Model study of Lighting Protection of 110/20 kV Substation

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Abstract – **The purpose of the current report is to be examined a model study of the influence of the lighting strokes, which occur in the electric distributional lines, on the electrical equipment of the substation and on the protective effect of the metal-oxide surge arresters (MOSA).**

Keywords – **Lightning strokes, Metal-oxide surge arresters, Protective effect**

I. Introduction

The electrical equipment in the electrical substations for middle and high voltage, which are connected to the overhead power lines, are protected of lightning strokes through metal-oxide surge arresters [1]. The type and place of the connection of the protective means for surges are in в immediate connection with the coordination of the isolation of the equipment and their stable work.

II. Simulational model of a power transformer 110/20kV

The input data for the model of the power transformer in MATLAB SIMULINK must be in relative units in relation to the nominal data of the equipment. The following data should be entered: active resistance R1 [o.e.] and R2 [o.e.] and the self-induction of the coils L1 [o.e.] and L2 [o.e.]; the active resistance Rm [o.e.] and the self-inductance Lm [o.e.] in the magnetizing branch of the substitute circuit. The standard block for modeling of the power transformer is being used for the research of the stationary modes of work.

By the examination of the wave processes is necessary to be considered the influence of the longitudinal Кт and the transversal capacitances Ст of the coils. Therefore is formed a model scheme of the power transformer in SIMULINK, which could be used in the examination of the wave processes. Model scheme of a power transformer for the examination is shown on figure 1 [2].

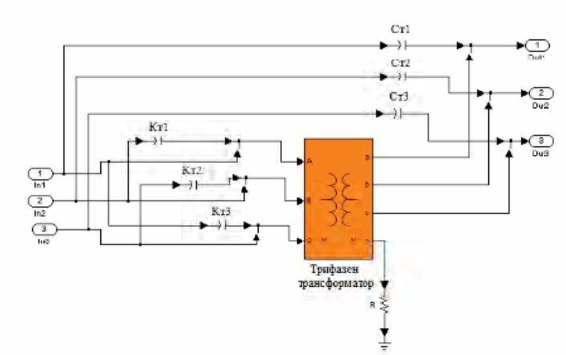

Fig. 1 Model of a power transformer for the examination of wave processes

The mathematical equations for the definition of the parameters of the substitute circuit of the power transformer are [4]:

$$z_T = z_k = \frac{U_k\,\%}{100} * \frac{U^2_{н.ном}}{S_н}\ ,\ \Omega \tag{1}$$

$$R_T = \Delta P_k * \left(\frac{U_{н.ном}}{S_н}\right)^2\ ;\ \Omega \tag{2}$$

$$X_T = \sqrt{Z_T^2 - R_T^2}\ ;\ \Omega \tag{3}$$

$$G_T = \frac{\Delta P_{n.x}}{U^2_{н.ном}}\ ;\mathrm{S} \tag{4}$$

$$B_T = \frac{I_\mu\,\%}{100} * \frac{S_н}{U^2_{н.ном}}\ ;\mathrm{S} \tag{5}$$

$$Z_T = Z_k = R_T + jX_T \tag{6}$$

$$Y_T = G_T - jB_T \tag{7}$$

$$Z_m = \frac{1}{Y_T} \tag{8}$$

$$Z_н = \frac{U^2_н}{S_н} \tag{9}$$

$$R_m = real(Z_m) \tag{10}$$

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$$X_m = imag(Z_m) \quad (11)$$

$$R_{m.o.e} = \frac{R_m}{Z_н} \quad (12)$$

$$X_{m.o.e.} = L_{m.o.e.} = \frac{X_m}{Z_н} \quad (13)$$

$$R_{T.o.e} = \frac{\Delta P_k}{S_н} \quad (14)$$

$$R_{1.o.e.} = R_{2.o.e.} = \frac{R_{T.o.e.}}{2} \quad (15)$$

$$X_{T.o.e.} = \frac{X_T}{Z_н} \quad (16)$$

$$L_{1.o.e.} = L_{2.o.e.} = X_{1.o.e.} = X_{2.o.e.} = \frac{X_{T.o.e.}}{2} \quad (17)$$

$$\sigma = \sqrt{\frac{C_T}{K_T}} \quad (18)$$

$$C_{вх.} = \frac{C_T}{\sigma} \text{ [5]} \quad (19)$$

$S_н$ – rated power of PT, VA;

$U_{н.ном}$ – Secondary rated voltage, kV;

$U_н$ – Primary rated voltage, kV;

$\Delta P_{п.х.}$ – no-load losses, kW;
ΔP_k – short circuit losses, kW;
$I_\mu\%$ - magnetizing current, A;

$U_k\%$ -short circuit voltage;
σ - pulse factor of the coil
(for disc coils σ =10÷20, for interwoven coils σ = 3÷5);
C_T - transversal capacitance of the coil of CT;
K_T – longitudinal capacitance of the coil of CT;
$C_{вх}$ – input capacitance of the coil ($C_{вх}$=800 pF for CT 20/0,4 kV; $C_{вх}$=2500 pF for CT 110/20 kV) [6].

III. VARIANT STUDIES

III.1. Research on the effect of the lightning strokes, which occur in the electrical distributional lines, on the electrical equipment in substation 110 kV without MOSA.

The voltages in the three phases are being controlled in the place of strike of the lightning stroke and on the power transformer. A model scheme of the substation is shown on figure 2 [3].

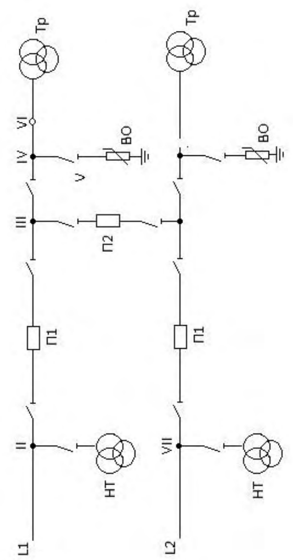

Fig. 2 Single line diagram of a substation

A. Strike of a lightning stroke on a phase conductor of power line L1.

The considered case is of a strike of a lightning stroke on phase B of an overhead power line L1. The struck section is at a distance of 100 m away from the substation. The power line L2 is connected to the system. The results of the research are given on figure 3.

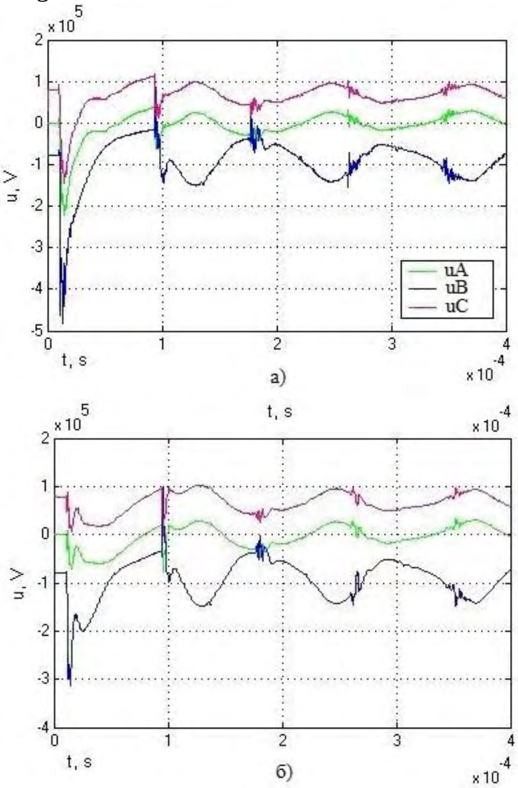

Fig. 3 Voltages in the case of strike of a lightning stroke on a phase conductor of a power line L1 without MOSA in an electrical system:

a) in the place of the strike; б) by the power transformer;

B. Strike of a lightning stroke on a phase conductor on power line L2.

The considered case is of a strike of a lightning strike on phase B of an overhead power line L2. The struck section is at a distance of 100 m away from the substation. Power line L1 is connected to the system. The results of the research are given on figure 4.

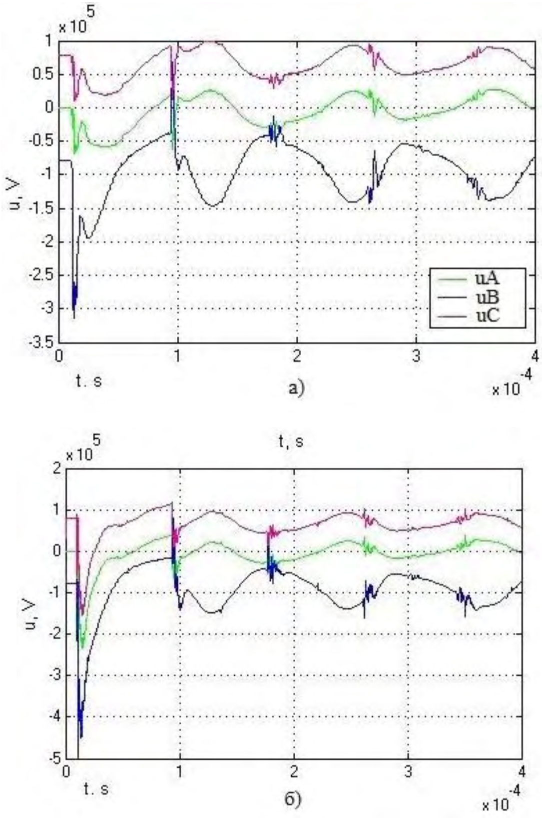

Fig. 4 Voltages in the case of strike of a lightning stroke on a phase conductor of a power line L2 without MOSA in an electrical system: a) by the power transformer; б) in the place of the strike;

The voltages, influencing the insulation of the power transformer, in case where it's not being protected, exceed its insulation level. Therefore they are dangerous for its insulation and should be restricted under 470 kV.

III.2. Research of the protective effect of MOSA in case of influence of the lightning strokes, which occur in the power lines, on the electrical equipment in substation 110 kV. Situations A and B are considered from p. III.1., but in case of existence of MOSA in electrical system. The results are given on fig. 5 and fig. 6.

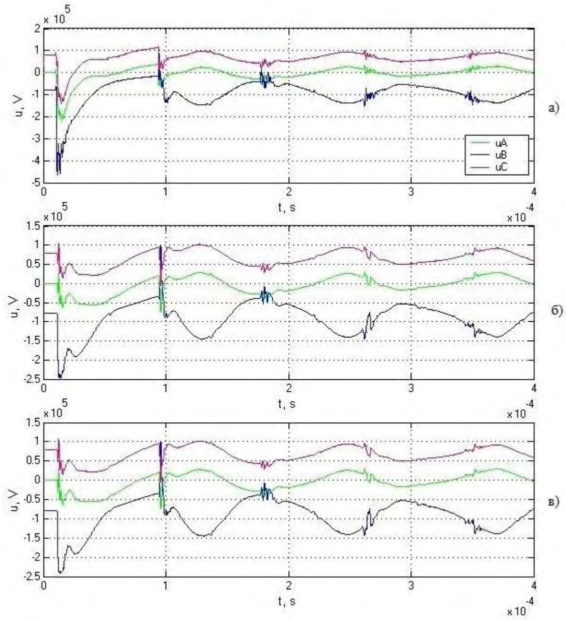

Fig. 5 Voltages in case of strike of a lightning stroke on a phase conductor of power line L1 with MOSA in an electrical system: a) in the place of the strike; б) by the MOSA; в) by the power transformer

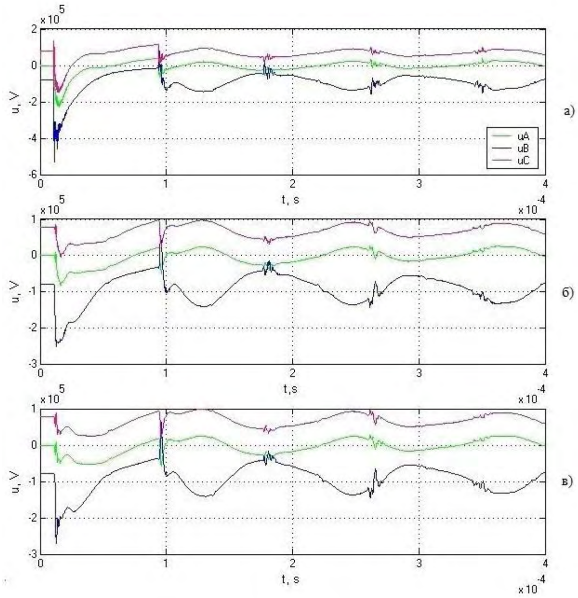

Fig. 6 Voltages in the case of strike of a lightning stroke on a phase conductor on a power line L2 with MOSA in an electrical system: a) in the place of the strike; б) by the MOSA; в) by the power transformer;

IV. Conclusion

The simulation model of a power transformer, given in the report, can be used for a research of wave processes in the electrical substations.

The developed model provides precise data for research of the protective effect of the metal-oxide surge arresters.

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