Seism simulation of the SMEP 400kV high-voltage disconnector structure using Finite Element Method

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Abstract: - This paper present a Finite Element model of a high voltage disconnector structure made using ANSYS program and the spectrum analysis of the model. The study was made in order to simulate the behaviour of the structure during different types of earthquakes. The collapse of a disconnector determined by earthquake has determinant implications in breaking the power supply for large territorial areas. The design of the disconnector structure must include the simulations of the earthquakes, made by experiments and by Finite Elements Methods programs. This paper presents the simulation of behaviour of the SMEP 400 kV disconnector during three types of earthquake using ANSYS program and offer a FEM model validated with experimental results in modal and spectrum analysis.

Key-Words: - Seism Simulation, Spectrum Analysis, Finite Element Method, ANSYS, Disconnector

1 Introduction

The safe functioning of the power system is a major demand for development in good conditions of the activities in a modern society. Therefore it is necessary the safe functioning of all equipments in the system, especialy in the limit conditions of working, like as seism, a special concern beeing to the expensive and vital equipments like high voltage disconnector.

Fig. 1 The SMEP 400kV Disconnector

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.

These are equipments with 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 at the seism.

The international standards recommend verification of the seismic capability by tests, but admit the simulation using Finite Element Method

A correct simulation model permit the evaluation of the structure response to diverse external excitations like: seism, electrodynamic forces and wind action.

2 Problem Formulation

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:

$$\begin{bmatrix} [M_{ff}] & [M_{fr}] \\ [M_{rf}] & [M_{rr}] \end{bmatrix} \begin{Bmatrix} \{\ddot{u}_f\} \\ \{\ddot{u}_r\} \end{Bmatrix} + \begin{bmatrix} [C_{ff}] & [C_{fr}] \\ [C_{rf}] & [C_{rr}] \end{bmatrix} \begin{Bmatrix} \{\dot{u}_f\} \\ \{\dot{u}_r\} \end{Bmatrix} + \\ + \begin{bmatrix} [M_{ff}] & [Mr] \\ [M_{rf}] & [M_{rr}] \end{bmatrix} \begin{Bmatrix} \{\ddot{u}_f\} \\ \{\ddot{u}_r\} \end{Bmatrix} = \begin{Bmatrix} \{F\} \\ \{0\} \end{Bmatrix} \tag{1}$$

-[M]- the system mass matrix or the inertia matrix ;
-[C] - the system damping matrix;
-[K] - the system stiffness matrix;
-$\{u_f\}$ - the free DOF
-$\{u_r\}$ - the restrained DOF that are excited by random loading
-{F} - the nodal force excitation
Damping is evaluated for each mode and is defined as:

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

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”;

3 Seism simulation by F.E.M.

The seism simulation using FEM is a two step analysis. First we have made a modal analysis of the SMEP disconnector FEM model and we have compared the results with the experiment in order to validate the FEM model.

The second step, which is the objective of the paper, is the spectrum analysis of the validated F.E.M. model of the high voltage disconnector for different seism types.

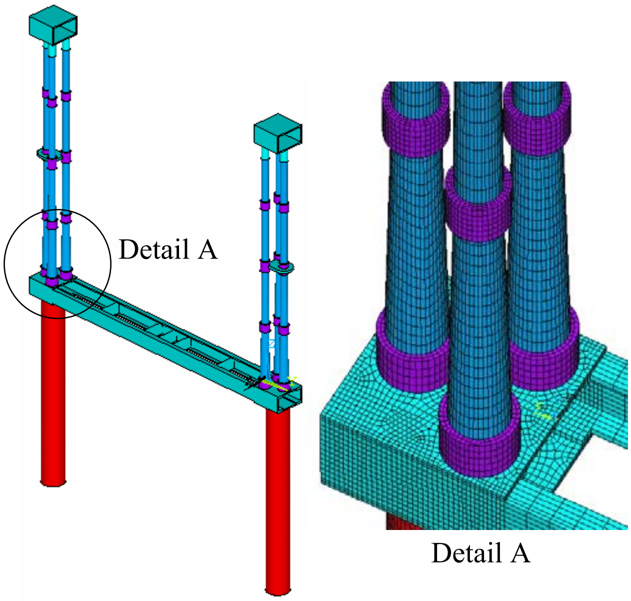

Fig. 2 F.E.M. model of the disconnector

The first simulation is the seism type AF2 with the intensity smaller the 5.5 degrees Richter.

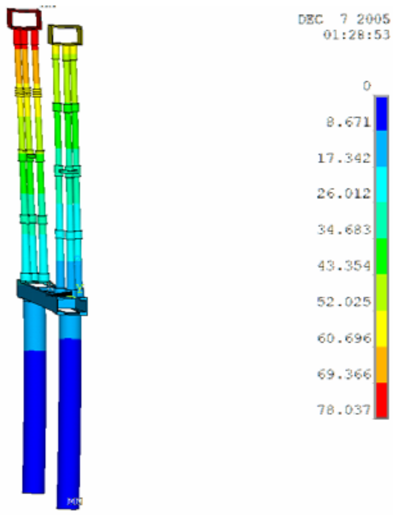

Fig. 3 Displacements during AF2 seism [mm]

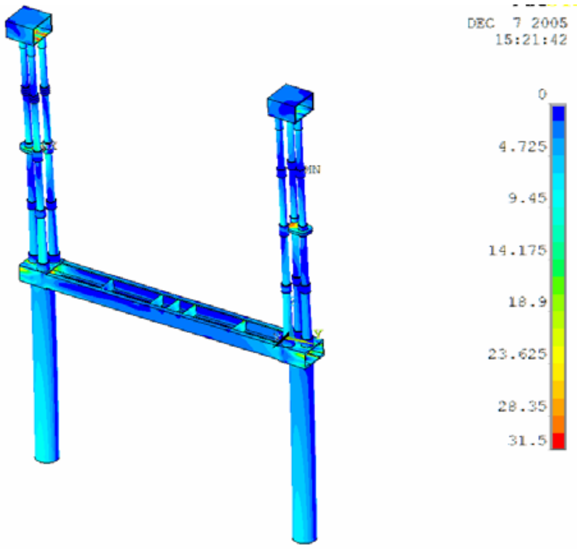

Fig. 4 Von Mises stresses during AF2 seism [MPa]

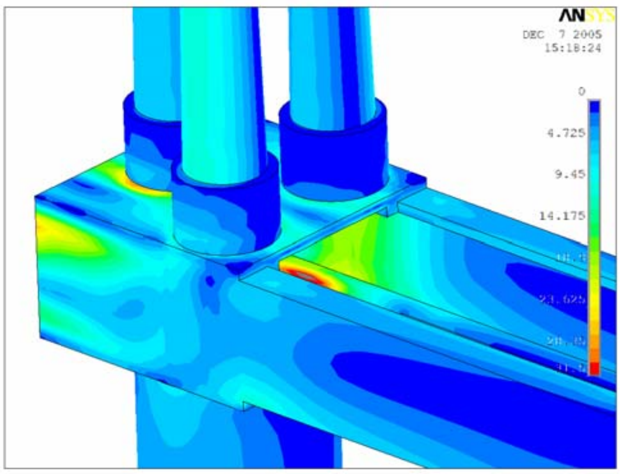

Fig. 5 Von Mises stresses during AF2 seism [MPa] (zone of maximal stresses)

The second simulation is the seism type AF3 with the intensity between 5.5 and 7 degrees Richter.

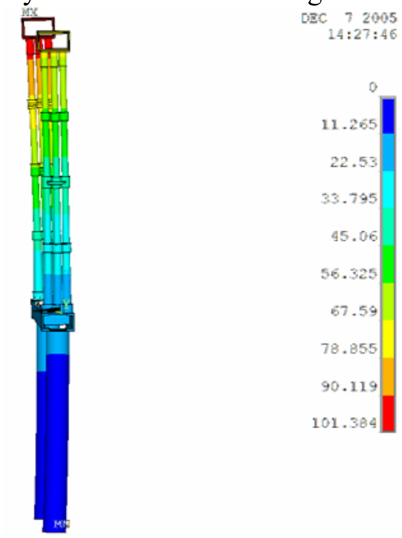

Fig. 6 Displacements during AF3 seism [mm]

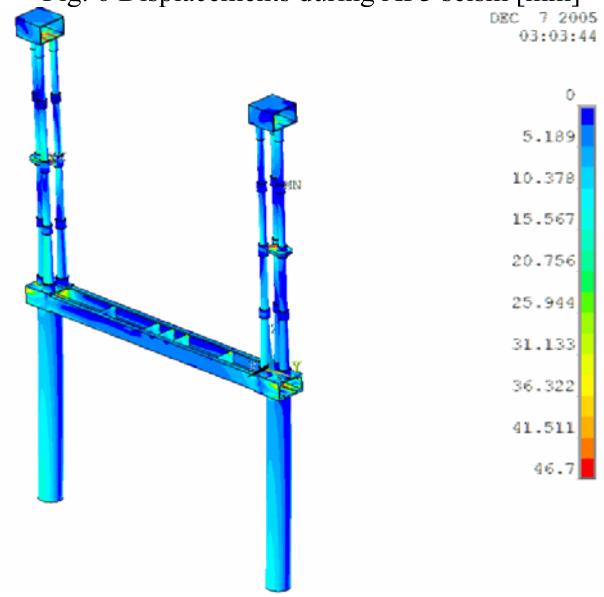

Fig. 7 Von Mises stresses during AF3 seism [MPa]

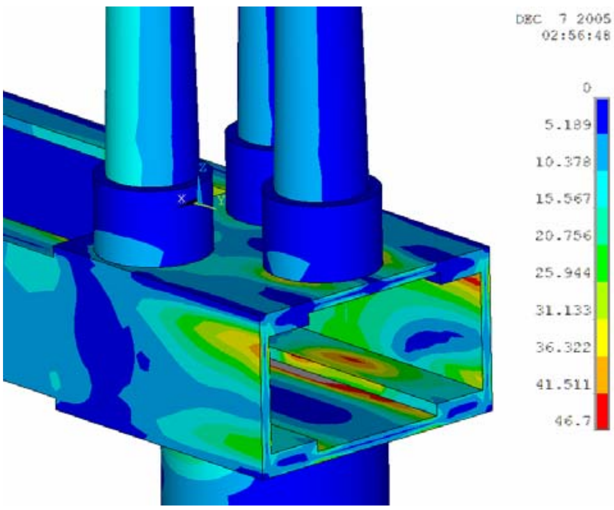

Fig. 8 Von Mises stresses during AF3 seism [MPa] (zone of maximal stresses)

The third simulation was made for the seism type AF5 with the intensity bigger then 7 degrees Richter.

For seism type AF2 and AF3 the stresses achieved are not dangerous, but during AF5 seism the stress is 79 MPa which is greater then the admissible stress of 40 MPa for the isolator ceramic material.

In order to validate the results of FEM simulation we will compare them with the experimental results.

3 Experimental results

The experiments were made on the real structure and were used piezoelectric acceleration transducers with electronic integrated circuit type 353B32. The measuring points are presented in fig. 12

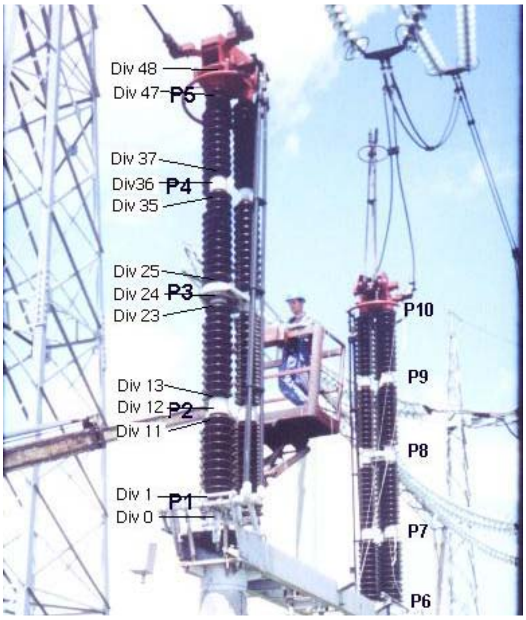

Fig. 12 The map of measuring points

Table 1, 2 and 3 present the comparison between the displacements obtained by experiment and by simulation with FEM of the three types of seism

Table 1 – comparison for seism type AF2

Points	Displacements AF2 Seism		
	FEM [mm]	Experim [mm]	Error [%]
P1	13	12,78	1,5
P2	20	19,64	1,8
P3	29	25,54	12
P4	41	39,11	4,6
P5	59	57,75	4,3
P6	17	17,21	1,23
P7	31	33,44	7,2
P8	44	45,26	2,8

P9	58	55,18	4,8
P10	70	66,35	5,1

Table 2 – comparison for seism type AF3

Points	Displacements AF2 Seism		
	FEM [mm]	Experim [mm]	Error [%]
P1	16	17,6	9,3
P2	23	21,6	6
P3	38	35,4	6,5
P4	55	54,3	1,2
P5	74	76,0	2,6
P6	22,5	21,3	9,7
P7	42	47,1	10,8
P8	57	62,3	8,5
P9	75	73,7	1,7
P10	90,2	85,6	5,1

Table 3 – comparison for seism type AF5

Points	Displacements AF5 Seism		
	FEM [mm]	Experim [mm]	Error [%]
P1	25	27,22	8
P2	38	38,41	1
P3	58	54,26	6,3
P4	83	82,2	0,9
P5	109	113,9	4,3
P6	34	36,19	6,05
P7	65	70,91	8,3
P8	83	88,69	6,4
P9	110	108,7	1,18
P10	135	132,7	1,7

4 Conclusion

The results obtained during simulation with F.E.M. of the seismic behavior of the disconnector are very similar with those obtained by experiment. The maximal error of 10.8% validates the F.E.M. model which simulate the dynamics of the SMEP 400kV disconnector structure.

Analyzing the computed values we can see that in the case of the high voltage disconnector, the most vulnerable parts are the isolator columns made by ceramics for which the admissible stress is $\sigma = 40$ MPa.. These parts are destroyed during a AF5 seism type, so is necessary to improve the structure of resistance.

This validated FEM model can be used for further static and dynamic analysis in order to optimize the high-voltage disconnector structure.

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