Transactions of the **13th International Conference on Structural Mechanics in Reactor Technology** (SMiRT 13), Escola de Engenharia - Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil, August 13-18, 1995

Earthquake design of switchgear cabinets of the VVER-440/213 at Paks

Katona, T.[1], Kennerknecht, H.[2], Henkel, F.-O.[2]
1) Paks Nuclear Power Plant Ltd., Hungary
2) Wölfel Beratende Ingenieure, Würzburg

1 INTRODUCTION

The electrical and instrumentation and control area of NPP Paks is upgraded with new switchgear cabinets. In connection with the emergency power supply a rectifier switchgear cabinet is installed. The electric components inside, especially the extensive control electronics, are designed according to the German safety standard KTA 3703 (1986) as well as to withstand a high level earthquake.

Investigated switchgear cabinets constructed as steel frames have plan dimensions of 800 x 1600 mm and heights of 2200 mm as well as total masses of approximately 1400 kgs (Figure 1).

For the required earthquake design of the switchgear cabinets with safety relevant components inside the present seismic design basis of Paks is used.

Proof of global stability of the steel frame as well as the determination of earthquake loading for the electric components mounted to the steel frame are established by Finite-Element-Calculations. The functionability of electric components during and after an earthquake is tested with real components by experimental earthquake simulation. For similar cabinets and equal or similar electric components the functionability is proved by analogy, see Figure 3 and Henkel et al. (1987).

This contribution presents the course of calculation and performance of tests as well as selected results.

2 CALCULATIONS

The supporting structure of a switchgear cabinet is a welded framework with stiffening trusses in side walls, back wall and head. Walls and head are covered by bolted sheets. This structure together with the masses of the built-in electric components is modelled by Finite Elements. Figure 2 shows the geometry plot of the Finite-Element-Model (FEM) for the investigated switchgear cabinet. It consists of beam elements. The stiffness of the bolted sheets is neglected. The masses of the supporting structure and of the equipment are lumped at the nodes.

The seismic input is given by the floor response spectra for the location point of the switchgear cabinet (Figure 4).

For proof of strength and stability of the switchgear cabinets the dynamic response is calculated by use of the response spectrum modal analysis (RSMA) and superposed with dead load. With the force and stress results welding seams are designed and allowable stresses are checked.

For evaluation of the earthquake loading of the electric components within the cabinet time history (THMA) calculations are established. The Finite-Element-Model is excited by artificial time histories compatible with the spectra of Figure 4. With the resulting time history responses of FEM-nodes enveloping acceleration spectra are developed for the horizontal and vertical direction of the switchgear cabinet.

3 TESTING

Most of the electric components have a complex mechanical structure, in addition proof of functionability is requested. Thus for the electric components tests are recommended. Figure 9 shows tested electric components mounted on the test facility.

Tests are performed taking into account safety standard KTA 2201.4 (1990) of the German Nuclear Technical Committee.

To simulate the earthquake loading for the electric components harmonic excitation is chosen. A shaking table is used as test facility.

The shaking table consists of a 1 m by 1.6 m very stiff steel plate movable on an air-cushion in one horizontal direction. The plate is driven by a servo-hydraulic cylinder with 100 kN nominal load and ± 100 mm nominal displacement. The facilities for mounting the original test specimens to the table are very stiff and therefore without influence on the frequency range of interest up to 30 Hz. The specimens are fastened with original screws. For exciting all three directions of each specimen successively the mounting facilities respectively are rotated as requested. Thus during the tests for the vertical direction dead load differs from the real direction, which is acceptable within the whole procedure.

Test load is controlled via computer by measurement of the acceleration of the steel plate.

The calculated enveloping response spectra for the switchgear cabinets (Figure 7) are modified to the test load input taking into account the amplification effect of harmonic excitation with a sine sweep as well as the possible existence of adjacent frequencies. The sine sweep covers the range between 0.4 Hz and 30 Hz with a frequency rate of one octave per minute. Rigid body motion is tested by a separate run for each direction. During the shaking tests the electric components are connected to the working voltage; the instruments which control the function or disfunction of the switchgear cabinet are active.

In Figure 8 the requested loading spectrum (acceleration versus frequency) for horizontal excitation is compared with the test result of a run up. The documented accelerations of the test are in sufficient agreement with prescribed loading. For the tested components of Figure 9 no essential amplification of motion was noticed.

4 PROOF BY ANALOGY

The performed tests for electric components in a standard switchgear cabinet can be used as standard for equal or similar electric components. If the construction of switchgear cabinet also is equal or similar to the standard ones with respect to stiffness and mass the standard tests can hold for the built-in components. In addition to the mentioned similarities the modal parameters and especially the given seismic input have to be compared.

Figure 6 shows the fundamental eigenmode of the Paks SGC (12.8 Hz) compared with the ones of the standard SGC (15.2 Hz). Comparison of horizontal floor response spectrum for Paks and standard (Figure 5) shows the excitation for Paks to be about factor 0.5 less than for standard in the frequency range greater than 2.5 Hz, which only may be relevant. Thus the standard horizontal test load contains reserves.

5 CONCLUSION

The presented investigations show an expedient procedure for proof of stability and functionability for switchgear cabinets. Proof of stability for the supporting frame is established by calculations. The calculated stresses are well below the allowable stresses. Functionability of the built-in electric components during and after an earthquake is performed by shaking tests using precalculated loading for earthquake simulation. For the tested components no mechanical damage appeared. Electric function of the tested components was controlled during the tests notifying no disfunction, functionability is proved.

REFERENCES

Henkel, F.O., Kennerknecht, H., Wölfel, H. (1987). Conception of Analytical and Experimental Earthquake Design of Nuclear Process Devices. Transactions of the 9th International Conference on SMIRT, Vol. K2, pp. 1221-1227.

KTA 2201.4 (6/90). Auslegung von Kernkraftwerken gegen seismische Einwirkungen Teil 4: Anforderungen an Verfahren zum Nachweis der Erdbebensicherheit für maschinen- und elektrotechnische Anlagenteile

KTA 3703 (6/86). Emergency Power Facilities with Batteries and Rectifiers in Nuclear Power Plants (6/86)

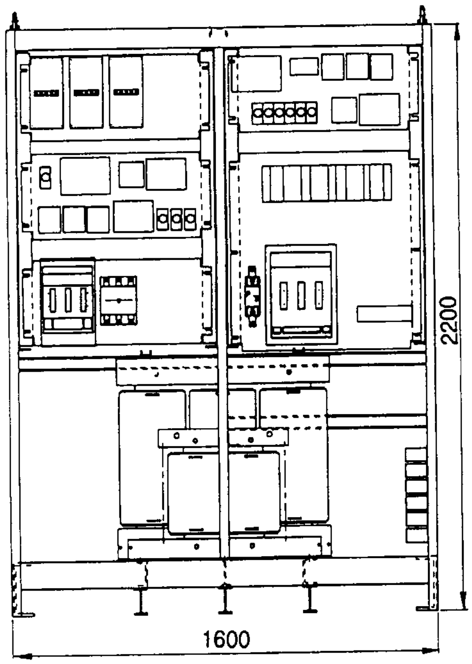


Figure 1. View of switchgear cabinet

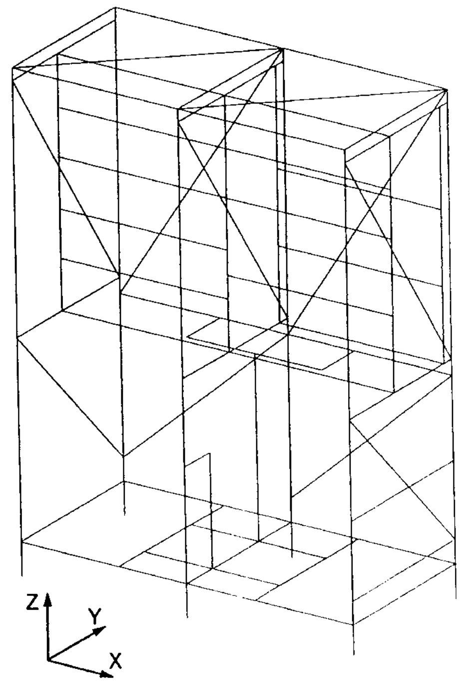


Figure 2. FE-model of switchgear cabinet

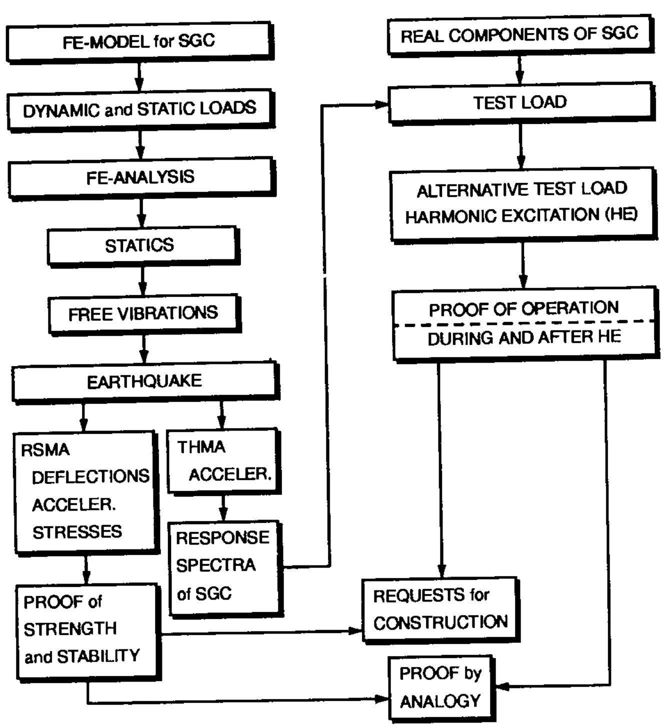


Figure 3. Conception of proof for a switchgear cabinet (SGC)

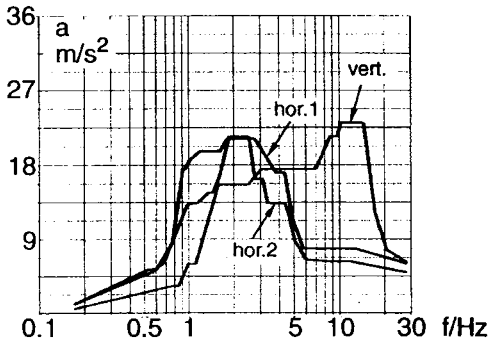


Figure 4. PAKS, FRS, D = 0.05, a_g = 3.5 m/s^2,horizontal,vertical

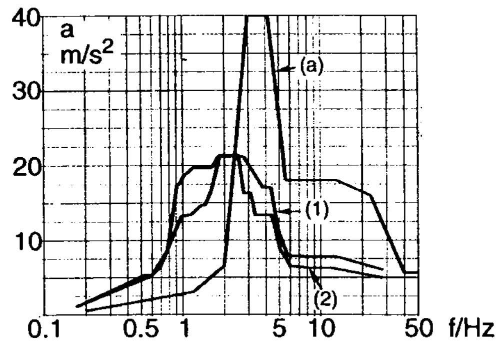
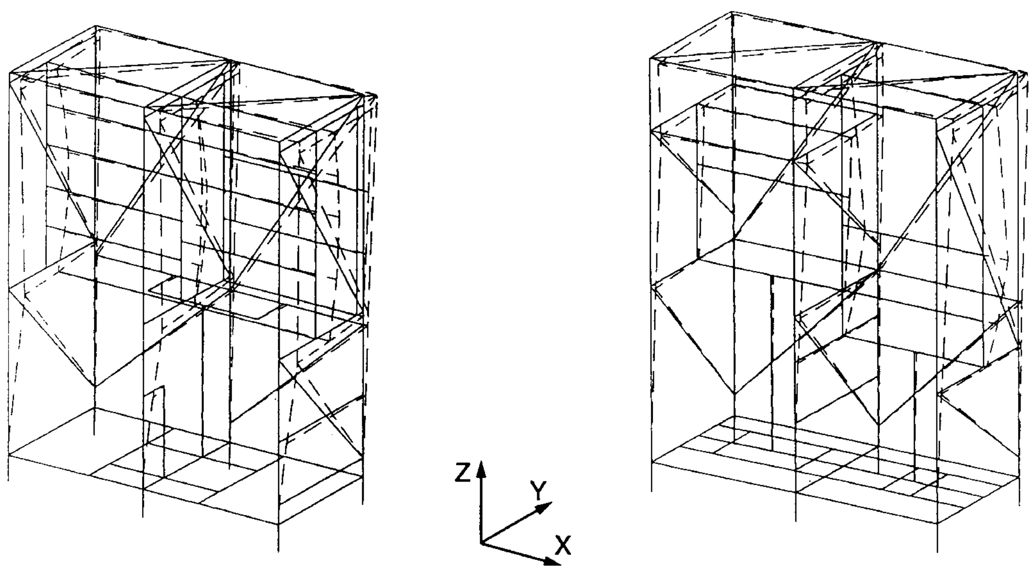


Figure 5. Comparison of FRS, (1),(2) PAKS hor. 1 and 2 (D = 0.05); (a) STANDARD hor. (D = 0.04)



(a) PAKS, f_1 = 12.8 Hz

(b) STANDARD, f_1 = 15.21 Hz

Figure 6. Basic vibration modes

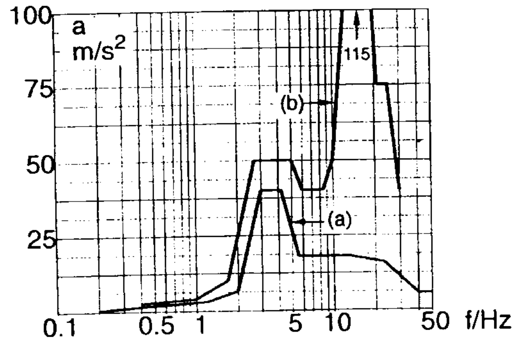


Figure 7. STANDARD: (a) FRS (D = 0.04), (b) RS of SGC (D = 0.04)

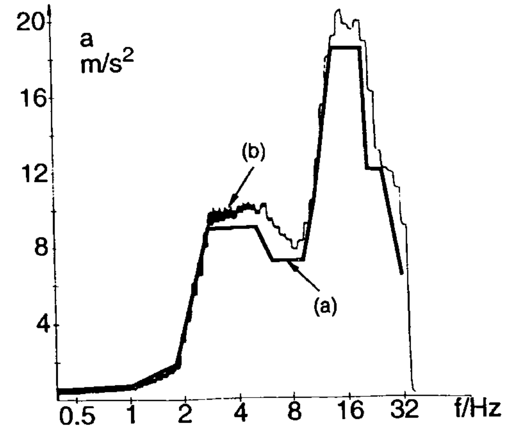


Figure 8. Test load horizontal (a) requested, (b) measured

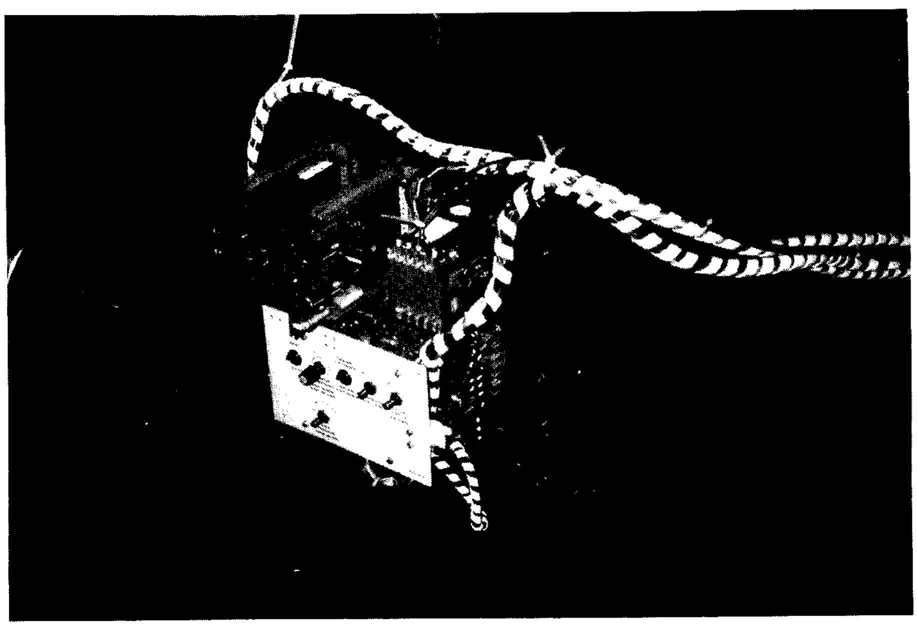


Figure 9. Test specimen on test facility