Transactions of the Korean Nuclear Society Spring Meeting
Gwangju, Korea, May 30-31, 2013

Preliminary Seismic Response and Fragility Analysis for DACS Cabinet

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1. Introduction

The data acquisition control system (DACS) of a low power research reactor such as TRIGA provides the functions to regulate the reactor power based on the control algorithm and operator input in a stable and reliable manner. The DACS is physically separated and electrically isolated from the reactor protection system (RPS) to guarantee that the failure of the DACS will not affect any safety function of the RPS [1]. A DACS cabinet is installed in the main control room.

The objective of this paper is to perform seismic analyses and evaluate the preliminary structural integrity and seismic capacity of the DACS cabinet. For this purpose, a 3-D finite element model of the DACS cabinet was developed and its modal analyses are carried out to analyze the dynamic characteristics. The response spectrum analyses and the related safety evaluation are then performed for the DACS cabinet subject to seismic loads. Finally, the seismic margin and seismic fragility of the DACS cabinet are investigated.

2. Design of DACS Cabinet

The DACS cabinet is composed of a frame, door, door handle, inside panel, cabinet base plate, chassis, neutron flux monitor, temperature and smoke detector, ventilation system, and other equipment necessary for a data acquisition and control system. The DACS cabinet is usually installed on the floor of the main control room using anchor bolts. The configuration of the DACS cabinet is shown in Fig. 1.

3. Modeling of DACS Cabinet

The 3-D finite element model of the DACS cabinet in Fig. 2 was developed by utilizing the ANSYS program. All parts of the DACS cabinet structure are modeled as solid elements and non-structural masses. The total number of elements is 36,603, and the total number of nodes is 12,734.

The boundary conditions of the DACS cabinet are shown in Fig. 2. The fixed boundary conditions of the displacement and rotation are imposed on the anchor bolt positions of the DACS cabinet, since it is bolted to the floor. Most parts of the DACS cabinet are made of structural steel (SS400) and poly carbonate (LEXAN). The maximum strength of the structural steel and poly carbonate are 450 MPa and 66 MPa, respectively.

4. Seismic Response Spectrum Analysis and Fragility Analysis of RPS Cabinet

To investigate the dynamic characteristics of the DACS cabinet, a modal analysis of the developed finite element model is performed. Typical measurements of the dynamic characteristics, natural frequencies and mode shapes are obtained. Fig. 3 summarizes two mode shapes in the structural model of the DACS cabinet. It can be observed that the first natural frequency is 14.8 Hz.

4.1. Design Loads and Load Combination

The weight of the main DACS cabinet is about 130 kg. The electrical components and other equipments are about 56 kg. The horizontal and vertical design ground response spectra (DGRS) for the SSE at the installing position of the DACS cabinet are shown in Fig. 4. 3% damping is used for the DGRS since the DACS cabinet is categorized as an electrical cabinet. The load combination used in the RPS cabinet is self weight plus SSE load.

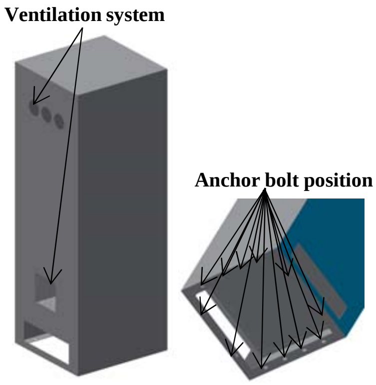


Fig. 1. Configuration of the DACS cabinet

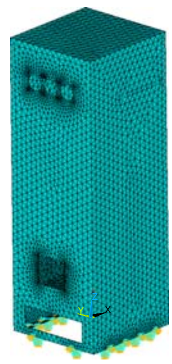
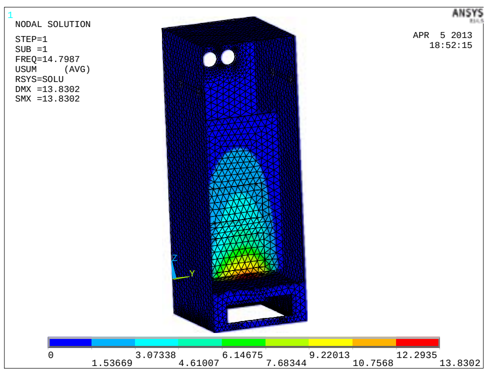
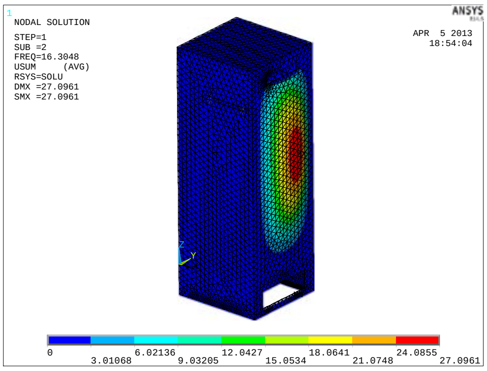


Fig. 2. 3-D finite element models of the DACS cabinet



(a) 1st mode (14.8 Hz)



(b) 2st mode (16.31 Hz)

Fig. 3. Natural frequencies and mode shapes of the DACS cabinet

4.2. Results

The effective stress (von-Mises stress) of the DACS cabinet under self weight and SSE load are evaluated, as shown in Fig. 5. The maximum effective stress is 82.6 MPa, which is less than the structural design limit of 450MPa. The weakest location is made in the anchor bolt positions of the DACS cabinet.

In addition, the maximum effective stresses of the DACS cabinet are analyzed according to the increase of the SSE load for investigating the seismic safety margin of the DACS cabinet. Table 1 shows the maximum effective stresses of the DACS cabinet in accordance with the increase in SSE load. From these results, we can judge that the DACS cabinet can structurally withstand until less than SSE 3g.

Finally, for a fragility analysis, the structural failure mode of the DACS cabinet is defined when the stress at the plate of the anchor positions reaches maximum strength and the logarithmic standard deviations for a randomness and uncertainty are 0.33 in this study. Fig. 6 shows a fragility curve of the DACS cabinet for the DGRS of the SSE 0.3g. The high confidential and low probability of failure (HCLPF) capacity for the DGRS of the SSE is 0.55g.

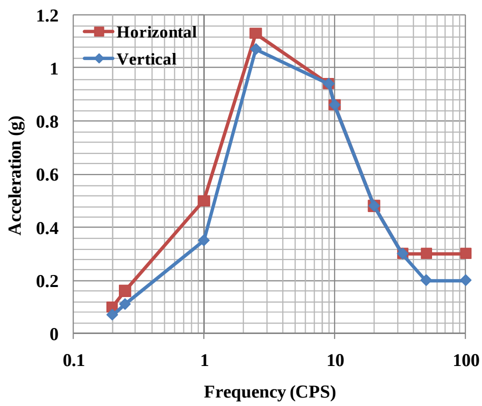


Fig. 4. Design ground response spectra for SSE (0.3g)

6. Conclusion

A seismic analysis and preliminary structural integrity of the DACS cabinet under self weight and SSE load have been evaluated. For this purpose, 3-D finite element models of the DACS cabinet were developed. A modal analysis, response spectrum analysis, and seismic fragility analysis were then performed.

From the structural analysis results, the DACS cabinet is below the structural design limit of under SSE 0.3g, and can structurally withstand until less than SSE 3g based on an evaluation of the maximum effective stresses. The HCLPF capacity for the DGRS of the SSE 0.3g is 0.55g. Therefore, it is concluded that the DACS cabinet was safely designed in that no damage to the preliminary structural integrity and sufficient seismic margin is expected.

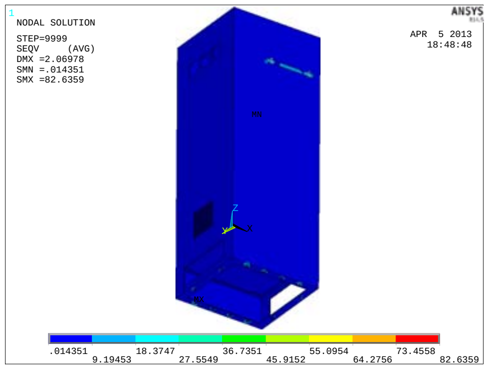


Fig. 5. Effective stress of DACS cabinet under self weight and SSE (0.3g)

Table 1. Maximum effective stress of the DACS cabinet according to the increase of the SSE load

Seismic Shutdown Earthquake (g)	Maximum effective stress (MPa)
0.3	82.6
1.0	169.7
2.0	306.4
3.0	443.2
4.0	580.0

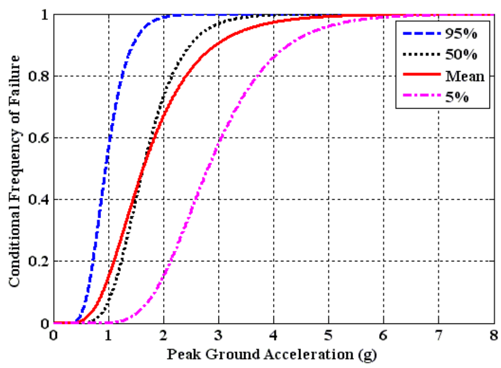


Fig. 6. Seismic fragility curve of DACS cabinet for the DGRS of the SSE (0.3g)

REFERENCES

[1] Dane Baang, Gwi-Sook Jang, Jong Bok Lee and Young-Ki Kim, Design Requirement for Data Acquisition and Control System, Korea Atomic Energy Research Institute, 2013.