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MODAL ANALYSIS OF THE HIGH-VOLTAGE DISCONNECTOR USING FINITE ELEMENT METHOD

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Abstract
The paper present a Finite Element model of the .high-voltage disconnector type SMEP–400 kV made using ANSYS program and the modal analysis of this model. The study was made in order to determine the behavior of this type of disconnector during different types of earthquake. The modal analysis is the first step in earthquake F.E.M. simulation. The results presented are the first 12 natural frequencies and the corresponding vibration modes. The FEM model can be validated with the experimental results and can be used in earthquake simulation by performing a FEM spectrum analysis.

INTRODUCTION

The high-voltage disconnector is a large structure which contains two poles. The structure is 8 meters height and is used to connect and disconnect the high voltage electrical circuit in order to assure the power connections between cities or remote locations.

One of the principal difficulties of the high-voltage disconnectors producers consist in reconciling flexibility and resistance of the disconnectors in order to make it possible for the cable to support millions of torsion movements, resonance and extreme climatic conditions. Also, the disconnector structure must be reliant during different types of earthquake because the damage of a high-voltage disconnector determined by earthquake has determinant implications in breaking the power supply for large territorial areas or even in producing fire disasters by letting the power cables to fall down on the earth. So, the design and verification of the high-voltage disconnector structure must include the simulations of the earthquakes, made by experiments and by Finite Elements Methods programs. The first steps in this study are the construction of the FEM model and the modal analysis.

They are many types of high voltage circuit breakers and the type which was modeled with F.E.M.is presented in figure 1.

The SMEP–400 kV high voltage disconnector is manufactured at Electroputere Craiova (Romania) and is made of 3 vertical columns with three isolator parts like those presented in figure 1.

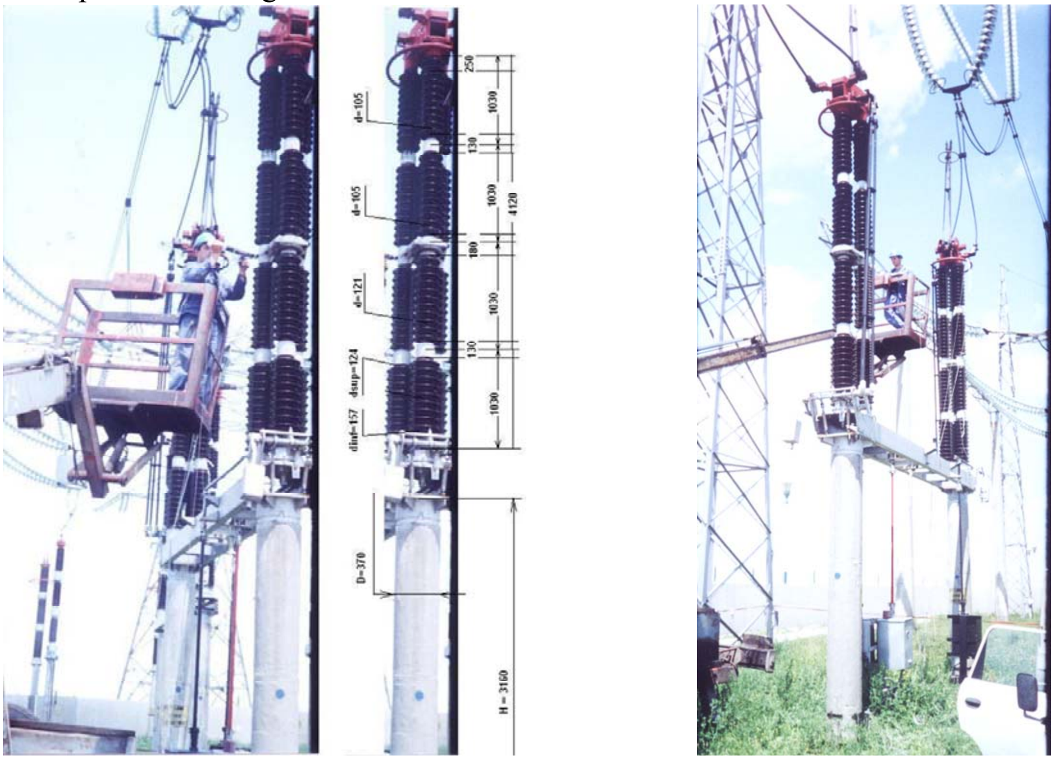


Figure 1 - The SMEP-40 kV high-voltage disconnector

As we can see, the system of circuit disconnector has two units interconnected, so our study will consider the entire system.

THEORETICAL BACKGROUND

This analysis type is used for natural frequency and mode shape determination. The equation of motion for an undamped system, expressed in matrix notation is:

$$[M]\{\ddot{u}\} + [K]\{u\} = \{0\} \qquad (1)$$

where: [M] - the mass matrix;
[K] - the stiffness matrix

For a linear system, free vibrations will be harmonic of the form:

$$\{u\} = \{\Phi\}_i \cos \omega_i \ t \qquad (2)$$

where: $\{\Phi\}_i$ = eigenvector representing the mode shape of the ith natural frequency;
ω_i = i^{th} natural circular frequency (radians per unit time);
t = time.

Thus, equation (1) becomes:

$$\left(-\omega_i^2[M]+[K]\right)\{\Phi\}_i=\{0\} \qquad (3)$$

and the solution is:

$$|\,[K]-\omega^2[M]\,|=0 \qquad (4)$$

This is an eigenvalue problem which may be solved for up to n values of ω^2 and n eigenvectors $\{\Phi\}_i$ which satisfy equation (3) where n is the number of DOFs.

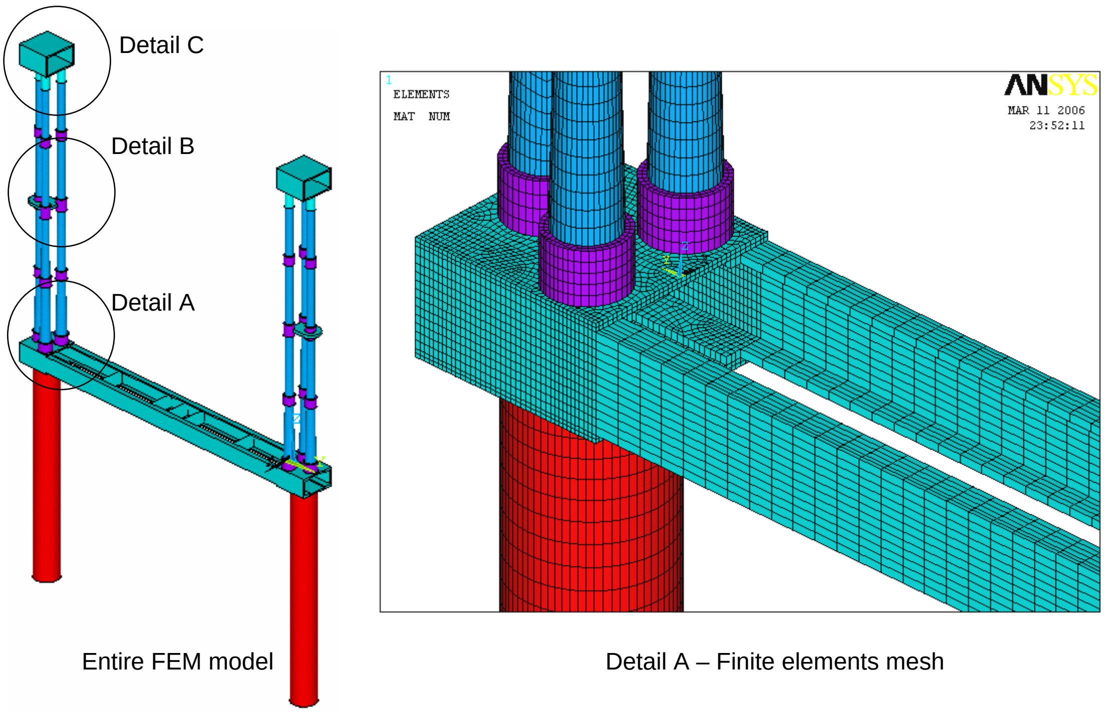
The natural frequencies (f) are:

$$f_i=\omega_i/2\pi \qquad (5)$$

where f_i = i^{th} natural frequency (cycles per unit time).

MODAL ANALYSIS OF DISCONNECTOR

The FEM model of the disconnector was entirely realized using ANSYS programs.



Entire FEM model

Detail A – Finite elements mesh

Figure 2 - FEM model of the SMEP-40kV high-voltage disconnector

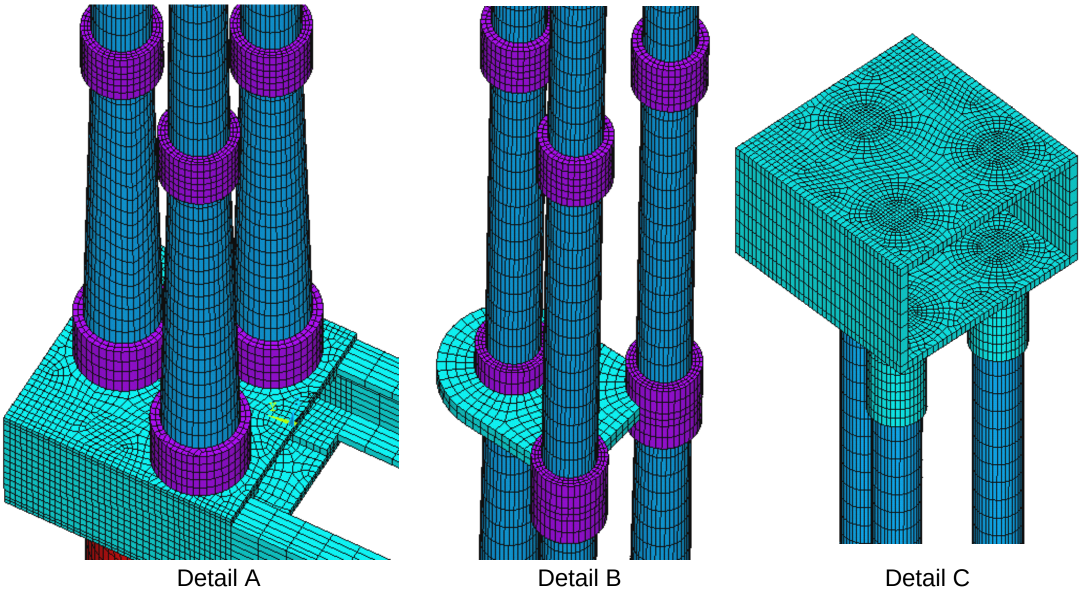


Figure 3 – Finite elements model (mesh details)

As we can see in fig. 2 and 3 the FEM model was mapped meshed using hexahedrons in order to obtain best results of analysis. The model simulate both units of disconnector connected to each other.

We have perform a modal analysis of the FEM model in order to determine the first 12 natural frequencies and the vibration modes – as the first step of the earthquake analysis. The results obtained with ANSYS program are as follows:

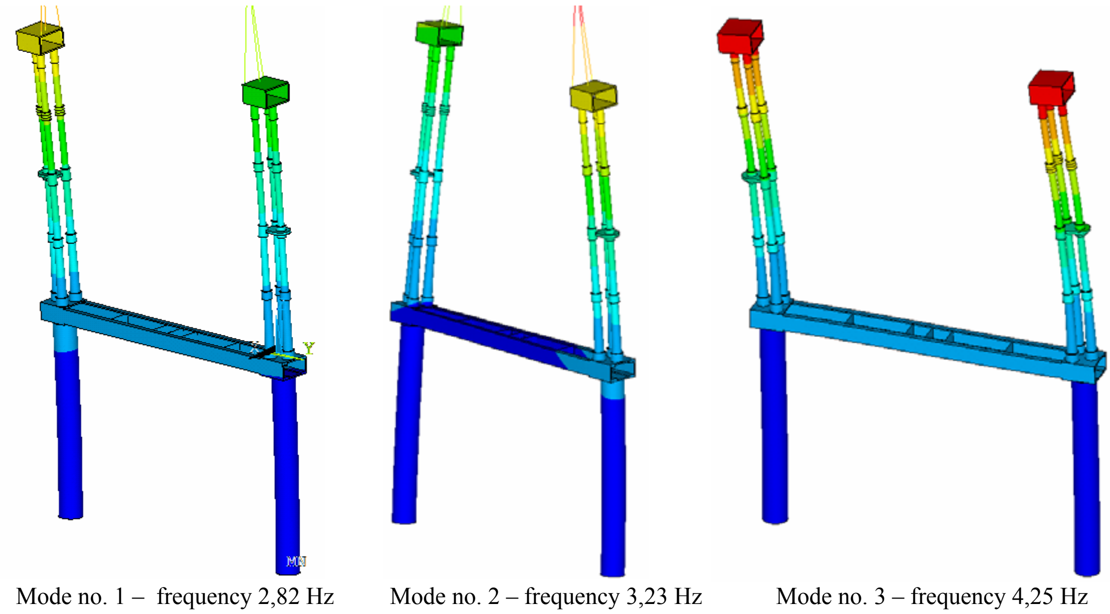
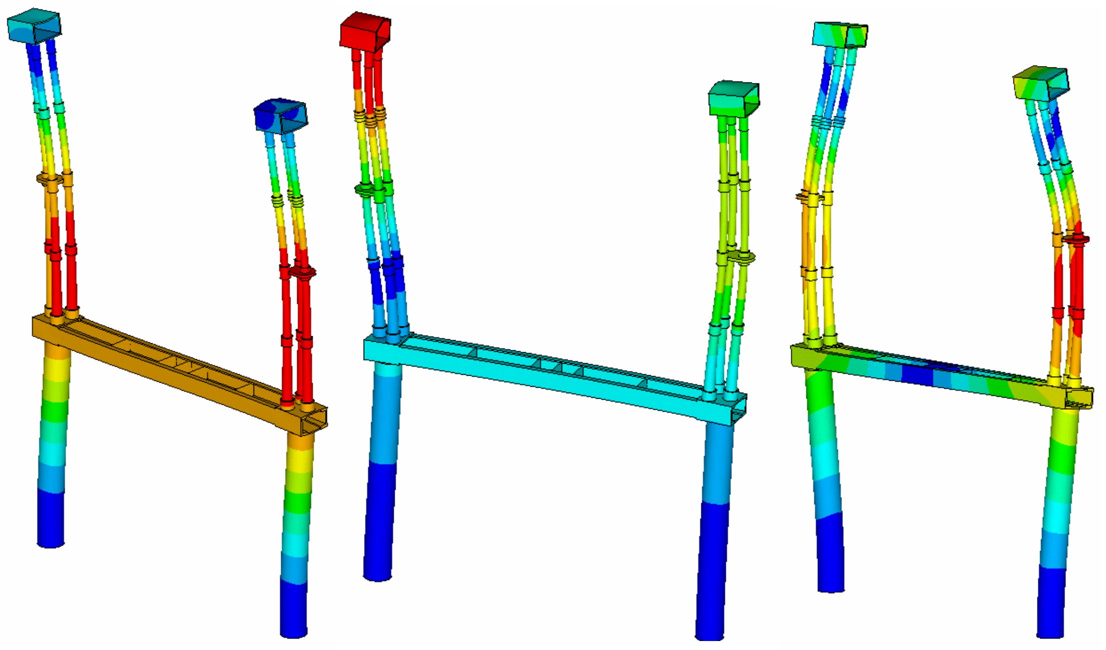
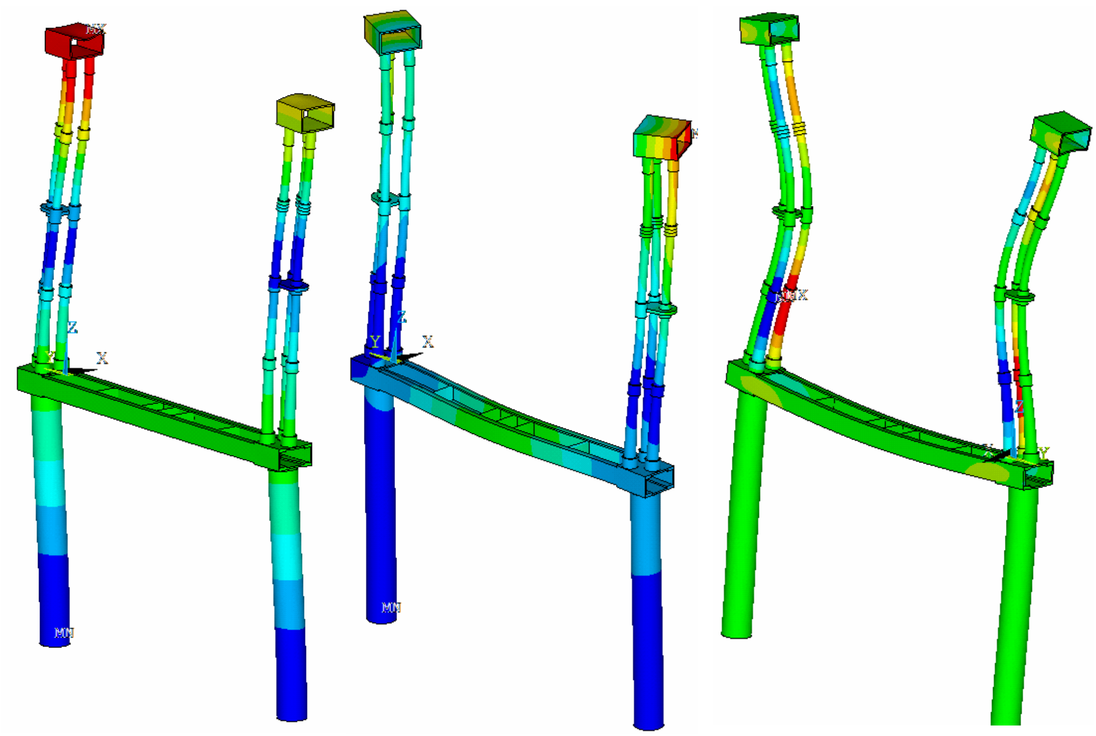


Figure 4 - The natural frequencies for Vibration Modes 1, 2 and 3



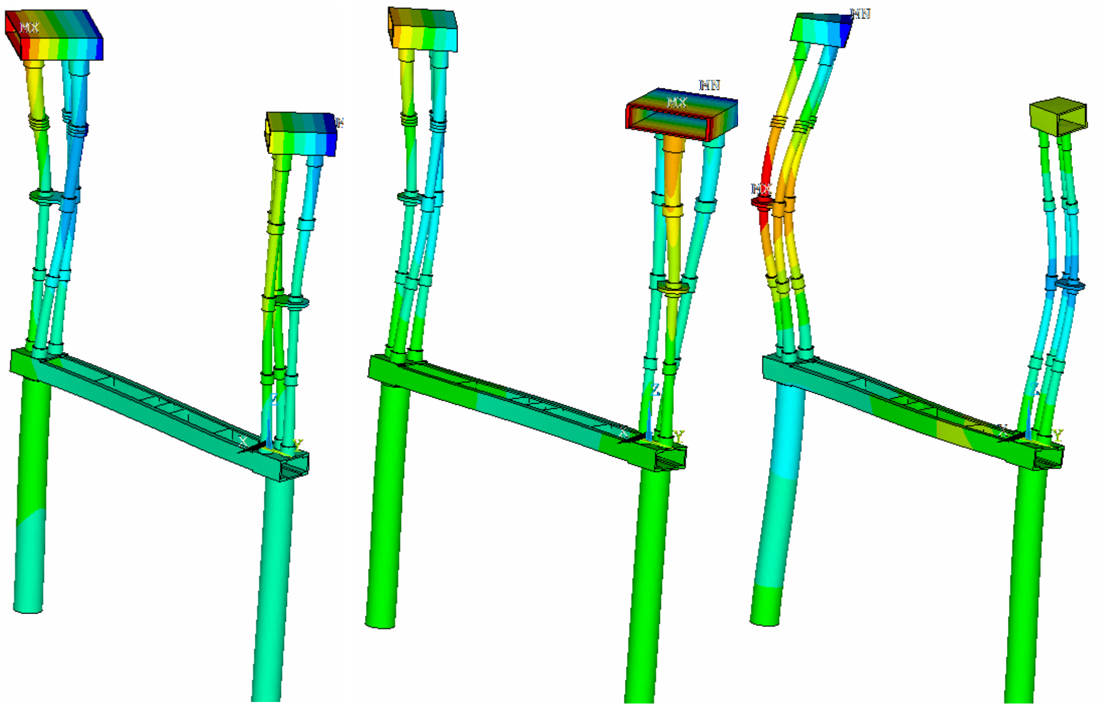
Mode no. 4 – frequency 4,405 Hz Mode no. 5 – frequency 10,27 Hz Mode no. 6 – frequency 11,83 Hz

Figure 5 - The natural frequencies for Vibration Modes 4, 5 and 6



Mode no. 7 – frequency 12,24 Hz Mode no. 8 – frequency 12,98 Hz Mode no. 9 – frequency 15,804 Hz

Figure 6 - The natural frequencies for Vibration Modes 7, 8 and 9



Mode no. 10 – frequency 28,83 Hz   Mode no. 11 – frequency 29,409 Hz   Mode no. 12 – frequency 30,355 Hz

Figure 7 - The natural frequencies for Vibration Modes 10, 11 and 12

CONCLUSIONS

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

The results presented in this paper are the first step of the entire process and consist in identifying the vibration modes which correspond to the earthquakes frequency range. The frequency range is varying depending on geographical position. In Romania the frequency range for earthquakes is 0.1 Hz … 35 Hz. Analyzing the computed frequencies we can se that all 12 vibration modes are corresponding to the earthquakes frequencies range, so an earthquake simulation is highly necessary.

This model can be used to optimize the actual resistance structure of the high-voltage disconnector in order to achieve a good resistance during earthquakes.

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