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SPECTRUM ANALYSIS OF THE SF6 HIGH-VOLTAGE CIRCUIT BREAKER USING FINITE ELEMENT METHOD

Mihai Negru*[1], Paul Rinderu[1], and Ion Manea[2]

[1]Mechanics Faculty, University of Craiova
Str. Calea Bucuresti nr. 107, 200512 Craiova, Romania
[2]SC ICEMENERG Craiova
Str. Brestei nr. 1, 200581 Craiova, Romania
negrum@mecanica.ucv.ro

Abstract

The paper present a Finite Element model of a circuit breaker made using ANSYS program and the spectrum analysis of the model. The study was made in order to determine the behaviour of the structure during different types of earthquakes. The collapse of a circuit breaker determined by earthquake has determinant implications in breaking the power supply for large territorial areas. So, the design of the circuit breaker structure must include the simulations of the earthquakes, made by experiments and by Finite Elements Methods programs. This paper presents the behaviour of the SF6 circuit breaker during three types of earthquake using ANSYS program and some FEM models validated with experimental results in modal analysis.

INTRODUCTION

The SF6 high voltage circuit breaker are expensive and vital equipments, therefore it is necessary the safe functioning of these equipments, especialy during limit conditions, like earthquake. These are tall structures (8 meters height) and they have a column type construction, having the weight center positioned very high and a low moment of inertia for the support columns. These particularities offer them a high vulnerability during earthquakes. The international standards recommend verification of the seismic capability in the design process.

For a complete test of the seismic capability it is necessary to perform an experimental study combined with a numerical simulation because the experiment is expensive and not so flexible regarding the simulation of all types of limit conditions of earthquakes. The numerical simulation of the seism is made using FEM and ANSYS program which permit to perform a spectrum analysis on the FEM model of the circuit breaker.

The seism simulation using FEM is a two step analysis. First we have made a modal analysis of the SF6 circuit breaker FEM model [4] and we have compared the results with the experiment in order to validate the FEM model [5]. Then it must be done the spectrum analysis on the validated FEM model for different seism types.

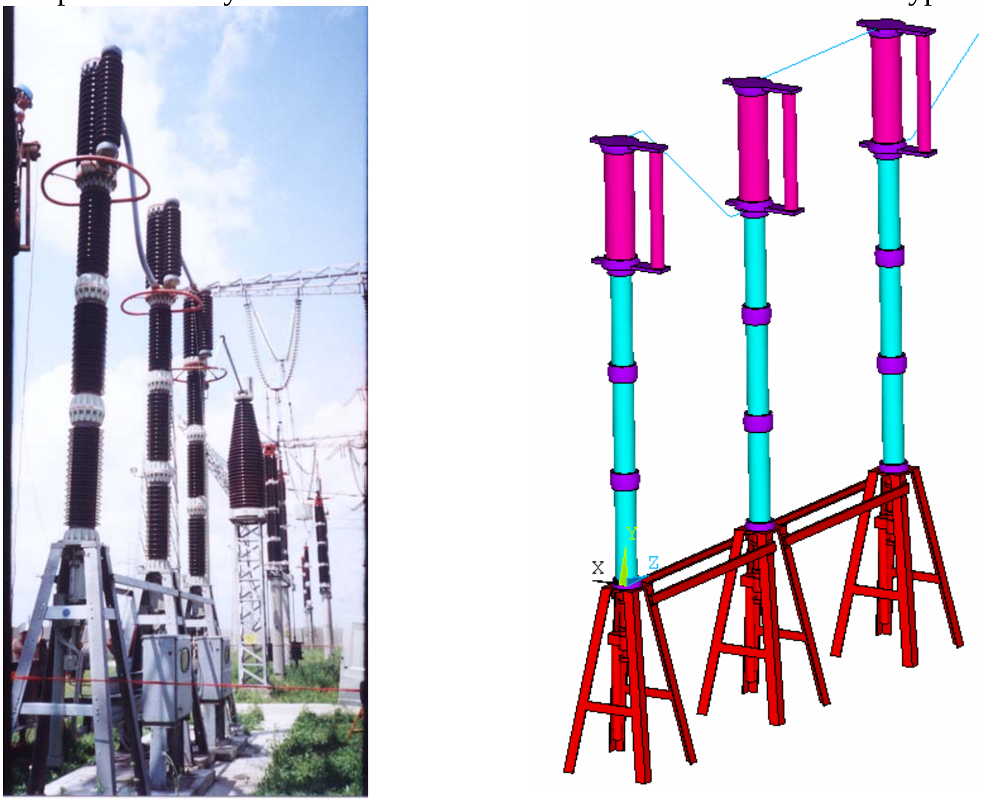

Figure 1 – SF6 circuit breaker (real – left, FEM model – right)

THEORETICAL BACKGROUND

A spectrum analysis is one in which the results of a modal analysis are used with a known spectrum to calculate displacements and stresses in the model.

For partially correlated nodal and base excitations, the complete equations of motions are segregated into the free and the restrained (support) DOF as:

$$\begin{bmatrix} [M_{ff}] & [M_{fr}] \\ [M_{rf}] & [M_{rr}] \end{bmatrix} \begin{Bmatrix} \{\ddot{u}_f\} \\ \{\ddot{u}_r\} \end{Bmatrix} + \begin{bmatrix} [C_{ff}] & [C_{fr}] \\ [C_{rf}] & [C_{rr}] \end{bmatrix} \begin{Bmatrix} \{\dot{u}_f\} \\ \{\dot{u}_r\} \end{Bmatrix} + \begin{bmatrix} [K_{ff}] & [K_{fr}] \\ [K_{rf}] & [K_{rr}] \end{bmatrix} \begin{Bmatrix} \{u_f\} \\ \{u_r\} \end{Bmatrix} = \begin{Bmatrix} \{F\} \\ \{0\} \end{Bmatrix} \qquad (1)$$

- $[M]$ - the system mass matrix or the inertia matrix ;
- $[C]$ - the system damping matrix;
- $[K]$ - the system stiffness matrix;

$\{u_f\}$ are the free DOF
$\{u_r\}$ are the restrained DOF that are excited by random loading
$\{F\}$ is the nodal force excitation
Damping is evaluated for each mode and is defined as:

$$\xi_i' = \frac{\beta\omega_i}{2} + \xi_c + \frac{\sum_{j=1}^{N_m} \beta_j^m E_j^s}{\sum_{j=1}^{N_m} E_j^s} + \xi_i^m \qquad (2)$$

where: ξ_i – effective dumping ratio for mode „i";
β – dumping factor;
ω_i – undamped natural circular frequency of the ith mode;
ξ_c – damping ratio;
N_m – number of materials;
β_j^m – dumping constant stiffnes matrix multiplier for material „j";

SPECTRUM ANALYSIS OF CIRCUIT BREAKER

The FEM spectrum analysis was performed on the validated FEM model of the SF6 circuit breaker [4]. The following results were obtained for three type of earthquake:

- earthquake type AF2 (<5.5 degrees Richter)
- earthquake type AF3 (5.5…7 degrees Richter)
- earthquake type AF5 (> 7 degrees Richter)

The displacements and the Von Mises stress for these three types of seism are:

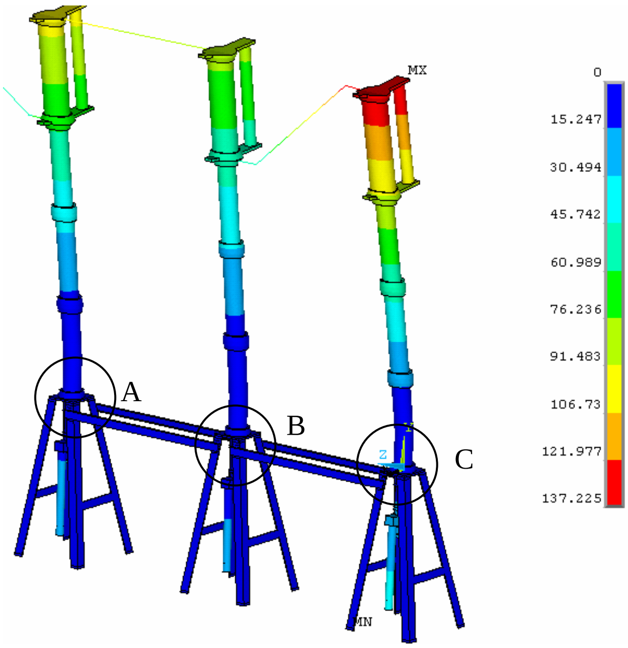

Figure 2 – Displacements during AF2 earthquake (MX = 137 mm) [mm]

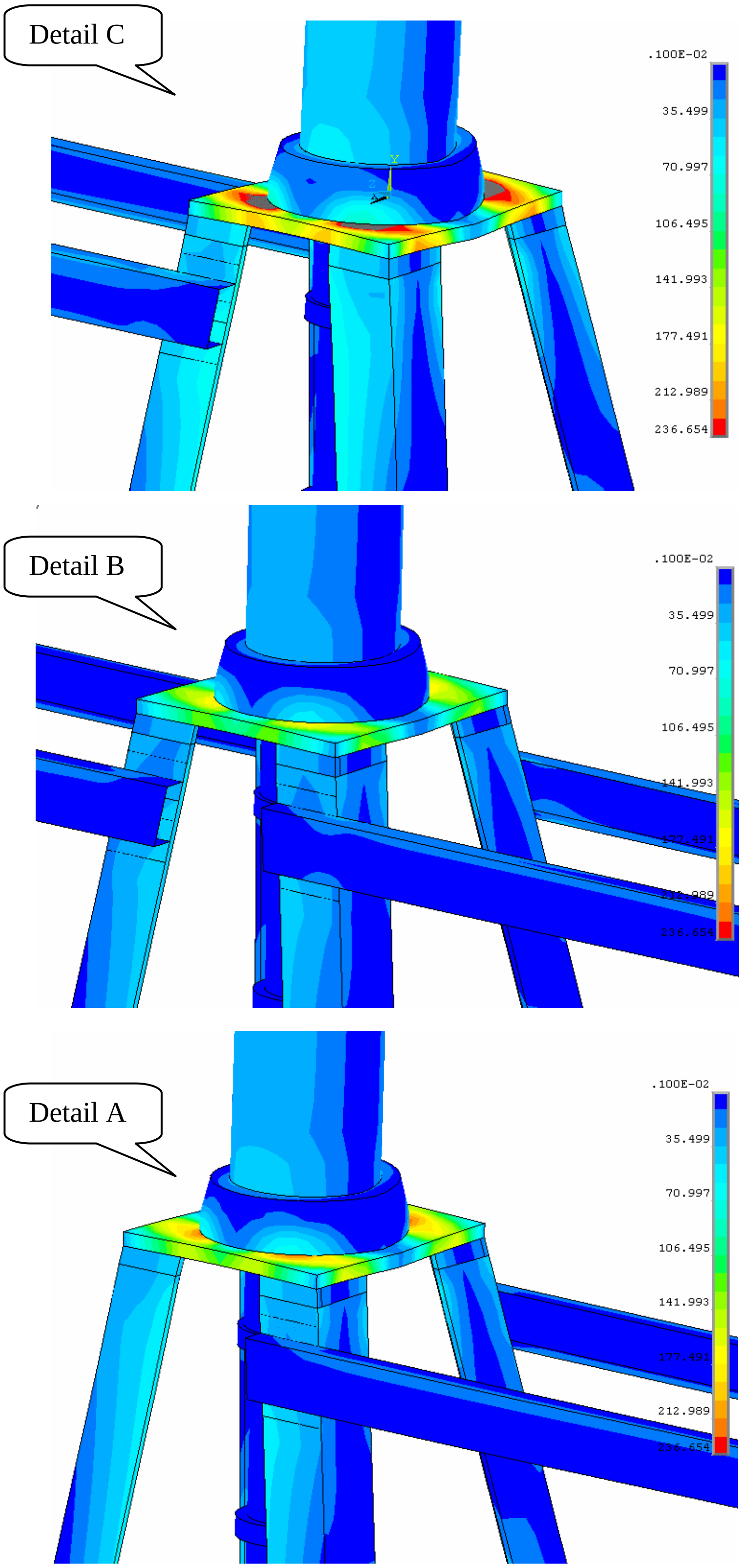

Figure 3 – Von Mises Stress during AF2 earthquake (details C, B, A) [MPa]

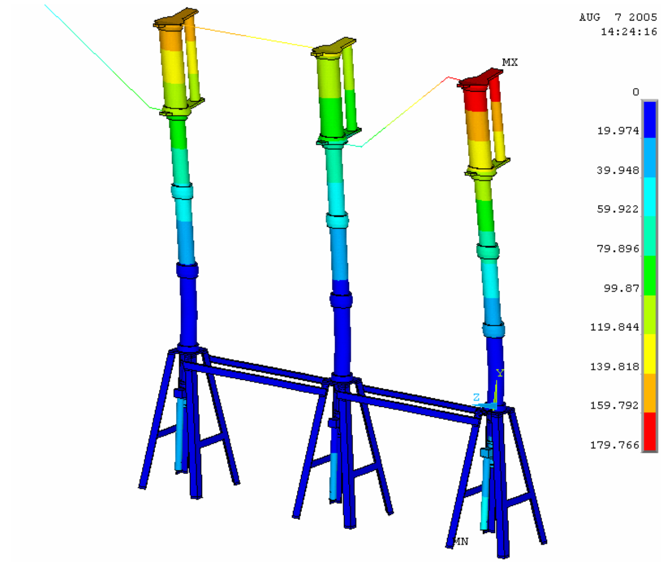

Figure 4 – Displacements during AF3 earthquake (MX = 179 mm) [mm]

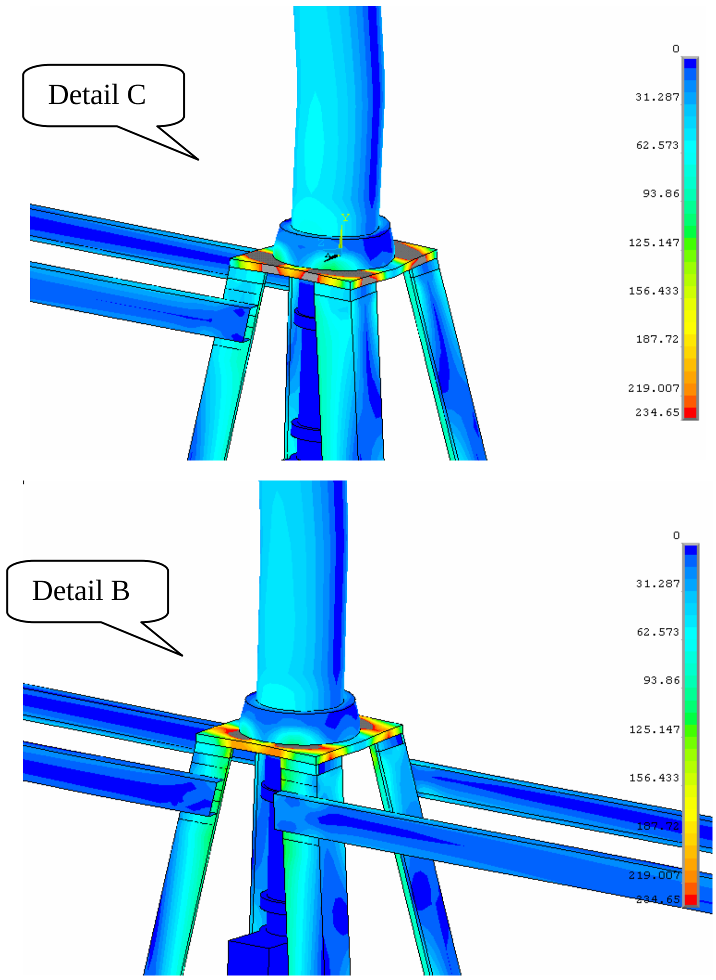

Figure 5 – Von Mises Stress during AF3 earthquake (details C, B) [MPa]

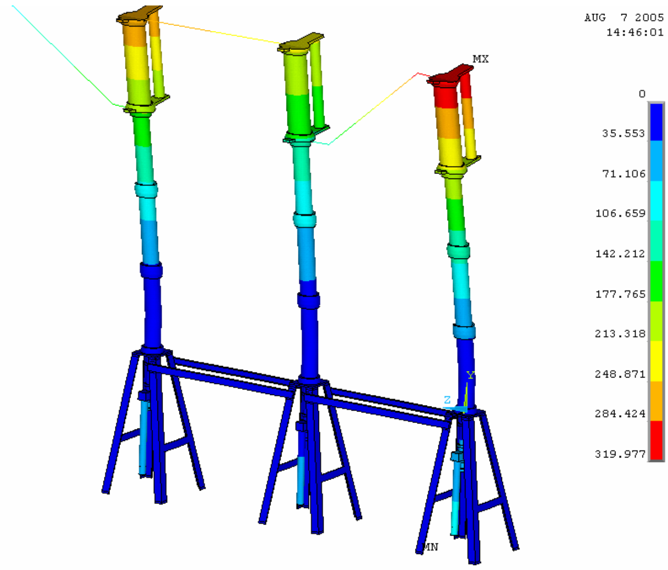

Figure 6 – Displacements during AF5 earthquake (MX = 319 mm) [mm]

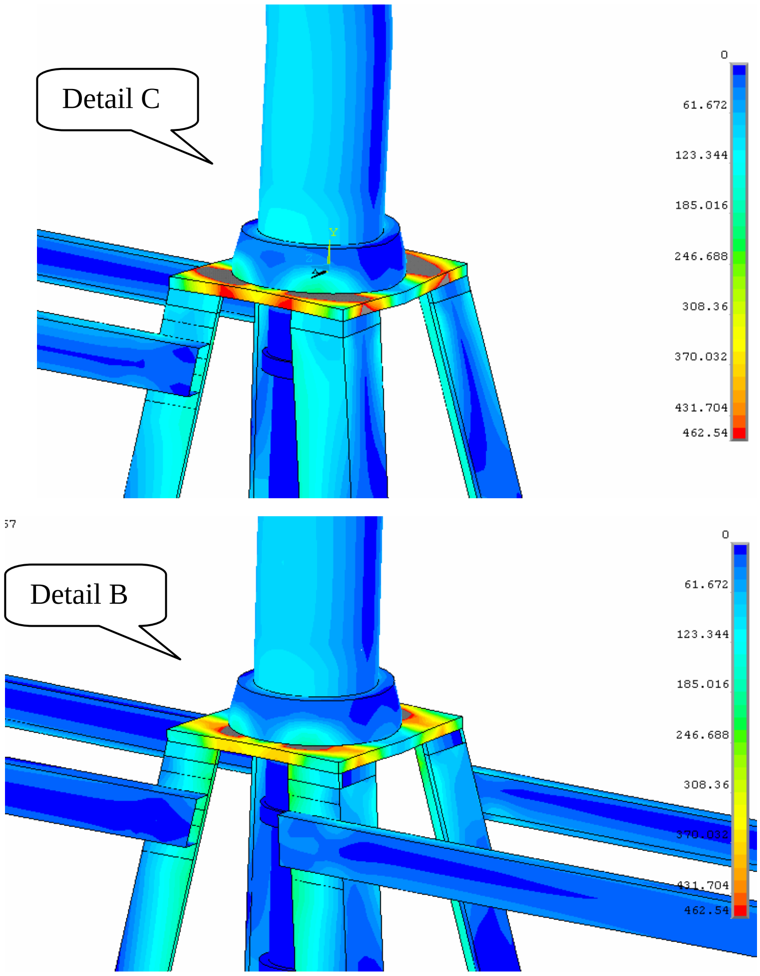

Figure 7 – Von Mises Stress during AF5 earthquake (details C, B) [MPa]

CONCLUSIONS

The Finite Element Method can be used in simulation of the entire system of three units high voltage circuit breaker during earthquakes, as a spectrum analysis.

The results presented in this paper are the final step of the entire process of earthquake simulation and consist in determination of displacements and stresses values achieved during three types of earthquake (AF2, AF3, AF5).

Analyzing the computed values we can see that in the case of the circuit breaker the most vulnerable parts are the isolator columns made by ceramics for which the admissible stress is $\sigma = 40$ MPa.

During earthquake type AF2 the stress value over the isolator parts are smaller then 40 MPa, so all three poles (A, B and C) stand out to a AF2 seism.

By comparing with the value of 40,3 MPa determined by FEA for the lower part of the isolator column of the pole “C” it can be considered that the pole “C” stand out to a seism type AF3 corresponding to a 7 degrees seism on Richter scale. Similar conclusions can be made for pole “A”. Some problems are with the pole “B”, because of the rigid connections with poles “A” and “C” and looseness of the shrinkages.

For seism type AF5 the stresses obtained are superior to the admissible value of the stress for ceramics material so, the base isolator of the pole C and B will collapse.

This FEM model can be used to optimize the actual resistance structure of the high-voltage circuit breaker in order to achieve a better resistance during earthquakes.

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