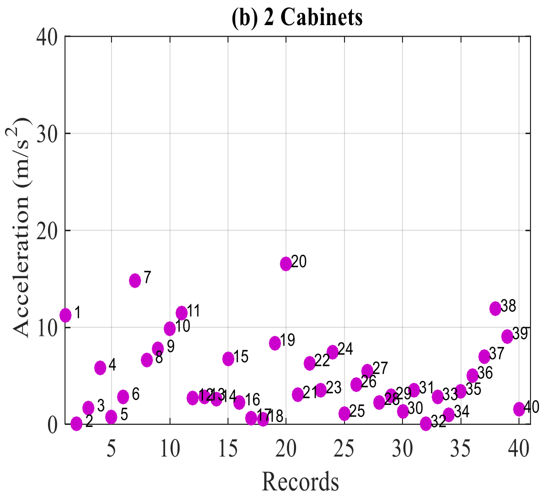
5. Fragility Assessment

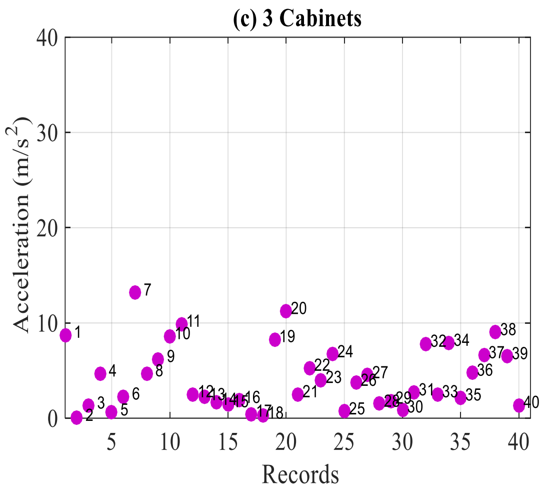
NUREG and HAZUS Based Assessment

NUREG

Acc Threshold
LS1=1.8g
LS2 < 1.8g

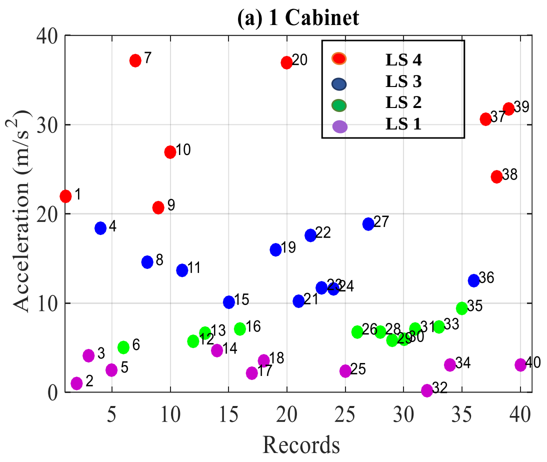


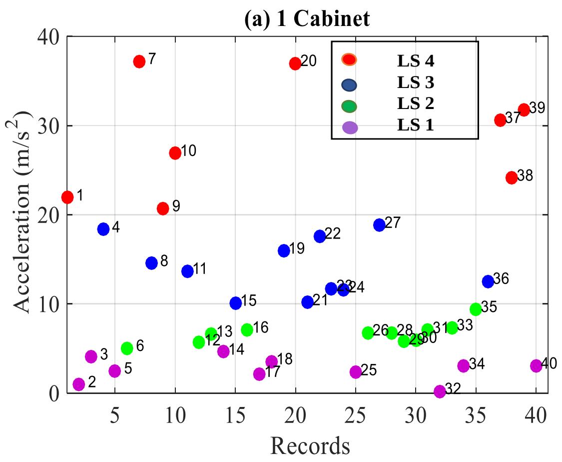


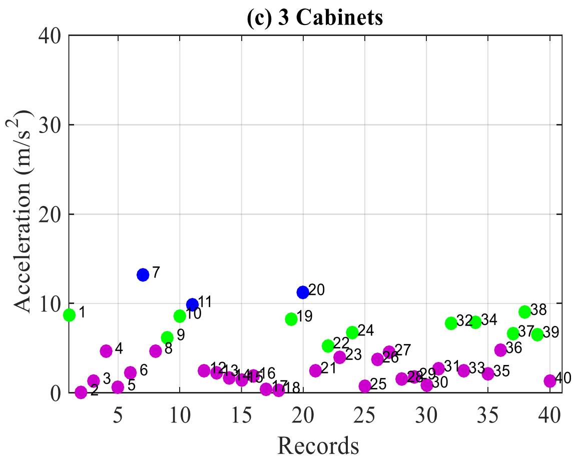


HAZUS

Acc Threshold
LS1=0.25g
LS2= 1g
LS3= 1.25
LS4 = 2g

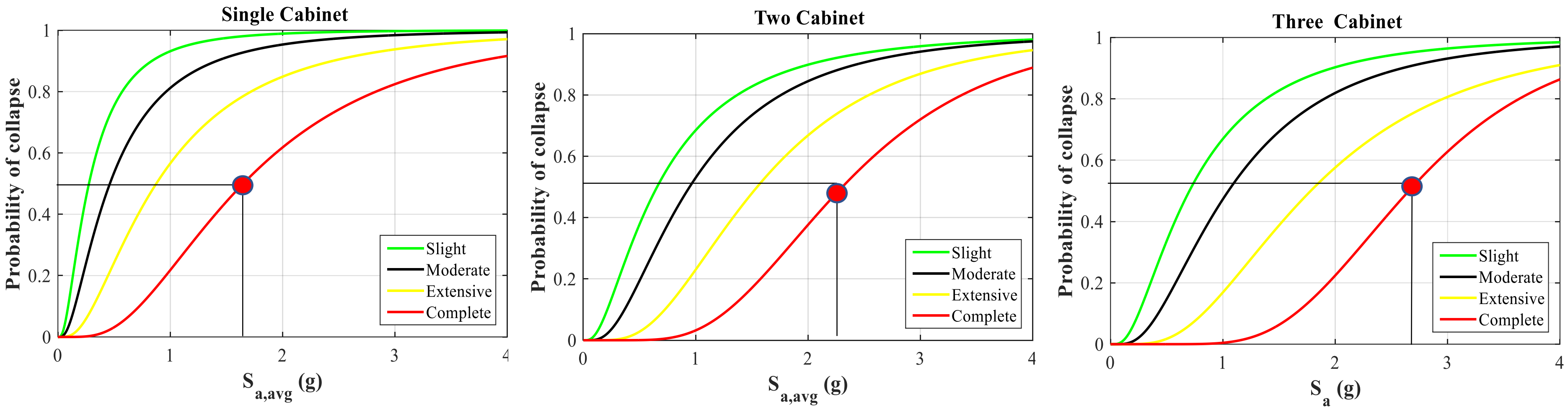






5. Seismic Fragility Assessment

HAZUS Based Curves



Case	One-Cabinet				Two-Cabinets				Three-Cabinets			
Damage	S	M	E	C	S	M	E	C	S	M	E	C
Acc. (g)	0.23	0.48	0.91	1.9	0.50	1.09	1.84	2.42	0.70	1.18	1.91	2.83

* S, M, E, C represents slight, moderate, extensive and complete damage.

<Acceleration Threshold form This Study and HAZUS>

5. Seismic Fragility Assessment

NUREG Based Curves

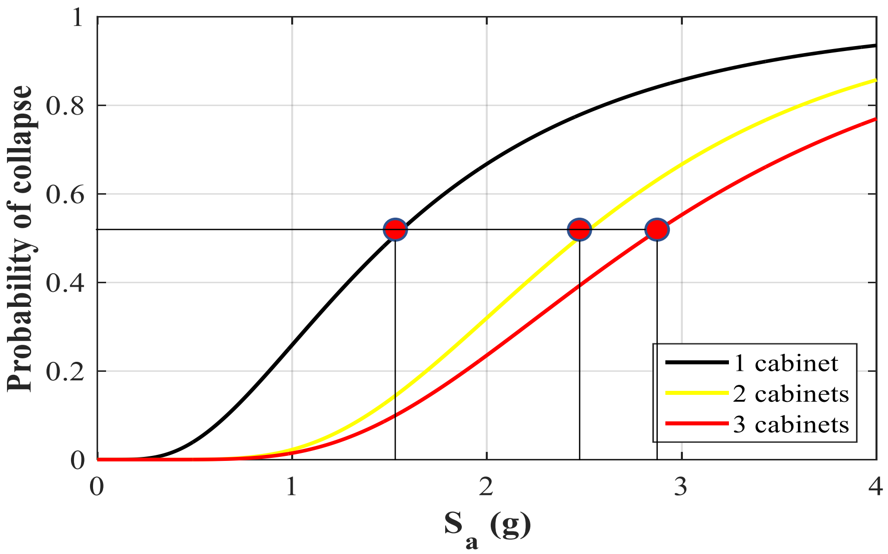


Table 3. Acceleration threshold for cabinets

Case	One-Cabinet		Two-Cabinets		Three-Cabinets	
	θ	β	θ	β	θ	β
Acc. (g)	1.861	0.66	2.4	0.45	2.8	0.41

<Acceleration Threshold form This Study and NUREG>

6. Conclusion

- Grouping effects of the cabinet is proved to be an important parameters for the analysis of electrical cabinet.
- Grouping effect of cabinet can reduce the uncertainty in the seismic response rather to extrapolate the dynamics characteristic of a single cabinet.
- Levels of seismic intensity and difference in the probability of sustaining damage for a group and a single cabinet varies about 50% and this extends up to 70% for more cabinets.
- This dramatic change in the fragility function can be corresponds to the structural dynamic modification of the cabinet system and support boundary condition.

THANK YOU!