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Study on the Effect of interconnected Cabinet Assembly on the In-Cabinet Response

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1. Introduction

Electrical equipment should be seismically qualified to ensure the safe operation of the nuclear power plant (NPP). In-cabinet response spectra (ICRS) is generated prior to the seismic qualification test for the internal components, however, the ICRS are significantly governed by the number of factors that include 1) loaded and unloaded condition, 2) the number of the interconnected cabinets (grouping effects) and 3) the incoherency in the seismic inputs.

The seismic response using finite element (FE) analysis manifests 1) natural frequency of the cabinet is reduced due to the in-cabinet components while due to the grouping effects the frequency increases significantly, 2) the contents of seismic inputs in the lower frequency range, a consistent reduction in ICRS was recorded due to the grouping effect while it was significantly amplified due to the high-frequency pulses. Using the Grouping effects of the equipment, a significant amplification under the high-frequency ground motion was observed. Numerical analysis is used to demonstrate these effects therefore this study does not represent the real scenario of cabinets in NPP.

2. Numerical study on ICRS

In this section, the ICRS is computed and reviewed based on the grouping effect and ground motion parameters. A numerical analysis of the cabinet models is performed to demonstrate the effect on the ICRS generation.

2.1 Purpose of the study

The generation of ICRS is one of the important tasks in the seismic qualification of the equipment, which mainly includes the safety-related cabinet. Some of the uncertainties that may affect the ICRS include the loading of the internal components and the grouping effect of the cabinets under the seismic excitation. As mentioned in a standard [1], the dynamics characteristic of a single cabinet cannot be extrapolated to the cabinet assembly. As in the current literature, most cabinets are analyzed without the internal equipment and a standalone cabinet. Some previous studies [2,3] have significant research on the seismic analysis of the internal equipment using the simplified model techniques, linear and non-linear analysis for generating the maximum ICRS. Cho et al. [4] studied the amplification of the ICRS in the cabinets using the in-situ testing.

As investigated by a previous study [5], a group of the cabinets without the internal components and devices reduces the amplitude of ICRS while for the loaded cabinets, the ICRS results show no potential difference for a single cabinet but a noticeable alteration for the number of cabinets.

Another aspect is the seismic response of the cabinets that are highly influenced by the input ground motion, so to evaluate this cause a set of ground motion was selected ranging from low to high frequency including the Gyeongju earthquake and scaled to 0.5g for the peak ground acceleration (PGA).

2.2 *Cabinet Model*

The cabinet prototype was modeled in the SAP2000 environment with the help of detail drawing and material specification. A cabinet consists of different members like main-frame, front and back door panels, side panels, column frame, and base subframe, etc. These elements are connected by bolts or threaded connectors, in which one side door is connected via door shim and the other side using a hinge which allow the rotation of the door in the opening.

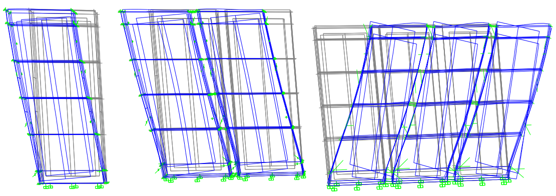

Fig. 1. FE Models of cabinets for the comparative analysis

Fig. 1 depicts the analytical models of the cabinets. The model was constructed to extract the natural frequencies of the cabinet considering the maximum mass participation ratio for the governing modes. Following the experimental analysis, three different models were generated for the loading condition to check the influence of the internal equipment on the dynamic characteristics of the cabinet. The cabinet model consists of plate and beam elements. A rigid link was assigned to the connecting points to represent that the side plates are primarily welded to the main frame and the connecting bolt penetrates. All the translational degrees of freedom are restrained as per the experimental test setup.

The experimentally validated model of a single cabinet was used to study the effect of interconnected cabinets on the ICRS generation. It was assumed that the cabinets have the same loading condition. As the cabinets are bolted with one another, the grouping effect of the cabinet in the FEM was considered by linking the cabinets together with a rigid link. The rigid links were used to combine the cabinet as one unit and not to induce any changes on the dynamic characteristics of the cabinet. The bolts are restrained at all the degrees of translation. Up to six cabinets were used to study the effect of grouping on the ICRS generation. Further to understand the grouping effect more explicitly the mass to stiffness ratio for the cabinet's assembly are analyzed.

2.3 Effect of Assumed Component loads mounted on cabinets

The dynamic characteristics of the cabinet assemblies were studied considering the effects of in-cabinet components. As Lin et.al [6] used the horizontal and vertical load distribution of the in-cabinet equipment to investigate the ICRS, however in this study, only the horizontally distribution was considered using the assumed weight of the components at different floors of the cabinet. Fig. 2 shows the dynamic properties of the cabinet under the assumed internal component load that manifests the effect of the internal component. Thus, it is significant to consider this effect in the seismic analysis of cabinets.

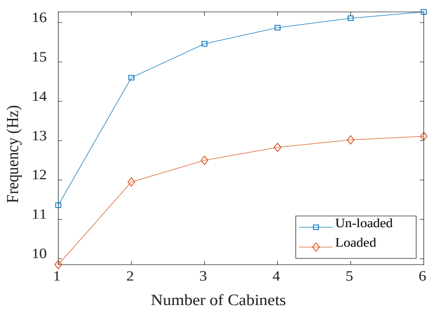

Fig. 2. Effect of the internal components load and number of cabinets.

2.4 Seismic response of the grouped cabinet

The response was computed at the top of the cabinet. Due to the rigid links at the connecting points, the response of the cabinet assembly to the seismic excitation will be the same at the top as the cabinets will excite as one unit. Fig. 3 represents the response of a single cabinet compared to the two connected cabinets and the three connected.

The response shown in the Fig. 3 is the average response for the 12 artificial earthquakes compatible with the design response spectra in RG 1.60. The ICRS pattern produced using the motion in RG 1.60 depicts no potential difference resulted from the grouping effect of the cabinets.

However, based on the modal analysis of the cabinet, it was understood that the addition of the cabinet will improve the dynamic integrity of the cabinets. It was found that the artificial motions in range of 2-10 Hz, the average response due this reason is not affected as the cabinet frequency may be distant from the peak frequency content of the input.

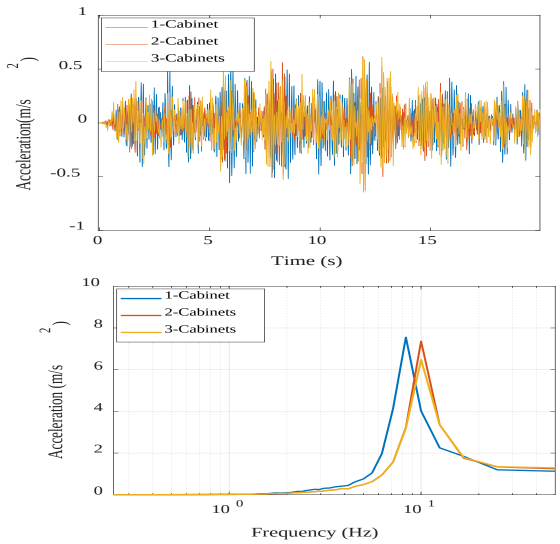

Fig. 3. Cabinet response under the Artificial ground motion compatible with RG 1.60

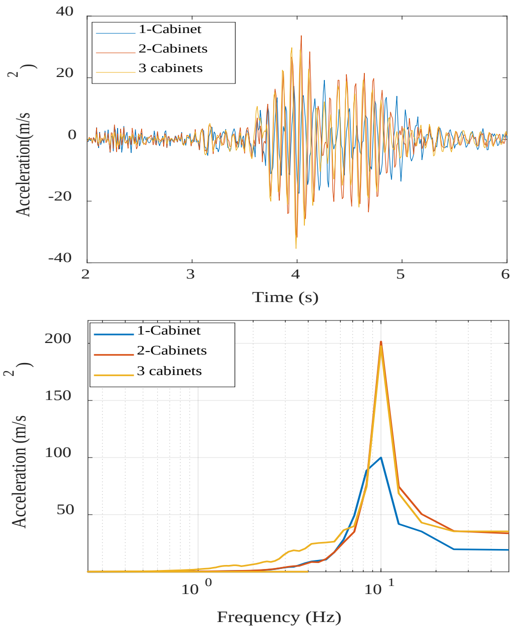

Fig. 4. Cabinet response under the Goungju Earthquake

In Fig.4 In case of one cabinet, the Sa is 100 m/sec^2 while for two and three cabinets it is almost 200 m/sec^2 that accounts for 100 % amplification in the response. In case of increasing the number of cabinets further will results in the amplification of the ICRS. This manifests that the dynamics characteristics of the ground motion have much more effect on the ICRS generation than the cabinets itself.

3. Conclusions

The seismic responses of the grouped electrical cabinets were investigated using linear time history analysis considering the effects of loading of the mounted components, grouping of the cabinets and the ground motion parameters that mainly contain the high-frequency pulses. The effects of component loading, and grouping were found to be important when generating the ICRS as these scenarios reflect the real condition of the cabinet. Grouping effect under the low-frequency range of the input motion has a constant deamplification in the ICRS that corresponds to the higher stiffness provided by the number of cabinets.
Conversely, at the high frequency of ground motion, the response of the cabinet is noticeably amplified. High frequency pulses of ground motion usually above 10 Hz can cause the interconnected cabinets to resonate as the cabinets frequencies lies in this range. Using the design earthquake presented in the standard RG 1.6, the response of the two and three cabinets was found higher than a single cabinet that manifests that cabinets interconnected in series may have high integral stiffness but due to their sensitivity to the input motion parameters can be more vulnerable than a single cabinet.

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